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Use of silver diamine fluoride in New Zealand public dental services: a scoping review on caries prevention and management in children

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ABSTRACT

Introduction. Despite government-funded dental care for children in New Zealand, dental caries was the leading cause of children's hospitalisations in 2019, with 10.4% of children aged <14 years having had teeth removed due to caries in 2023. Silver diamine fluoride, widely used internationally, presents potential preventive and therapeutic options for managing caries in children following recent approval in New Zealand. **Aim.** The review aims to map international literature on the use of silver diamine fluoride in preventing and managing dental caries, and to assess its contribution to achieving better and more equitable oral health outcomes for children aged 0–14 years. **Methods.** The scoping review adhered to the scoping review guideline from the Joanna Briggs Institute Manual for Evidence Synthesis. Six databases were searched for primary studies addressing the uses of silver diamine fluoride as a caries management tool in paediatric dentistry. **Results.** Of 1185 records screened, 88 studieswere included. The results were categorised into five themes: (1) effectiveness; (2) enablers; (3) adverse effects and barriers; (4) cost-effectiveness; and (5) promotion of oral health equity. The capability of silver diamine fluoride to arrest dental caries is well-supported by evidence, offering benefits such as non-invasiveness and improved quality of life for children. However, aesthetic concerns post-treatment and limited public awareness pose challenges to its broader application. **Discussion.** Silver diamine fluoride has the potential to significantly reduce caries rates among New Zealand children. Further research is needed to explore its role in promoting oral health equity, and tailored policies and protocols need to be developed to align with the local context.

Keywords: Aotearoa, children, dental caries, dentistry, health equity, oral health, silver diamine fluoride, systematic review.

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Introduction

Dental caries is the world's most prevalent dental disease, affecting nearly 2.3 billion people globally.[1] Oral health significantly impacts overall well-being; poor oral health can lead to pain and discomfort and affects growth, development and school performance in children.[2] Nevertheless, adequate home care and regular dental visits can help avoid complex and costly procedures because many dental diseases are preventable.[3] In Aotearoa New Zealand (NZ), the government provides free dental care to people aged up to 18 years, including annual check-ups, preventive and restorative treatments.[4] Generally, children from birth to school year eight are cared for by Health New Zealand–Te Whatu Ora Community Oral Health Services (COHS), whereas adolescents from school year nine onwards are cared for by private dental practices under the adolescents' Combined Dental Agreement.[5]

Despite free dental care, dental caries rates in NZ children, particularly among the Māori and Pasifika populations, remain high and are rising.[6] In 2023, 10.4% of children aged up to 14 years required dental extractions due to caries, with higher prevalence in Māori (15.5%) and Pasifika (14.6%) populations.[7] This issue also extends to adults, with 43.5% experiencing dental extractions, impacting 52.2% of the Māori adult population.[7] Dental caries is one of the leading causes of hospital admissions for children aged

WHAT GAP THIS FILLS?

What is already known: It is well-established that dental caries, despite being largely preventable, remains the leading cause of children's hospitalisations in New Zealand. Regular dental check-ups and early interventions are known to prevent and manage dental caries. However, there is a high prevalence of adverse oral health outcomes related to dental caries among children in New Zealand, particularly affecting Māori and Pasifika populations, indicating a need for more effective preventive measures.

What this study adds: This scoping review offers a systematic analysis of the potential role of silver diamine fluoride (SDF) in New Zealand's public dental services, based on international literature. It highlights SDF's effectiveness in arresting caries with minimal invasiveness, its cost-effectiveness, and the potential to promote oral health equity.

0–14 years, equating to 4.6% of all children's hospital events.[8] Each year, around 8000 children require general anaesthetic at a cost of 4000 NZ dollars per operation, which equates to around 32 million dollars annually.[9] The Wai2575 Hauora Report[10] confirmed that the Crown has failed to meet its obligation of Te Tiriti o Waitangi (Te Tiriti) to actively address Māori health inequities. This inequity is evidenced in the oral health status of Māori populations; a Te Tiriti lens is required with which to review this inequity and establish greater and more targeted interventions to reduce disparities and improve outcomes for the Māori population.[11]

NZ offers various caries management tools for paediatric patients, including fluoride varnishes, fissure sealants and restorative treatments, including resin composite and stainless steel crowns.[12] However, given that the prevalence of dental caries remains high, oral health practitioners (OHPs) are continually searching for more effective and patient-friendly methods for managing dental caries. Silver diamine fluoride (SDF), developed in Japan in the 1960s, is increasingly used worldwide, including in the United States of America (USA) and Australia, to manage dental caries for patients who are unable to undergo invasive dental treatments.[13] One significant adverse effect of SDF is the black staining on the treated lesion, which can act as a barrier to its use because it can be unsightly and socially stigmatising.[14,15] Stained teeth could be perceived as a sign of poor oral hygiene, affecting personal and professional interactions.[16]

Over the past decade, there have been multiple initiatives to introduce SDF to NZ. Although SDF is officially registered for treating dental hypersensitivity in numerous countries and is frequently used off-label for managing carious lesions,[17] this practice presented challenges to its formal registration as a caries management agent in NZ. Despite this, persistent advocacy from OHPs played a crucial role in its registration in September 2024 as a caries management (Provisional consent under Section 23(1) of the Medicines Act 1981[18]). All OHPs who care for children, including dentists, dental specialists, oral health therapists and dental therapists, are allowed to use SDF to address patients' oral health needs.

Previous systematic literature reviews have supported the effectiveness of SDF in caries prevention and arrest,[19] and the efficacy of it as a caries prevention agent.[20] A scoping review by Magno *et al.*[21] confirmed its increased acceptability for children requiring more advanced behaviour guidance methods. However, there has been no targeted review specifically for children aged 0–14 years, a demographic at great risk of poor and inequitable oral health outcomes In NZ.[7,8] As such, this scoping review is vital to bridge this gap, offering targeted insights that will enhance clinical practices and policy development for this age group. The scoping review methodology was selected for its capacity for a broad exploration of existing literature and the identification of key concepts, gaps in research, and types of available evidence, which is essential for informing a comprehensive understanding of SDF's impact on this specific population.

Considering NZ's unique cultural context and the obligations to uphold Te Tiriti in health care, it is critical to explore whether public funding and the use of SDF would effectively prevent dental diseases and treat early-stage caries in children, promoting improved and equitable oral health for all children in NZ based on other countries' experiences. This scoping review aims to mapping the literature to answer the following research questions:

- What is the use of SDF in preventing and managing caries in children aged 0–14 years?
- How can SDF contribute to achieving better and more equitable oral health outcomes for children aged 0–14 years?

Methods

This review was conducted following the Joanna Briggs Institute (JBI) methodology for scoping review guideline[22] and reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Review (PRISMA-ScR).[23]

Inclusion and exclusion criteria

The population, concept and context framework[22] was used to develop inclusion and exclusion criteria (Table 1) and a search strategy. The population included children aged 0–14 years, their caregivers and OHPs caring for paediatric patients. This age range was chosen as it aligns with the care provided by COHS in community settings. Caregivers were included to explore their perspectives on SDF, whereas the

Table 1. Inclusion and exclusion criteria.

Item	Inclusion	Exclusion
Population	• Children aged 0–14 years • Caregivers of children • OHPs providing care to children	• Children with medical conditions who are ineligible for SDF treatments
Concept	• Studies addressing the use of SDF as a caries preventive or management option • Studies addressing enablers and barriers to the use of SDF • Studies evaluating the cost-effectiveness of SDF compared to traditional treatments (including, but not limited to, composite or glass ionomer cement restorations)	• Studies using SDF as a part of restorative procedures or pulpal treatments • *In-vitro* studies • Studies about nano silver fluoride or using nano silver fluoride as a comparator for SDF
Context	• All international clinical settings	
Evidence source	• Primary studies, including quantitative, qualitative and mixed-methods • Discussion papers • Case reports • Year: Jan 2000 onwards • English, full text	• Book reviews, book chapters, news articles, protocols, editorials, commentaries and letters • Reviews and meta-analyses

OHPs, oral health practitioners; SDF, silver diamine fluoride.

Table 2. Comprehensive search terms used in EBSCO.

Order	Terms
1. Concept	'Silver diammine fluoride' or 'silver diamine fluoride' or sdf or 'diamine silver fluoride' or 'diammine silver fluoride'
2. Context	Dental or oral or caries or dentistry
3. Population	Child* or adolescent* or youth or teen* or paediatric* or paediatric* or kid*

All database fields were searched. Search terms were adapted to meet requirements for individual databases.

views of OHPs were considered to assess treatment feasibility and acceptance. The concept included any sources addressing the use of SDF as a caries preventive or management option. However, sources addressing the use of SDF as a part of restorative procedure were excluded to focus exclusively on its non-restorative applications. Relevant information, such as effectiveness compared to other caries management procedures, cost-effectiveness, enablers, adverse effects and barriers, were explored. For the context, all international clinical settings were considered.

The date range from 1 January 2000 to 8 May 2023 was selected to understand the contemporary trends and experiences related to SDF. Only articles written in English were included because of the limited resources and time available to engage with relevant translation services. Primary studies, discussion papers and case reports were included in this review to directly capture empirical data and diverse professional insights on SDF. Reviews and meta-analyses were excluded but used to identify related primary sources and grey literature, maximising the relevance and specificity of the findings.

Search process

This scoping review used the third-step searching process to identify relevant sources.[22] MEDLINE via EBSCO was used for the initial screening to understand the scope of the review and develop a comprehensive search strategy (Table 2). Then, the full search was conducted across six databases (MEDLINE-EBSCO, CINAHL-EBSCO, Dentistry & Oral Science Source-EBSCO, Cochrane Library, WHO Global Index and Scopus). Finally, the grey literature search was conducted using Google Scholar, ensuring a wide exploration of the topic, with the first 100 items being screened. References for related reviews and meta-analyses from the previous searches were screened as a part of the third step.

Source selection

After the search, all identified citations (n = 1185) were compiled and uploaded to Covidence, a web-based review software tool (Veritas Health Innovation, Melbourne, Vic, Australia), where duplicates were subsequently removed (n = 515). Two independent reviewers (Authors 1 and 2) conducted a source selection process using the two-step screening process[22] (title and abstract screening followed by full-text screening). Any disagreements between these two reviewers were resolved by a third reviewer (Author 3). Each step was piloted to ensure all reviewers shared a consistent understanding of the inclusion and exclusion criteria (Table 1). Titles and abstracts of 670 identified records were screened, and of these, full texts of 204 records were read and screened (Fig. 1). After the full-text screening, 116 studies

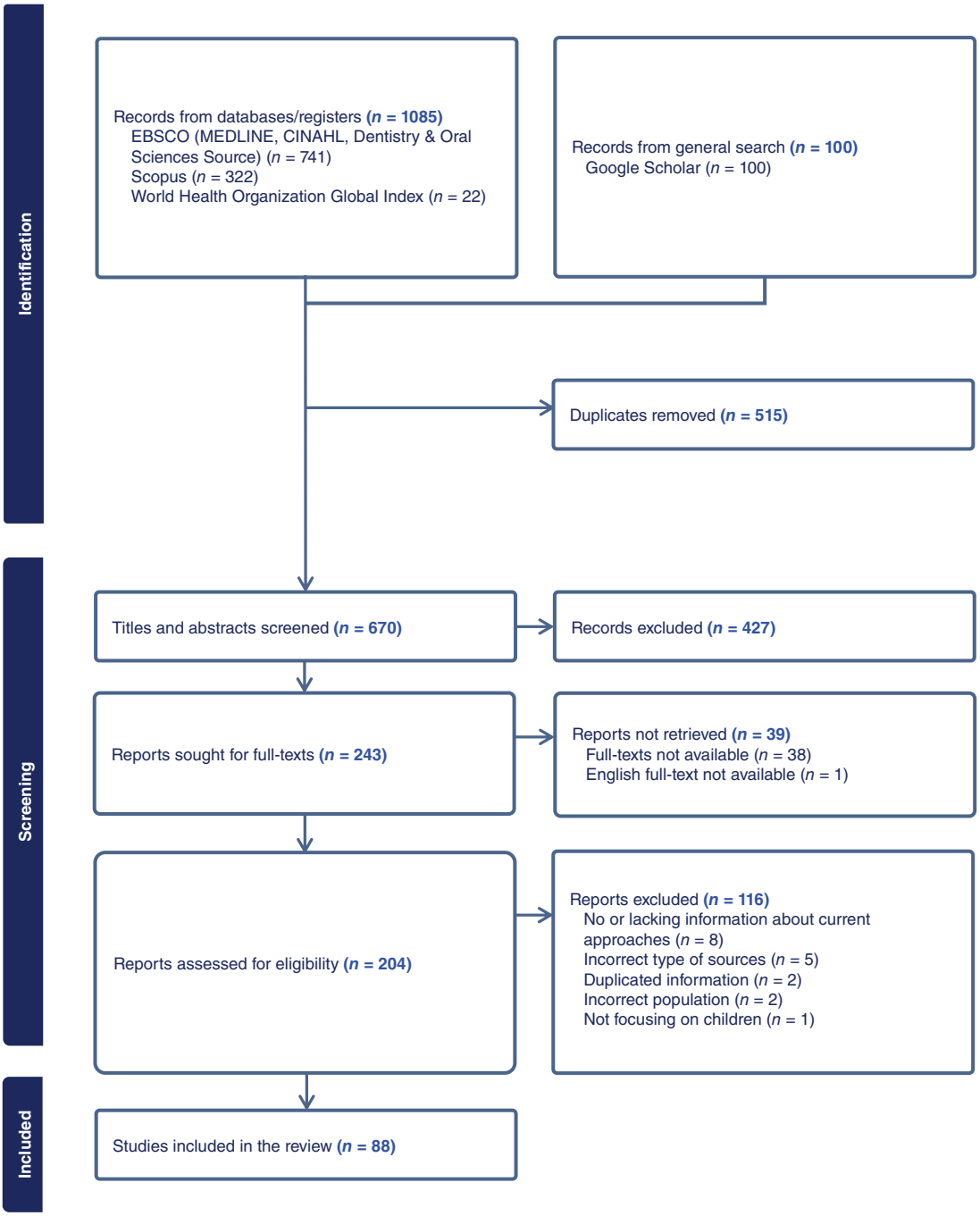

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Review (PRISMA-ScR) flow chart.

were excluded for various reasons, including ongoing studies, incorrect evidence types or incorrect population (Fig. 1).

Data extraction and synthesis

The data extraction table (Supplementary Material S1) was adapted from the JBI guideline[22] and modified to answer the research questions. All reviewers piloted the process using five sample sources to ensure the consistency and accuracy of data extraction. Once consensus was achieved by all three reviewers, one reviewer (Author 1) extracted the data, including title, year of publication, population, effectiveness, potential enablers, adverse effects and barriers, cost-effectiveness and equity. The second reviewer (Author 2) then meticulously reviewed and verified all the extracted data, making adjustments as necessary to ensure the accuracy and completeness

of the information. Once verified, the data were exported to Microsoft Excel (Microsoft Corporation, WS, USA) for analysis. Quality assessment of the included sources was not performed, as the primary objective was to map the existing literature on the topic rather than evaluate the quality or robustness of the sources identified. Narrative analysis was used to summarise the content of the data.[24] The findings were then presented in summarised tables and narrative statements. To ensure a thorough and standardised approach in reporting the scoping review, the PRIMSA-ScR checklist[23] (Supplementary Material S2) was used.

Results

Characteristics of included sources

Most of the 88 sources included in this scoping review were published in the USA (19 sources), India (16 sources) and China (16 sources), with the remainder published in other countries (37 sources). Most sources were published after 2015 (78 sources). Regarding methodological design, 44 sources (50%) were randomised control trials and 19 (21%) were prevalence studies. Other sources included cohort studies (11 sources), qualitative methods (five sources) and case reports (nine sources).

The results were categorised into five themes (Table 3): (1) effectiveness; (2) enablers; (3) adverse effects and barriers; (4) cost-effectiveness; and (5) discussion about oral health equity. The sources investigated how SDF can reduce the caries rate and enhance caries prevention among children aged 0–14 years to improve their oral health while identifying knowledge gaps.

Effectiveness of SDF

Thirty-one sources[25–55] addressed the effectiveness of SDF for caries management, with arrest rates ranging from 81 to 100% for the 38% concentration, which is the most commonly used concentration. Lower concentrations, such as 12%, were also effective; however, the arresting rates were lower than those of the 38% solution.[28,29,36] The higher concentration consistently achieves better arrest rates, making it the preferred choice in clinical settings. The studies reported varied re-application intervals for SDF, ranging from 3 to 12 months, with several studies advocating for bi-annual or annual applications to maintain over 80% caries arrest rates.[26,32,35,36,39,48,54]

Enablers to using SDF

Fifty-one sources[25–27,30,32,33,35–37,39,42–44,47,55–91] explored enablers to facilitate the use of SDF among children and adolescents. Fourteen sources[58,59,62,66–68,76,77,80–82,92–94] highlighted high parental acceptance of SDF as a dental caries treatment option due to its simplicity, comfort and non-invasive nature over conventional treatment options, such as restorations. Twenty sources[26,30,39,42,48,57,59,63,65,69,70,72,73,80,82,87–89,95,96] noted that SDF is safe, easy to use and time-efficient, helping prevent caries progression to the pulp, thus avoiding the need for general anaesthesia (GA) or sedation. Two sources emphasised that SDF could improve children's oral health-related quality of life.[60,85] Altner *et al.*[85] reported that parental awareness of staining from SDF often leads to improved hygiene practices in children. This observation suggests that when caregivers notice the aesthetic change in their child's teeth, they may be more motivated to ensure better oral hygiene practices to prevent further dental issues. A study in North Carolina found that areas where SDF was utilised demonstrated favourable community oral health metrics, with its use expanding over time to resource-limited areas.[88] Meanwhile, Vollú *et al.*[96] highlighted that SDF requires less technical skill and half the time compared to the atraumatic restorative treatment method, making it a preferred option in access-challenged environments.

Adverse effects and barriers to using SDF

Twenty sources[27,41,52,57,58,60,62,66,68,75,78–81,84,87,90,93,97,98] identified adverse effects and barriers to SDF usage among children and adolescents. The aesthetic issue of black staining by SDF, particularly on visible teeth, stands as a primary barrier, discouraging its use despite its effectiveness in arresting caries. This aesthetic concern affects parental acceptance, especially for anterior teeth.[67] This challenge is compounded by additional barriers, such as the need for enhanced parental education about SDF,[59,97] safety concerns over potential allergic reactions[59,60,78] and the need for more information on toxicity and long-term efficacy, underscoring the need for broader education and promotion of SDF among parents and clinicians to increase its acceptance.[60] Some OHPs have raised concerns about potential allergies associated with SDF, highlighting the necessity for more information on toxicity and the long-term impacts on health.[60]

Cost-effectiveness of using SDF

Seven sources[51,65,73,89,96,99,100] included in this scoping review emphasised the cost-effectiveness of SDF, compared with other dental caries management options, such as restorations and GA. The use of 38% SDF offers a low-cost treatment alternative and reduces labour costs due to its simple and quick application process.[51] Furthermore, it can serve as an alternative option compared to expensive procedures such as restorations, GA or sedation.[73,96] The use of SDF suggests that its application may largely contribute to improved access to a cost-effective and friendlyapproach for reducing the burden of tooth pain caused by dental caries in children.[65] Jain *et al.*[99] suggest that SDF appears to be a

Table 3. Summary of findings by themes.

Themes	Details
Effectiveness	• Different concentration of SDF effectively arrests active caries to different extents in deciduous and permanent teeth. • Effective in arresting caries by inhibiting bacteria growth and promoting remineralisation. • 12% concentration is effective but not as effective as 38% SDF, and 38% is the most used SDF. • High caries arrest rate of 81–100% with 38% concentration.
Frequency of application	• Effective SDF re-application widely varies from 3- to 12-month intervals. • Bi-annual to annual application with 38% concentration is effective. • Increased re-application frequency is needed for high caries risk.
Enablers	
Comparison with other treatments	• More effective than sodium fluoride gel and acidulated phosphate fluoride in arresting dentine caries or in primary teeth. • Both 38% SDF and ART are highly effective in arresting caries in primary teeth, with no significant difference between them regarding their effectiveness. • Non-invasive, painless, less-stressed treatment. • SDF shows increased acceptability with patients requiring more advanced behaviour guidance. • The use of SDF improves children's OHRQoL. • SDF as an interim treatment until comprehensive treatment is available leads to dental histologic changes that prevent pain, pulp exposure and pulp deterioration, and most likely facilitates pulp healing. • Shorter appointment time than endodontic. • Treatment and rampant caries are well-controlled with SDF.
Comparison with restorations	• SDF is slightly more effective and efficient than certain restorations. • SDF needs less chair time, which is better for children's comfort and parental acceptance.
Parental acceptance	• High acceptance, especially for primary and posterior teeth. • Acceptance increases with a positive history of tooth pain/inflammation or having scheduled sedation. • Influenced by financial backgrounds, education levels, age groups, ethnicities and residential status. • Parents feel guilty after seeing black staining and enhance their children's oral hygiene.
Dental practitioner's acceptance	• High acceptance, especially for managing caries in young, minimally cooperative children. • Increased use from 35 to 258 dentists between 2016 and 2018 in North Carolina, USA. • Cheaper and less technique-sensitive compared to ART.
Alternative to general anaesthetic	• Prevents stressful procedures and reduces GA use. • High caregiver acceptance due to avoiding extractions under GA or before shifting to have multiple restorations under GA. • Effective for children with special needs, including autism.
Adverse effects and barriers	
Staining	• Black staining of teeth. • Many parents declined SDF due to staining. • Parents with high incomes tend to prioritise aesthetics. • Insufficient public awareness of SDF and its uses, effectiveness and adverse effects. • Need for proper education for parents. • Children experience peer pressure after treatment.
Safety risk	• Concerns about safety, possible allergic reactions and need for more information on long-term effects. • Some parents are concerned about toxicity.
Others	
Cost-effectiveness	• Low-cost treatment, saving on labour and preventing expensive procedures. • Demonstrated cost-effectiveness in Australia and India. • Shorter treatment durations, reducing costs.
Health equity	• Cost-effective, suitable for basic clinic settings. • Promotes knowledge and use in underserved communities to reduce health inequities. • Enhances quality of life in areas with limited dental care access.

ART, atraumatic restorative treatment; GA, general anaesthesia; OHRQoL, oral health-related quality of life; SDF, silver diamine fluoride.

more cost-effective fluoride therapy than sodium fluoride applications. Moreover, SDF can act as a critical temporary measure to stop the progression of dental diseases when there are extended waiting periods for GA treatments.[100] Furthermore, the application of SDF does not require a fully equipped dental facility or expensive tools, making it a viable option for controlling caries in community programs within developing countries.[89]

Discussion regarding health equity

Vollú *et al.*[96] recommend SDF as a treatment option, particularly in community groups for whom access is a 'challenge', due to its shorter treatment durations, which are associated with lower costs and the capacity to serve more children. The debate about SDF in contemporary public health contexts centres on its potential to yield significant healthcare savings by reducing or eliminating the need for dental healthcare visits requiring GA. Utilising SDF as a preventive and therapeutic solution for dental caries in children presents long-term cost benefits because these patients eventually require treatments under GA.[100] The affordability and simplicity of SDF treatment makes it ideal for implementation in even the most basic clinic settings, which could be instrumental in formulating community-based dental health interventions aimed at reducing the burden of early childhood caries.[101] The capability of SDF treatment to be used in underserved communities with high caries risk has been suggested, expanding its use on a larger scale, which is the effort needed to reduce health inequities over a shorter timeline.[65]

Discussion

This scoping review of 88 sources highlights the global utilisation of SDF in effectively managing dental caries in children aged 0–14 years. SDF is particularly noted for its ease of application, non-invasive nature and cost-effectiveness,[51,73,96] making it an increasingly popular choice in international paediatric dentistry. The review draws from a rich mix of quantitative and qualitative studies, case reports and grey literature, offering a broad international perspective on its use. Although the acceptance of SDF among children and parents is on the rise, regional variations in concerns such as allergies,[60,78] lack of community awareness of SDF[67,89] and the aesthetic issue of black staining from SDF[27,52,79] are critical in shaping local guidelines for NZ. Understanding these international experiences helps tailor SDF approaches to NZ's unique needs, promoting equitable oral health outcomes.

This scoping review highlights the potential of SDF for applications in COHS for caries prevention and management given its availability for use by OHPs[18] and the high caries rates coupled with persistent dental inequities in NZ.[7] SDF presents a practical, cost-effective option for enhancing oral health services equitably among children. It is adaptable to different clinical scenarios and patient needs due to the variability in re-application intervals.[65] For policymakers and OHPs, this review offers valuable insights for optimising treatment protocols and resource distribution, aiming to improve paediatric dental care. Promoting SDF in underserved communities at high risk of caries could significantly impact public health efforts to lessen health inequities swiftly.

Incorporating SDF into NZ oral health strategies requires aligning with Te Tiriti obligations by ensuring equitable health outcomes and actively addressing inequities particularly affecting Māori and Pasifika children.[10,11,102] SDF is practical, easy to apply cost-effective, and friendly, making it feasible for widespread implementation to improve children's oral health equity. To implement SDF, dedicated funding is required for SDF materials, labour, training and community education programmes. Furthermore, it is essential to understand community perceptions of black staining and develop educational initiatives that prevent it from becoming a stigmatising issue within the community.[103] Tailored, culturally sensitive educational programmes are essential for SDF implementation, acknowledging these communities' unique cultural contexts and health priorities. Prioritising Māori and Pasifika populations and focusing on deprived areas are crucial steps. Māori and Pasifika communities and OHPs should be involved from the early stage of implementation planning to ensure culturally safe actions are planned and implemented.[11]

Although this review provides valuable insights into the use of SDF by publicly funded dental services in NZ for caries prevention and management in children, it has limitations. Primarily, its focus on public dental services limited its applicability to private dental practices, which may require different protocols and have varied patient demographics, both within NZ and internationally. The age-specific scope of the study, concentrating solely on children aged 0–14 years, further narrowed its relevance, omitting potential benefits or considerations of SDF treatments, particularly for adolescents and adults with disabilities. Additionally, the methodological diversity across the sources reviewed posed significant challenges in maintaining consistency and ensuring comparability of the results, potentially affecting the conclusions' robustness. Finally, given the rapid pace of advancements in dental research, particularly concerning innovative caries management techniques like SDF, this review may not have captured the most recent empirical and clinical studies, which might provide updated findings or emerging trends not covered in this analysis.

Further research is necessary to fully understand the potential of SDF and to meet Te Tiriti obligations. Future studies should aim to not only refine the application of SDF but also enhance oral health outcomes for all children in NZ, ensuring equitable health advancements. Specifically, qualitative research that actively involves communities and OHPs, particularly Māori and Pasifika communities and healthcare practitioners, from the planning stage will be beneficial in developing and refining culturally safe interventions. This Māori-led approach will help develop comprehensive SDF usage policies that will specifically target oral health inequities in the communities.

Conclusions

This scoping review systematically evaluates the use of SDF in NZ paediatric public dental services, affirming its efficacy as a

minimally invasive and cost-effective treatment for arresting dental caries in children aged 0–14 years. The findings highlight ease of SDF application and acceptance due to its non-invasive nature, which facilitates its use among caregivers and professionals. However, challenges such as aesthetic concerns from staining and the need for increased educational outreach persist. The review underscores the necessity for policies and protocols tailored to NZ's unique needs and cultural contexts, particularly emphasising alignment with Te Tiriti obligations to ensure equitable health outcomes. As such, integrating SDF into national oral health strategies for children could significantly enhance care quality, making ongoing research and policy refinement essential for optimising its benefits across diverse populations.

Supplementary material

Supplementary material is available online.

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