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RESEARCH

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A mixed methods evaluation of the implementation of silver diamine fluoride in NHS primary dental care

Laura Timms^{1*}, Helen Rodd¹, Paul Brocklehurst², Chris Deery¹ and Zoe Marshman¹

Abstract

Background The rates of dental caries in young children in England are high. Despite evidence-based guidance being available to manage dental caries for young children, this is not routinely implemented. Silver diamine fluoride (SDF) offers an alternative approach to caries management. However, its use in England is limited and there are no data on the implementation of SDF in NHS primary care, where most children are treated.

Aim Explore the factors affecting the ability to implement SDF and specifically the acceptability and feasibility of treatment with SDF from the perspectives of children, families, dentists and regional and national stakeholders.

Methods This was a mixed methods evaluation of the implementation of SDF in NHS primary care. Qualitative interviews were carried out with parents, children, stakeholders and dental professionals regarding the implementation of SDF. The data collection and analysis were informed by the Consolidated Framework of Implementation Research and the Theoretical Framework of Acceptability. Quantitative data were collected pertaining to the dose, reach and fidelity of delivery of SDF, from a subset of participants involved in a randomised feasibility study.

Results Interviews were conducted with 61 stakeholders, dental professionals, parents and children. Constructs from all the Consolidated Framework of Implementation Research domains were represented. Ease of use and child experience facilitated SDF implementation. Barriers were contracts and remuneration. SDF not requiring restorative treatment was both a barrier and facilitator simultaneously. The treatment protocol for SDF was adapted by dental professionals to add restorative care where they or their families had concerns over aesthetics or function.

Conclusions It was possible to implement SDF in NHS primary care where it addressed an unmet need for young children. However, there is professional concern around unrestored teeth and wider implementation is hampered by contractual arrangements.

Trial registration Registration is at Clinicaltrials.gov (NCT06092151) (date: 23/10/2023).

Keywords Caries, Paediatric dentistry, Silver diamine fluoride

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Background

Caries rates in young children in England remain high; 11% of three-year-olds, 24% of five-year-olds and 46% of eight-year-olds have caries in their primary teeth [1–3]. This is despite evidence-based preventative options. The Care Index indicates that only 10% of five-year-olds' carious teeth are treated restoratively [2]. Epidemiological survey data indicates 39% of eight-year-olds have untreated caries [3]. Where caries is not treated or treatment is unsuccessful, extraction under general anaesthesia may be required. Dental caries is the most common reason for a child aged five-nine-years-old to have a hospital admission in England [4].

Current evidence-based treatment options can have high success rates [5]. In particular, Hall Technique preformed metal crowns have success rates of over 90% for primary teeth [6]. However, there are data to demonstrate evidence-based treatments are not routinely implemented in primary dental care [7]. Varied or sub-optimal implementation can impact the effectiveness of an intervention. Implementation science can be defined as: "the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and, hence, to improve the quality and effectiveness of health services" [8, 9]. Implementation research is important to maximising patient benefit as where treatments are implemented without fidelity this may reduce their efficacy. Context is important to implementation. National Health Service (NHS) primary dental care is a complex environment with multiple factors that could affect implementation of treatments, challenging the ability to translate findings from research into practice. Consistent with this, there is evidence of contextual difficulties implementing evidence-based approaches to caries management in NHS primary dental care, despite their efficacy, with dental professionals opting for other approaches with a poorer evidence-base [10].

Given the number of children with untreated caries in England, it is important to consider other options that may be suitable and acceptable for this group of patients. Silver diamine fluoride (SDF) is a topical treatment with the potential to arrest caries [11]. It is considered a relatively simple treatment for children to accept, and does not require additional skills for dentists and dental therapists [11]. Systematic reviews have indicated success rates of 65–91% for SDF arresting carious lesions into dentine in primary teeth [12]. However, a recent Cochrane review considered the evidence for the efficacy of SDF is of very low certainty [13].

There are important side effects to the technique; SDF discolours carious tooth tissue black. Professionals have raised concerns over the parental acceptability, and licencing arrangements as SDF is licenced for

dentine sensitivity rather than management of dental caries in England [10, 14]. Data from England indicate 58% of parents of children with caries would accept SDF for the anterior teeth and 73% would accept SDF treatment for posterior teeth [15]. This research described a questionnaire based on photographs rather than considering experience of the technique. There is no data on the implementation of SDF in NHS primary care. Intervention fidelity factors such as application time and frequency could affect the effectiveness of SDF [16, 17].

Given NHS primary dental care is a complex environment with many factors affecting implementation, it is important to consider whether it is possible to implement SDF treatment in this context and explore what effects this. This includes from a policy, professional and patient perspective, uncovering any key barriers or facilitators.

Aim

The aim of this study was to explore the factors affecting the ability to implement SDF, from the perspectives of children, families, dentists and regional and national stakeholders.

Methods

The overall design of this study was a mixed methods evaluation exploring the implementation of SDF in NHS primary dental care using implementation science approaches.

This research was embedded in a feasibility study that assessed the ability to conduct a randomised controlled trial evaluating SDF, the protocol and findings are published elsewhere [18, 19]. Therefore, the sites and participants recruited were those involved in the feasibility study, where children were randomised to receive either SDF (SDF group) or usual care (usual care group) for caries in their primary teeth.

Feasibility studies afford an opportune time to assess implementation of an intervention [20]. Such evaluations can explore how the context impacts the implementation of interventions. This feasibility study was conducted in NHS primary care across multiple sites. This allowed the assessment of implementation of SDF in a 'real life' clinical setting. It is important to gain the perspective of all relevant stakeholders [21]. Therefore the study incorporated perspectives from patients, parents, dental professionals and policy makers. A mixed-methods approach was taken in keeping with recommendations from Moore et al., with quantitative and qualitative data complementing each other [21]. These data explored the contextual factors affecting implementation of SDF utilising a theoretically informed approach, and quantified how well SDF was implemented in terms of dose, reach and fidelity of delivery.

Ethics

Ethical approval was granted by the Leeds West NHS Research Ethics committee (23/YH/0053 4th April 2023). All participants provided written informed consent (for child participants, their parents provided this on their behalf).

Setting

Implementation was reviewed in NHS primary dental care practices and clinics which acted as the research sites across Yorkshire and the East Midlands [18]. They were specifically recruited to include those in areas of deprivation, with different contractual arrangements and of different sizes. Three sites of the eight had previously used SDF with varying degrees of success in regards to sustained implementation.

Interviews were carried out at the sites, participants' homes, virtually or over the telephone with the participants being at their own home or workplace.

Population/participants

There were three different participant groups; children and parents, dental professionals and national and regional stakeholders.

The child and parent participants were recruited from those taking part in the feasibility study. The inclusion criteria were children aged one to eight-years-old, with caries into dentine in a primary tooth, and their parents. Caries into dentine was diagnosed through visual and tactile examination, using ICDAS criteria for which assessors were trained and calibrated. The sample for the quantitative data was that of all participants who received SDF at least once during the feasibility study, this was 33 of 54 children recruited in total.

The sample of children and parents recruited for semi-structured interviews were a subset of those taking part in the feasibility study.

Dental professionals comprised a range of practitioners including NHS dentists (practice owners, dental associates and salaried dentists), dental therapists, dental nurses and practice managers.

National and regional stakeholders had policy and leadership roles across the United Kingdom.

The sampling strategy was purposive. Recruitment stopped when no new significant information was gained from the data determined by LT.

For children and their parents, the aim of the purposive sample was to have heterogeneity in terms of child age, site attended and caries experience. For dental professionals, the sample aimed to include those across sites, job roles and with previous and no experience of using SDF. Stakeholders were sampled to represent different regions and roles in policy and leadership.

Recruitment

For quantitative data, children and parents were approached by the recruiting dentist at their site. For qualitative data; on recruitment to the feasibility study, children and parents indicated on their consent form whether they gave permission to be contacted regarding an interview. They were contacted by telephone by LT and further information was provided, including a written participant information leaflet. Dental professionals and stakeholders were approached via an invitation email or letter with a participant information leaflet.

Data collection

Qualitative data were collected through semi-structured interviews. These were conducted by LT based on topic guides that were informed by the Consolidated Framework of Implementation Research (CFIR) and the Theoretical Framework of Acceptability (TFA) [22, 23] (Supplementary material). The CFIR combines identified factors affecting implementation and allows consideration of implementation from a policy, professional and participant perspective. It is based on appraisal of previous research identifying which factors may determine successful implementation. The CFIR is organised into five domains; innovation, outer setting, inner setting, individuals, and implementation process. Each domain has constructs that have been demonstrated in previous research and theory to have an impact upon implementation. Previous research and stakeholder engagement highlighted potential factors that may affect SDF implementation that align with the CFIR constructs. Therefore it is an appropriate framework through which to explore the determinants of successful implementation of SDF in the UK.

The TFA was used in addition to the CFIR. This was owing to acceptability of SDF being considered critical to its implementation, with professional hesitation demonstrated regarding parental acceptability as a barrier [14]. The TFA was developed through a review of the literature and appropriate theory and specifically considers acceptability and is based on seven constructs; affective attitude, burden, ethicality, intervention coherence, opportunity costs, perceived effectiveness and self-efficacy [23]. It has been previously used to consider acceptability of other treatments for young children with caries in the UK [24].

Quantitative data was recorded on case report forms and participant questionnaires. This was to assess implementation outcomes of:

- Dose: whether the number of applications of SDF was in keeping with national standard operating procedure (SOP)

- Reach: whether the children that were planned to have SDF treatment went onto receive SDF treatment
- Fidelity: whether the application of SDF and clinical technique was in keeping with the SOP. These data were collected when participants received SDF treatment, and where relevant at review appointments up to twelve months.

Case report forms included demographic details, caries experience, treatment delivered and an implementation checklist for SDF application to review fidelity in comparison to a SOP endorsed nationally [25] (supplementary material). Parents and children completed two item questionnaires based on their experience of receiving SDF treatment, specifically peri-procedural pain, these were completed at appointments where SDF was applied (supplementary material). This included asking children if the procedure hurt, and parents if they thought it was painful, they are not validated. The questions used were based on those used in a previous study in primary care, and were reviewed by PPI contributors including parents and children for language and burden [26].

Data analysis

Quantitative data were analysed using descriptive statistics. This included the frequency of application of SDF in comparison to the recommendations (dose), the frequency of adherence to the implementation checklist stages (fidelity), frequency of treatment adaptations (fidelity), and proportion of participants planned to receive SDF who ultimately did (reach). Data were inputted into SPSS and analysed using this software.

Qualitative data were analysed by LT, and reviewed by ZM. Coding was both inductive and deductive and framework analysis was used [27]. The coding used the CFIR and TFA constructs for the deductive approach. Inductive coding was also carried out with labels applied to the data based on LT's interpretation. These were then incorporated into the CFIR and TFA constructs where they best aligned to produce a framework. Patient and public involvement (PPI) contributors reviewed the findings of from the parent and child interviews in terms of the codes and constructs applied to the data.

To ensure rigour in the qualitative analysis included discussion of interpretation of the data with ZM and PPI members, review of coding and the frameworks by ZM and triangulating data from the different participant groups and quantitative implementation data.

Results

Quantitative findings

Data are presented for the 33 children that received SDF in the feasibility study. Children had a mean age of 5.5

Table 1 Parental-reported child treatment experience for treatment visits where children were treated with SDF

Parental response	Frequency of response	Percentage
Not painful at all	50	89
A little painful	5	9
Somewhat painful	1	2
Painful	0	0
Very painful	0	0
Total	56	100

Table 2 Child-reported treatment experience for treatment visits where children were treated with SDF

Child response	Frequency	Percentage
Not hurt at all	45	83
Hurt a little	9	17
Hurt a lot	0	0
Total	54	100

years-old (standard deviation 1.23, range 3–8 years). The mean number of decayed, missing or filled primary teeth was 3.36 (standard deviation 2.21, range 1–10 teeth). The caries arrest data following SDF application are presented in another paper focussing on the feasibility of a trial [19]. The completion of ICDAS was inconsistent over follow up visits, and as such this was challenging to interpret.

Child and parent treatment experience

At treatment visits, participants and their parents completed a 3- and 5-item questionnaire, respectively regarding peri-procedural pain. Table 1, and 2 provide scores for treatment visits where SDF was placed and demonstrate for the majority of children, SDF application was considered pain free. This is in keeping with qualitative data described below regarding the treatment experience with SDF. The frequency of responses is higher than the 33 children that received SDF, this is because this questionnaire was completed each time SDF was applied, which was more than once for many children.

Dental professional's implementation of SDF

The implementation dose of SDF delivery was compared to the recommended application intervals in the national standard operating procedure [25]. Of the total number of participants that had SDF application, $n = 5$ (15%) had a six-month reapplication. For those where twelve-month follow-up information was available, $n = 1$ (3%) had SDF reapplication.

Table 3 details dental professionals' self-reported compliance with the technique outlined in the SOP (implementation fidelity). Soft tissue isolation had more than one method for compliance, in keeping with clinical preference, as such different options are included for "yes" in Table 3 to provide the clinical detail. The mean

Table 3 Compliance with SDF treatment protocol for 62 applications

	Yes		No	Total
Were the soft tissues isolated	Riva star Paste	Cotton-wool/Vaseline	3 (5%)	64 (100%)
	10 (16%)	51 (78%)	61 (95%)	
Was the tooth dried pre-application	64 (100%)		0 (0%)	64 (100%)
Was the tooth blotted dry post-application	63 (98%)		1 (2%)	64 (100%)
Stored in fridge	45 (70%)		19 (30%)	64 (100%)

Table 4 Information regarding qualitative interviews

Group	Number of participants	Dates of interviews	Duration of interviews
Stakeholders	<i>n</i> = 7	25/07/23 – 12/01/24	17–50 minutes
Professionals	practice owners (<i>n</i> = 4), dental associates (<i>n</i> = 5), salaried dentists (<i>n</i> = 1), dental therapists (<i>n</i> = 3), practice managers (<i>n</i> = 3), dental nurses (<i>n</i> = 9)	11/01/24 and 28/08/24	6–60 minutes
Children and parents	child patients (<i>n</i> = 12) parents (<i>n</i> = 17)	24/11/23 and 30/07/24	10–33 minutes

application time was one minute and 44 s (range five seconds to three minutes).

Dental professionals reported that for 13 of the 33 patients that received SDF (39%) an addition of glass ionomer cement was applied either at the same visit as the SDF or at a subsequent visit. This was the case for 24 of the 89 teeth treated with SDF (27%). This reasons as to why restorations were placed are elaborated upon in the qualitative findings below.

The majority of participants who were planned to receive SDF, received it as a treatment (implementation reach). For those in the SDF group, 23 of 26 children randomised received SDF. One participant was withdrawn prior to application owing to one parent not wishing for them to have SDF, one was a recruitment error and for one the dentist felt a different treatment was in the patients' best interest. Additionally, one participant was given SDF as the dental professional chose to apply this and not use randomisation to allocate treatment. Nine of those randomised to usual care received SDF. The qualitative data presents themes and constructs which explain why SDF may have been chosen for this cohort. This resulted in 33 children receiving SDF at least once.

Qualitative findings

Table 4 details the number of participants, interview times and dates. Seven dental professionals and three parents and children undertook a second interview at a later date. Children who took part were aged between four- and eight-years-old.

Perspectives of children, families, dentists and regional and national stakeholders on factors affecting SDF implementation

Constructs from all five CFIR domains were evident in the data. The seven TFA constructs were demonstrated and aligned with the innovation and individuals domains of the CFIR. Multiple constructs were demonstrated for each domain across participant groups. Key constructs from the innovation domain that affected the implementation of SDF were its relative advantage (and disadvantage) in comparison to alternatives, its simplicity and its cost. The outer and inner setting domains were instrumental to understanding the contextual factors that determined successful implementation. This included patient needs, tension for change in relation to dissatisfaction with current options, remuneration and contracts, guidance, and communications between families and dental professionals. The tension for change in particular may explain the quantitative findings in terms of reach of delivery of SDF. How child-centred the site was, and the relative priority of treating children with caries to parents, dental teams and policy makers were also important. Individuals' roles and characteristics affected implementation through their understanding of how SDF worked and its purpose, how well this aligned with their views on treatments for children's carious teeth and how effective they felt SDF was. Individuals reflected that overall implementation of SDF in NHS primary care had been poor, but assessing needs and working with teams were important to successful implementation.

Three key themes are considered specifically as to how they have influenced the implementation of SDF; these are the patient treatment experience, the lack of tooth preparation and restoration and the contractual arrangements. Multiple constructs that bridged domains and participant groups are related to each of these three themes, although in some instances they were operationalised differently as described below.

Patient treatment experience

The key cohort identified was young children requiring treatment for dental caries, for whom a less invasive option to traditional methods was deemed valuable. Dissatisfaction was shared with current options available for this group of children that prompted consideration for an alternative to meet their needs. Specific areas of deficiency were; failing treatments, treatments not

compatible with children's co-operative ability or procedures causing pain or patient discomfort intra-operatively. It was acknowledged that the current alternative for the group where co-operation was not sufficient for alternatives, was often treatment under general anaesthesia. This provided a further tension for change through a wish from a public health, professional and parent and child perspective to avoid such treatment. Therefore, the lack of invasiveness and relative advantages of SDF being a simple treatment for children to receive were fundamental to its implementation. This was particularly the case for those not amenable to care involving the air rotor drill, hand instrumentation or local anaesthesia, or where avoiding these elements would reduce anxiety and traumatic treatment experiences. This is in keeping with the quantitative findings demonstrating SDF was a positive treatment experience.

Notwithstanding this, there were negative elements of the treatment experience with SDF that were a barrier to implementation. This includes the taste of SDF and families and professionals described instances of application where they felt the child had discomfort. Professionals found challenges in terms of avoiding soft tissue contact with the SDF. Reflecting on implementation elucidated that the recommended application time was not always feasible and there was a range of views as to how this affected the effectiveness of SDF.

"No, I think it's more advantage because obviously like I said, with the filling, he kept having fillings every so often, and it just either kept shrinking or coming off completely, so then he'd have to keep coming back." [Parent 12]

"Yeah, I'll probably say the painting because the filling—the filling, it's like you have to—... you'll like have to get right, like right in and the painting you don't go that far for it." [Child 26]

Lack of requirement for caries removal and restoration

The fact that SDF treatment did not include removing caries and restoring the tooth interacted with multiple constructs across all domains and participant groups. It was seen as both a relative advantage and disadvantage; the lack of caries removal and restoration supported co-operation but led to other concerns over efficacy, function and aesthetics.

Participants discussed SDF causing the lesion to turn dark in colour, and that as the tooth was unrestored this was visible. Stakeholders shared diverse views as to the extent of this as a barrier, feeling it would be specific to this group of patients. Nonetheless, there was unease that this would affect those from more deprived communities unequally; they are the most likely to be affected by dental caries and may be more likely to accept the treatment despite having reservations regarding the aesthetics. The simplicity of SDF and lack of restoration may cause

scepticism amongst the public as to healthcare professionals and providers motivations for providing it, seeing it as a lesser and cost saving alternative to conventional treatments, which would affect its wider implementation.

Dental professionals reported differing experiences in terms of families' acceptance of SDF application without restoration. They found communication of the procedure and the aesthetics improved acceptance. Nonetheless, conceptually it was more challenging to comprehend as it was at odds with families' previous experiences. Regarding aesthetics specifically, dental professionals had come across parents who declined SDF for their child as a result.

These mixed views were echoed by families. Despite expressing a preference for natural tooth colour and white materials, many were accepting of the appearance SDF. It was considered less salient for posterior teeth. Parents stated they would not have accepted SDF or would not have accepted it without a subsequent restoration, and that other children or parents may not. The visible display of their child having had dental caries, if treated but particularly when untreated, gave parents concern that they would be judged regarding their care for their child. This concern regarding societal views was echoed by dental professionals and stakeholders who also considered that the public may negatively view those treated with SDF. Parents stated the aesthetics was more impactful on them than their child although one did note their child would be worried people may notice. Children also showed a range of views, there was concern about how their teeth looked, whereas others were not concerned or had not contemplated aesthetics. Parents reported that having an unrestored tooth had been noticed by their child, and were concerned regarding the feeling of this and the functionality.

There was further tension among dental professionals about the 'ethicality' of not restoring SDF based on their own beliefs and principles. With some professionals and stakeholders raising concern this meant it was a lesser treatment and less likely to be effective. Dental professionals stated they themselves preferred a restored tooth, they postulated this could be as a result of their training, but there were also concerns regarding the lack of seal would lead to failure of treatment. Indeed teeth were subsequently restored owing to clinical concern over caries progression. Dental professionals were sentient of parental concern regarding lack of restoration. Contractual relations were also linked; restorations were better remunerated intoning they are superior. The actual implementation of SDF was affected by these factors, both by some families not accepting the treatment and dental professionals adapting the treatment by restoring the tooth following application, without which its implementation may have been further limited. This is mirrored in

quantitative findings demonstrating a high proportion of participants had addition of glass ionomer cement.

"is it trustworthy in the eyes of the public or is it because again you can see the negative spin. Oh, well you're just trying to save money or you just wanted to get more people through and I'm getting poorer treatment because I used to have my teeth drilled et-cetera, et-cetera. So there's a lot of...there's that acceptability to the public as well as to the profession." [Stakeholder 4]

"I don't know, I suppose there's the sort of thing in the back of your head that says, well, am I going to be judged for my child having holes in their teeth at this age?... I suppose, yeah, that could be from other parents' perspectives." [Parent 17]

Contractual arrangements

Views of various contractual arrangements were shared, and how they may affect implementation differently. The General Dental Services contract in England was a key barrier to SDF being delivered in primary care. Both stakeholders and dental professionals highlighted that it did not provide additional remuneration for treatment with SDF, and that restorative work was better funded. When introducing treatments following the implementation of this contract, the cost of the new treatments either fell to the wider NHS or individual dental practices. Stakeholders' decisions regarding advocacy were based on evidence, return on investment and ability to address oral health inequalities. Importantly, the opportunity cost of funding treatments such as SDF had to be seen in the context of the budget for dental services in competition with areas felt to be a greater priority. Stakeholders were clear that without remunerating dental professionals adequately they would not adopt a treatment, but they highlighted limitations in their ability to advocate for SDF. For some, a lack of licence for caries arrest was an absolute barrier, although opinion on this differed with it not being a universal problem.

There was a range of views about the cost of purchasing SDF within the contractual arrangements, with some considering it expensive and some cheap. Given the lack of funding, the additional cost fell to individual practices to make a decision whether to invest. The potential cost savings to the NHS through reduced secondary care and general anaesthesia referrals would not be directly realised by practices, despite them bearing the cost of purchasing the SDF.

The visit schedule for patients receiving SDF treatment, advocates for a review visit to check whether caries has arrested and if an additional SDF application is required. This was conflicting with the UDA contract, causing fear that following an alternative path could lead them to be an outlier in key performance indicators from regulators. The additional visit time and lack of remuneration were

an impediment to meeting contractual targets. A different approach to contracting services providing funding for a session, rather than for specific work delivered, was seen to be more amenable to delivering paediatric care.

There was reflection from dental professionals that they had previously tried to implement SDF within their setting but the contract was why implementation had failed. A contrasting experience was that others were clear it was a barrier to wider implementation and would stop other professionals, but in their settings they made the decision to use it where they saw the patient need, acknowledging this carried financial repercussions. Overall it was felt that implementation in primary care was very limited.

"Yeah, obviously because it needs multiple appointments and it comes under just about one, it is quite costly. I sort of feel like that with paediatric dentistry anyway, unless you are just putting GIs, you know, kind of with the crowns as well, it's not very cost effective. So, I suppose, I'm aware of it but I don't think it would impact on... it wouldn't stop me doing it." [Dental professional 16]

The factors influencing the implementation of SDF were complex. There was interaction between constructs and domains and across participant groups, demonstrating the need to consider implementation at an individual, local, societal and population level. Adaptations to the standard operating procedure for SDF were seen in both quantitative and qualitative data.

Discussion

Multiple contextual factors effected the ability to implement SDF in NHS primary care, including the acceptability of treatment from parents and children, professionals and stakeholders.

There was concern over the influence of aesthetics on the acceptability and ability to implement SDF at an individual level, and how those treated with SDF may be viewed by the wider society. This has been reported in the literature from research with different cohorts. Soares' review of qualitative research regarding SDF included concern over the societal view of the discolouration as a result of SDF [28]. A qualitative study conducted in Scotland found parents and children were worried about peer's views of the aesthetics [29]. Similar findings have been demonstrated in international studies [30, 31]. Kyoon-Achan's work echoed this study in that children were thought to be less concerned than their parents regarding aesthetics [30]. Gilchrist and co-workers found that younger children had less concern over the appearance of caries [32]. Nonetheless there is research to demonstrate children are cognisant of the appearance of their teeth [33]. This highlights the importance of discussing this side effect with children and parents as part of the consent process.

This concern over aesthetics was one reason that dental professionals adapted the treatment protocol for SDF, subsequently adding a glass ionomer restoration. The evidence on the effectiveness of this technique is limited [34, 35]. In contrast to these published studies, professionals in this study felt it improved the effectiveness of SDF and glass ionomer cement restorations. Addition of a restoration restricts the ability to reapply SDF which has been shown to increase efficacy, however it does mean the restoration is sealed should the restoration be placed to a high standard [17]. Notwithstanding it is important to consider the propensity for multi-surface glass ionomer cement restorations to fail [17].

This research has strengths in multiple areas. The exploration of implementation across eight diverse NHS primary care settings meant different complex environments were considered leading to rich data on the factors effecting implementation of SDF. The use of a theoretically informed approach added rigour to the data collection and analysis. The CFIR specifically allowed assessment from a policy, professional and public and patient perspective. Involvement of these participant groups was a further strength. Using a mixed quantitative and qualitative approach provided complementary data, with qualitative findings explaining the quantitative data. This was particularly the case related to the reach and fidelity of implementation.

Limitations included that interviews with some participants, and younger children in particular were limited in depth. This was in part owing to the use of telephone interviews which made it more difficult to build rapport, however this did mean more participants were included than otherwise would have been. Similarly, not all participants consented to qualitative interviews, this may again mean a different group of participant's experiences were not heard. Furthermore, the majority of participants had application of SDF to posterior teeth. As such most participants had not experienced SDF application for anterior teeth, although perspectives were still given on this. The reapplication rates of SDF were low which is an important finding, as it may limit the effectiveness of SDF in practice in comparison to research evidence where application rates were adhered to, however reasons for this were not discussed in qualitative interviews, which is a limitation. While the population was representative of those seen in NHS dental primary care, and sites had different characteristics, the evidence regarding implementation is specific to this context. This limits the generalisability to different settings and populations.

In terms of taking a reflexive stance, LT designed the data collection tools, conducted the interviews and led the analysis. Therefore their prior assumptions and perspectives had the potential to affect the findings. To try to mitigate this, both the data collection and analysis were

informed by the CFIR and TFA. The topic guides and analysis were informed by PPI for parent and child data. ZM and HDR reviewed the data collection tools and ZM reviewed the findings. LT was both interviewer and analyst. This may have impacted the findings further through LT interpreting responses both within the interview and subsequently in analysis in the same manner. Having different interviewers and analysts would have brought more perspectives to the data and as a result informed the findings.

It is also important to note that LT had led the production of SDF training tools and resources from the British Society of Paediatric Dentistry. Some stakeholders and professionals were aware of this and indeed commented on this. This will have influenced the data they shared, although they were encouraged to give their opinion including what may be perceived as negative views. LT had a working relationship with professionals in the study through the feasibility study, and similarly children and parents knew LT was leading the research and was a dentist. This again could have impacted the data shared.

Future research should evaluate how adaptations made by dental professionals affect the effectiveness of SDF in a pragmatic setting, and consider the implementation of other treatments for caries utilising a theoretically informed approach from multiple perspectives.

Conclusion

This research found that it was possible to implement SDF in NHS primary care. However, policy makers, professionals and parents had concerns about resultant aesthetics. It was felt for wider implementation, better remuneration and contractual change was required. Dental professionals made adaptations to the clinical protocol in response to their own and parent perspectives.

Abbreviations

CD	Chris Deery
CFIR	Consolidated framework of implementation research
HR	Helen Rodd
LT	Laura Timms
NHS	National Health Service
PB	Paul Brocklehurst
PPI	Patient and public involvement
SDF	Silver diamine fluoride
TFA	Theoretical framework of acceptability
UDA	Units of dental activity
UK	United Kingdom
USA	United States of America
ZM	Zoe Marshman

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12903-026-08618-7>.

Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Supplementary Material 4.

Supplementary Material 5.

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Authors' contributions

LT designed the study, collected and analysed data and prepared the manuscript. PB, CD, ZM and HR designed the study and contributed to the manuscript. ZM supported data analysis.

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Data availability

Consent was not sought for data sharing from participants. The datasets generated during the current study are not publicly available as a result but some anonymised data may be available from the corresponding author on reasonable request and in compliance with governance requirements and the consent provided following consultation with the study sponsor.

Declarations

Ethics approval and consent to participate

Ethical approval was granted by the Leeds West NHS Research Ethics committee (23/YH/0053).

All parents provided written consent for their child to participate, and consent for themselves as research participants in the interview. Dental professionals and stakeholders provided written consent for participation in the interviews. The research was conducted in compliance with the Declaration of Helsinki.

Consent for publication

Consent was given for publication of anonymised quotes. There are no patient images or identifiable information included in the manuscript, therefore consent for this is not applicable.

Competing interests

The authors declare no competing interests.

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