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COVID-2019 – Time to Use Silver Diamine Fluoride for Caries Arrest in General Dental Practice?

Abstract: Silver diamine fluoride (SDF) is applied topically to arrest caries and has an increasing evidence base to support its efficacy, both in the primary dentition and to arrest root caries in older patients. It can be used as a non-aerosol generating procedure and is a simple technique. It has a side-effect of discolouring caries black, a factor which requires discussion with patients and their carers prior to application. Due to its efficacy and simplicity, it is a useful intervention for the management of caries.

CPD/Clinical Relevance: Caries is a common condition in the UK, and silver diamine fluoride offers a simple alternative management technique when case selection is appropriate.

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Background

Silver diamine fluoride (SDF) has been used for caries management throughout the world for decades.^{1,2} It has a strong track record of use, particularly in Asia, having been developed in Japan in the 1960s.^{1,2} Research has demonstrated that SDF can arrest caries and relieve dentine hypersensitivity.¹⁻³ Interestingly, there has been a recent rejuvenation of interest in the application of SDF in the UK, perhaps stimulated by increasing waiting lists for children requiring multiple extractions under general anaesthesia (GA) and the recent availability of a product marked 'CE' for use in Europe.¹⁻⁴ The emergence of the COVID-19 pandemic and the subsequent preference to avoid aerosol generating procedures (AGPs) has further raised the profile of SDF as a simple intervention for caries management. This use of SDF has been endorsed for caries management in children and mineralization control

in adults, in primary care and specialist paediatric dentistry recovery guidelines, issued by the Office of the Chief Dental Officer and the Royal College of Surgeons of England, respectively.^{5,6} The British Society of Paediatric Dentistry has also launched a portfolio of resources to support the use of SDF for children in primary and secondary care services.⁷⁻⁹

Clinical research has consistently found that SDF effectively arrests caries in the primary dentition. The evidence suggests that it arrests caries 66% more effectively than topical sodium fluoride varnish (5%) and the atraumatic restorative technique.^{3,10} Currently, around a quarter of 5-year-olds in the UK have dental caries in their primary dentition.¹¹ This unmet need is likely to be compounded by measures taken during the COVID-19 pandemic mandating the cessation of routine dentistry. This spanned both primary and secondary care, leaving children waiting for treatment and without access to professional preventive



Figure 1. Dark discoloration of caries in a child's anterior teeth following application of silver diamine fluoride.

care and school-based brushing clubs.¹² The necessary precautions required for reopening practice limit the capacity to see the previous levels of patients, meaning fewer children are able to access face-to-face care. These restrictions apply in both primary and secondary care services, consequently there are likely to be many children requiring caries management.

This unmet need mainly falls on primary care, as the majority of children are treated in general dental practice. Consistent with this, recent NHS England commissioning guidance suggests caries management as a 'tier one' level of treatment suitable for general dental practice.¹³ For children that do require secondary care, the wait for assessment and treatment is likely to be longer due to the reduced capacity in hospitals, meaning that children will need effective interim caries management in primary care.¹²

Silver diamine fluoride application can be carried out as a non-aerosol generating procedure and is a simple technique for the child and clinician. It is therefore a useful tool in the caries management armamentarium, particularly during the recovery phase of the pandemic, and in dealing with the unmet need for children with caries.

Importantly, due to its simplicity of application, SDF offers a useful alternative for children with dental anxiety or neurodevelopmental needs who may find conventional treatment challenging to accept. A recent study conducted in Singapore found that around two-thirds of parents of children

with autism found SDF to be acceptable for caries management.¹⁴

What is SDF?

Silver diamine fluoride contains silver and fluoride stabilized in ammonia.² It is a clear, odourless liquid that has a metallic taste on application. There is one SDF product available in the UK at the time of writing; *Riva Star* manufactured by SDI, Australia and this is 'CE' marked for sensitivity and cavity cleansing in Europe.^{1,2} *Riva Star* is 38% SDF and contains 44800ppm fluoride, approximately double the concentration of sodium fluoride varnish.^{1,2}

How does SDF work?

For caries arrest, the components of SDF work synergistically. The fluoride promotes remineralization and makes the dentine less susceptible to acid dissolution.^{1,2,4,15} The fluoride penetrates into dentine, and there is 2–3 times more fluoride retained in the tooth structure than where sodium fluoride varnish is used.^{1,15} The silver has bactericidal properties interfering with bacterial metabolism and inhibiting biofilm formation.^{1,2,4,15} SDF also inhibits the action of matrix metallo-proteinases that breakdown collagen.^{1,2,4,15} The mode of action to relieve dentine sensitivity is through the occlusion of dentinal tubules by SDF.^{16,17}

Evidence base

A comprehensive review published in 2020 examined the evidence from 11 systematic reviews reporting on 30 unique trials of SDF for caries management.³

Systematic reviews consistently found SDF to have efficacy for caries arrest in the primary dentition.³ One systematic review performed a meta-analysis of two randomized controlled trials that compared SDF to ART and fluoride varnish and found that caries arrest was 66% greater at 12 months for SDF.¹⁰

For the permanent dentition, evidence has found that SDF promotes caries arrest in root caries.³ Some trials have looked at coronal caries in the permanent dentition, however, the evidence base is less robust. While there is potential for SDF to be applied in this clinical presentation, further research is required.

Similarly, trials have found SDF to have efficacy for caries prevention in both the permanent and primary dentitions, but these results are uncertain and further research is required.³

Trials have demonstrated that SDF performs well for short-term management of dentine hypersensitivity, and this is the indication for which SDF is licenced.^{16,17}

In the UK, the *Riva Star* product comes with a potassium iodide solution to place in a two-stage procedure in order to reduce the side-effect of black discoloration that comes from SDF use. However, the evidence of using this two-stage procedure with potassium iodide is uncertain, with suggestions that staining persists and that the efficacy of SDF may be reduced.^{2,18,19}

The optimum frequency of application for SDF for caries arrest has not been robustly demonstrated. It is generally accepted that 6-monthly applications are appropriate for caries arrest. This has been found to be safe and not at risk of additional side-effects over annual application and is suggested in national guidelines.^{4,20,21}

Benefits

Application of SDF is a simple technique, with stages that are similar to those of topical fluoride varnish use. For patients who cannot manage more demanding treatment options, it presents an alternative active treatment with efficacy for caries arrest. This also makes it useful for acclimatization and stopping progression until a patient is able to manage other procedures or engage with preventive practice. It is also an alternative for those requiring relief from dentine sensitivity.

Disadvantages

The main disadvantage of using SDF is that it discolours carious tooth tissue black (Figure 1). There is research from the USA showing that this is not acceptable to many parents, but that when compared to alternatives, such as extractions and pharmacological behaviour management, acceptance increases.²² A study from Singapore found that 60% of parents found SDF acceptable.¹⁴ There is a paucity of UK data, although research is in progress to explore parental and child perspectives.

Consent form for the use of Silver Diamine Fluoride (SDF) liquid for treatment of tooth decay

SDF liquid is painted on to teeth to slow down or stop tooth decay progressing. It is reapplied every 6 months. More information is available in the Silver Diamine Fluoride (SDF) liquid patient information leaflet.

What are the benefits?

- It is a simple treatment
- It stops decay progressing

What are the risks?

- Decay may continue to develop, and further treatment such as fillings or extractions may be required
- SDF permanently discolours areas of tooth decay black, as shown here:



- Temporary stain to the skin, lips, gums and cheeks for 1-3 weeks
- Discoloration of tooth coloured fillings
- Staining to clothing
- Temporary metallic taste

What are the alternatives?

- Taking no action and keeping the teeth under review (it is probable the decay will get worse)
- Application of fluoride varnish, fillings, crowns/caps or tooth removal

By signing below I agree:

- I have read and understood the SDF liquid treatment patient information leaflet
- I have discussed with my dentist the risks and benefits of treatment
- I have had all my questions answered
- I consent to my child having Silver Diamine Fluoride (SDF) liquid treatment

Parental agreement to treatment:

Name: _____ Signature: _____
 Relationship to Child: _____ Date: _____

Child agreement to treatment:

Name: _____ Signature: _____
 Date: _____

Staff name: _____ Signature: _____
 Job role: _____ Date: _____

Figure 2. British Society of Paediatric Dentistry consent form for the application of silver diamine fluoride for caries arrest.⁹

Information sharing and an informed consent process is therefore extremely important (Figure 2).

Indications

In the primary dentition, SDF is indicated for caries into dentine. This would be

for cases where other evidence-based biological techniques, such as the Hall Technique for preformed metal crowns, were not possible.⁷ It is important to note that efficacy of SDF has been described as greater where good oral hygiene practice is in place. It is therefore essential to ensure

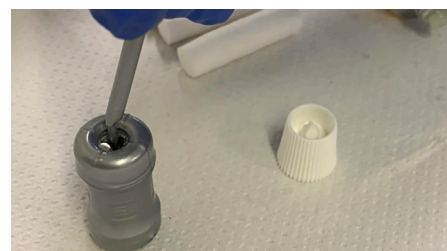


Figure 3. Piercing silver capsule of silver diamine fluoride with a micro-brush.



Figure 4. Application of silver diamine fluoride using a micro-brush.

excellent prevention and that lesions are cleansable.^{2,4} SDF may be used in order to avoid GA if other management techniques would be only possible under GA, or to avoid extraction. SDF can be used as an active treatment during acclimatization, or as a measure while a child awaits access to secondary care or treatment under GA. Provided that the staining is not an issue, it may be considered as a treatment in itself given its effectiveness. In the permanent dentition it may be used to relieve sensitivity, and for arrest of root caries.²

Contra-indications

Silver diamine fluoride is contra-indicated where there is any sign or symptom of pulpal involvement.^{2,7} This would include clinical (sinus, swelling or abscess) or radiographic signs of infection (peri-apical or intra-radicular radiolucency). Caries that has reached, or is close to, the pulp clinically or radiographically should not be treated with SDF. Other contra-indications are where patients have an allergy to any component, including silver or heavy metals, or if there is active ulceration, mucositis or stomatitis.^{2,7}

The risk of toxicity from SDF is thought to be low.² Duangthip *et al* studied the adverse effects of SDF application for 799 children, none of which was found to have systemic toxicity.²¹ They estimated

that, for a 3-year-old child weighing 10 kg to suffer a toxic dose of fluoride, eight times the quantity of SDF required to treat 20 teeth would be required.²¹

Clinical procedure

A standard operating procedure is available from the British Society of Paediatric Dentistry for the application of SDF for arrest of caries in the primary dentition.⁷ The following clinical procedure is based on that guidance and other published protocols.^{2,7,20}

Step 1

Apply petroleum jelly to the soft tissues, including the lips, if possible. Protect the gingiva using petroleum jelly and cotton wool rolls or *Riva Star* gingival barrier. This is required to prevent a chemical burn, although clinical experience suggests that this risk is very low.

Step 2

Ensure that teeth are clean and dry (using a 3 in 1 syringe (air and water functions used separately), cotton wool roll or gauze) and free of debris.

Step 3

Use a micro-brush to pierce the silver capsule (Figure 3). Carefully apply the solution from the silver capsule (SDF) to the treatment site with a micro-brush or other single use applicator (Figure 4). Each capsule is for use on one patient only. A maximum of one silver capsule should be used per visit. This should be left to dry for at least 1 minute, ideally 3 minutes.

Optional step

If a decision has been made with the patient to use potassium iodide (green capsule), pierce the foil of the green capsule. Apply solution from the green capsule (potassium iodide) to the treatment site, with a micro-brush or other single use applicator. Continue application until the creamy white solution created turns clear.

Step 4

Blot the teeth dry using a cotton wool roll, gauze or fresh single use micro-brush. Remove the gingival barrier if used.

Using SDF with glass ionomer cement (GIC)

In 2016, Alvear and co-workers described the silver-modified atraumatic restorative technique (SMART).²³ The SMART technique involves application of SDF following caries removal before the placement of glass ionomer cement.² A recent systematic review was unable to draw conclusions over whether or not SDF affects the bond strength of GIC to dentine.²⁴ An important finding in one study was that SDF reduced the bond strength, however, rinsing with water following SDF application meant that there was no subsequent reduction in bond strength.²⁵ Therefore, if the SMART technique is utilized, patients should be asked to rinse their mouths with water, then the lesion dries and is restored with glass ionomer cement.²

Using SDF with preformed metal crowns

Seifo and co-workers have described a technique named the SMART Hall, using SDF in conjunction with the Hall Technique with the rationale of caries arrest before sealing caries.² However, there is limited research into this technique and, as the Hall Technique is so effective as a stand-alone technique, it is difficult to believe a significant amount of additional benefit would be achieved by using SDF prior to placement of the preformed metal crown.²⁶ Nonetheless, if this technique were to be used, as GIC is used as the luting agent, the patient should rinse with water prior to the clinician cementing the crown.

Using SDF with composite resin

A number of *in-vitro* laboratory-based studies have been undertaken to examine the bond strength of dental adhesives following application of SDF. A recent systematic review concluded that there was insufficient evidence to draw conclusions on the effect of SDF on bond strength.²⁴ Included studies had mixed results, with some suggesting no difference in bond strength of adhesive bonding systems and some showing reduced bond strength. If SDF is used

prior to composite resin, it would seem prudent to clean the margins with damp cotton wool or get the patient to rinse, as with glass ionomer.

Use of SDF off-licence

SDF is 'CE' marked, meaning that it is licenced for use in Europe. This 'CE' mark is for use for sensitivity and as a cavity cleanser.² Other use of SDF, including caries arrest, is therefore off-label or off-licence. The Medicines and Healthcare Regulatory Agency approve medicines for use in the UK, based on an assessment of their safety, quality and efficacy for specified indications.²⁷

Using a medicine outside of these approved indications is considered to be off-licence prescribing. However, this is allowed when the clinician is prescribing in the patient's best interest, based on the best available evidence, and there being no suitable alternative.^{2,27}

As there is evidence from multiple systematic reviews showing that SDF has efficacy for caries arrest, this appears to meet the evidence requirements.^{2,3} As it is indicated here for use where other evidence-based alternatives are not available, either due to co-operation, the lesion itself, or as a temporary measure, it is used where other alternatives are not available. When case selection is appropriate, SDF therefore meets MHRA guidance for prescribing off-licence.²

It is important to note that the prescriber takes on more responsibility that may otherwise be attributed to the manufacturer when prescribing off-licence.² The MHRA states that 'The responsibility that falls on healthcare professionals when prescribing an unlicensed medicine or a medicine off-label may be greater than when prescribing a licensed medicine within the terms of its licence. Prescribers should pay particular attention to the risks associated with using unlicensed medicines or using a licensed medicine off-label.'

This has been raised as a potential barrier to the use of SDF. However, many drugs are used off-licence, especially in children, so this is not an unusual situation. The support for its use by specialist societies, such as the British Society for Paediatric Dentistry and the

Office of the Chief Dental Officer (England), means that the practitioner can use SDF with confidence.⁵⁻⁷

Conclusion

Silver diamine fluoride is currently experiencing increasing attention in the UK and is acknowledged to be a valuable tool for caries management during the recovery phase of the COVID-19 pandemic and beyond. Case selection is important and SDF is not a panacea for all patients. The acceptability to patients and their carers must be considered due to the black discoloration of treated teeth and this must be discussed with patients prior to application. Lesions should be monitored carefully for any progression of caries. The use of SDF for caries arrest is evidence based and, due to familiarity of the stages involved in the technique, it is well suited to primary care practice, particularly when other treatment options are not available.

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Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest.
Informed Consent: Informed consent was obtained from all individual participants included in the article.

References

1. Timms L, Sumner S, Deery C, Rogers H. Everyone else is using it, so why isn't the UK? Silver diamine fluoride for children and young people. *Community Dent Health* 2020; **37**: 143–149.
2. Seifo N, Robertson M, MacLean J, Blain K, Grosse S, Milne R, Seeballuck C, Innes N. The use of silver diamine fluoride (SDF) in dental practice. *Br Dent J* 2020; **228**: 75–81.
3. Seifo N, Cassie H, Radford JR, Innes NPT. Silver diamine fluoride for managing carious lesions: an umbrella review. *BMC Oral Health* 2019; **19**: 145.
4. Crystal YO. Silver diamine fluoride (SDF): its role in caries management. *Dent Update* 2019; **46**: 1016–1022.
5. NHS England: Office of the Chief Dental Officer. *Novel Coronavirus-2019. Standard Operating Procedure. Transition to Recovery*. 2020. Available from: <https://www.england.nhs.uk/coronavirus/wp-content/uploads/sites/52/2020/06/C0575-dental-transition-to-recovery-SOP-4June.pdf>
6. Royal College of Surgeons of England. Faculty of Dental Surgery. *Recommendations for the Recovery Phase of the COVID-19 Pandemic*. 2020. Available from: <https://www.rcseng.ac.uk/dental-faculties/fds/coronavirus/>
7. British Society of Paediatric Dentistry. *Standard Operating Procedure for the Application of Silver Diamine Fluoride*. 2020. Available from: <https://www.bspd.co.uk/Professionals/Resources>
8. British Society of Paediatric Dentistry. *Patient Information Leaflet for the Application of Silver Diamine Fluoride*. 2020. Available from: https://www.bspd.co.uk/Portals/0/BSPD_SDF%20patient%20leaflet_For%20printing.pdf
9. British Society of Paediatric Dentistry. *Consent form for the use of Silver Diamine Fluoride (SDF) liquid for treatment of tooth decay*. 2020. Available from: <https://www.bspd.co.uk/Portals/0/Consent%20Form%20final.pdf>
10. Chibinski AC, Wambier LM, Feltrin J, Loguercio AD, Wambier DS, Reis A. Silver Diamine Fluoride has efficacy in controlling caries progression in primary teeth: a systematic review and meta-analysis. *Caries Res* 2017; **51**: 527–541.
11. Public Health England. 2019. *National Dental Epidemiology Programme for England: oral health survey of 5-year-olds 2019*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/873492/NDEP_for_England_OH_Survey_5yr_2019_v1.0.pdf
12. Zaitoun H, Kandiah P, Yesudian G, Rodd HD. COVID-19: implications for paediatric dental general anaesthetic services. *Fac Dent J* 2020; **11**: 114–119.
13. NHS England. *Commissioning Standard for Dental Specialties – Paediatric Dentistry*. 2018. Available from: <https://www.england.nhs.uk/wp-content/uploads/2018/04/commissioning-standard-for-dental-specialties-paediatric-dentistry.pdf>
14. Hu S, Meyer B, Lai BWP, Chay PL, Tong HJ. Parental acceptance of silver diamine fluoride in children with autism spectrum disorder. *Int J Paediatr Dent* 2020; **30**: 514–522.
15. Rosenblatt A, Stamford TCM, Niederman R. Silver diamine fluoride: a caries “silver-fluoride bullet.” *J Dent Res* 2009; **88**: 116–125.
16. Castillo JL, Rivera S, Aparicio T, Lazo R, Aw TC, Mancl LL *et al*. The short-term effects of diamine silver fluoride on tooth sensitivity: a randomized controlled trial. *J Dent Res* 2011; **90**: 203–208.
17. Craig GG, Knight GM, McIntyre JM. Clinical evaluation of diamine silver fluoride/potassium iodide as a dentine desensitizing agent. A pilot study. *Aust Dent J* 2012; **57**: 308–311.
18. Zhao IS, Mei ML, Burrow MF, Lo EC, Chu CH. Effect of silver diamine fluoride and potassium iodide treatment on secondary caries prevention and tooth discolouration in cervical glass ionomer cement restoration. *Int J Mol Sci* 2017; **18**: 340.
19. Li R, Lo EC, Liu BY, Wong MC, Chu CH. Randomized clinical trial on arresting dental root caries through silver diamine fluoride applications in community-dwelling elders. *J Dent* 2016; **51**: 15–20.
20. Crystal YO, Marghalani AA, Ureles SD, Wright JT, Sulyanto R, DivarisK *et al*. Use of silver diamine fluoride for dental caries management in children and adolescents, including those with special health care needs. *Pediatr Dent* 2017; **39**: 135–145.
21. Duangthip D, Fung MHT, Wong MCM, Chu CH, Lo ECM. Adverse effects of silver diamine fluoride treatment among preschool children. *J Dent Res* 2018; **97**: 395–401.
22. Crystal YO, Janal MN, Hamilton DS, Niederman R. Parental perceptions and acceptance of silver diamine fluoride staining. *J Am Dent Assoc* 2017; **148**: 510–518. e4.
23. Alvear Fa B, Jew JA, Wong A, Young D. Silver modified atraumatic restorative technique (SMART): an alternative caries prevention tool. *Stomatol Edu J* 2016; **3**: 18–24.
24. Jiang M, Mei ML, Wong MCM, Chu CH, Lo ECM. Effect of silver diamine fluoride solution application on the bond strength of dentine to adhesives and to glass ionomer cements: a systematic review. *BMC Oral Health* 2020; **20**: 40.
25. Knight GM, McIntyre JM, Mulyani. The effect of silver fluoride and potassium iodide on the bond strength of auto cure glass ionomer cement to dentine. *Aust Dent J* 2006; **51**: 42–45.
26. Innes NP, Evans DJP, Stirrups DR. The Hall Technique; a randomized controlled clinical trial of a novel method of managing carious primary molars in general dental practice: acceptability of the technique and outcomes at 23 months. *BMC Oral Health* 2007; **7**: 18.
27. Off-label or unlicensed use of medicines: prescribers' responsibilities. MHRA. 2014. Available from: <https://www.gov.uk/drug-safety-update/off-label-or-unlicensed-use-of-medicines-prescribers-responsibilities>