ARRESTING EARLY CHILDHOOD CARIES WITH SILVER DIAMINE FLUORIDE

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CLINICAL ARTICLE:

Early childhood caries (ECC) is one of the most widespread diseases in children and often accompanied by severe co-morbidities, affecting not only the children and their families, but also society and the healthcare system.[1] Given the large number of affected children in Germany (approx. 10 to 50 percent, depending on the age group)[2], in combination with children's dental anxiety or phobia, paediatric dentists face the problem of how to effectively treat carious teeth. Sometimes treatment under general anaesthesia seems to be the last resort. But is this always necessary? In the patient case presented in this article, caries was arrested by the application of a silver fluoride product, embedded in an overall concept.

Silver diamine fluoride (SDF) is the most widely used silver fluoride product. SDF solutions contain silver diamine ions and fluoride ions, which stop the demineralisation process and the breakdown of dentinal collagen and also support the remineralisation of carious, demineralised enamel and dentin.[3,4] The only product currently available in Germany consists of an ammonia based silver fluoride solution and a potassium iodide solution (Riva Star®, SDI Limited). In Europe, however, this product has so far been used mainly as a desensitiser for hypersensitive teeth, in contrast to Asia and Australia. Caries therapy is an "off label indication", although it is safe and effective.[37] Even the American Dental Association (ADA) recommends this treatment option.[8] The following clinical case shows that the use of SDF can help dentists buy time, especially when treating anxious children, to build enough trust for any invasive/restorative dental treatments that may be needed or desired at a later time and avoid the treatment under general anesthesia. Moreover, in times of COVID19, SDF is a caries therapy option generating fewer aerosols.

CASE REPORT

First Visit

A four year old boy presented with his parents at the Department of Paediatric Dentistry of the University of Greifswald, Germany. He had been referred by the family's general dental practitioner for the treatment of multiple carious lesions under sedation or general anaesthesia. According to the case history, the child was suspected to suffer from ADHD (attention deficit hyperactivity disorder). The parents reported that their dentist had tried to treat the carious lesions several times, but their son had not been cooperative enough for successful treatment at the dental practice. The mother said that her child consumed mainly sweet juices, junk food and sweet dishes. Furthermore, the boy habitually sucked his thumb when falling asleep and at night. No history of pain was reported by neither the mother nor the child.

Diagnosis: Early Childhood Caries (ECC)

The clinical examination did not show any extraoral abnormalities. Intraorally, early childhood caries (ECC) was diagnosed. Gingival inflammation and an anterior open bite were also found. Xrays were taken to better evaluate various factors, such as tooth germs, apical processes and the depths of the carious lesions, and to draw conclusions about final diagnosis. All deciduous teeth, except the lower anterior teeth, were affected by caries **(Fig. 1)**.

Prophylaxis Programme

After completing the examinations, the prophylaxis programme routinely used for any new patient was performed. A disclosing solution was used to show the existing dental plaque to both the child and his parents. Then the boy was asked to brush his teeth on his own, and his mother was informed and motivated regarding the proper brushing technique and the importance of rebrushing her child's teeth at home. This was subsequently practised, i.e. the mother brushed her son's teeth while he was sitting in the dental chair. Then the young patient's teeth were briefly brushed with an electric toothbrush attached to a contra angle hand piece to better assess his co-operatively during the use of rotary dental instruments and determine the extent to which he could be treated while awake and whether or not treatment under general anaesthesia was actually indicated. According to his parents, the boy's cooperation during this appointment was surprisingly good, as compared to previous visits to their dentist's practice.

Recommendation of a Tooth Friendly Diet

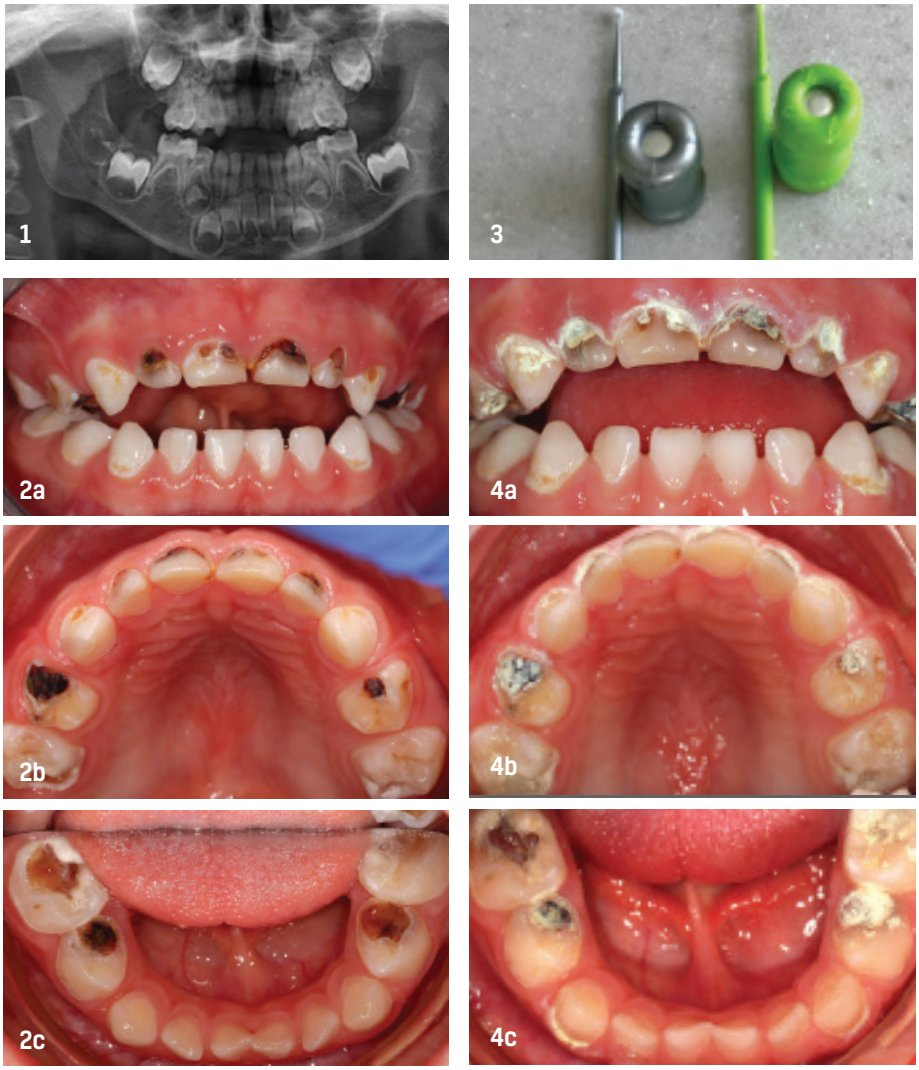
Finally, dietary habits were discussed with the boy and his mother, and a tooth friendly diet was recommended (sweets only during or immediately before/after meals; no sugar-containing drinks in between: water or tea instead of sweetened juices). Besides, the use of 1,000 ppm fluoride toothpaste for children in accordance with the current recommendations of dental societies (e.g. German Society of Preventive Dentistry DGPZM, 2019)[40] was discussed, and also the importance of regular preventive dental examinations.

Indicated Use of a Silver Fluoride Product

Due to the boy's hyperactivity, his impatience during long dental appointments and the large number of active, cavitated carious lesions, restorative treatment without the use of a general anaesthetic seemed hardly possible in an adequate time frame at that point. However, as mentioned above, the patient did not suffer from toothache, according to his mother, and the current waiting time for a dental treatment under general anaesthesia was several months. So, for the time being, it was recommended to apply a silver fluoride product to all carious teeth at the next visit. The objective was to buy time for building up cooperation and performing a restorative dental treatment while the child is awake (under laughing gas sedation, if necessary), or at least decreasing the risk of further caries progression and pulpal involvement. The expected black discoloration of the carious lesions was also discussed. Mother and child agreed to the recommended treatment.

Second Visit

At the second visit, mother and child said they had complied with the dietary and oral hygiene recommendations since the first visit. Oral hygiene had substantially improved, based on the plaque index measured using a disclosing solution, and gingival bleeding had been reduced. Besides, a few lesions already showed the first signs of caries arrest **(Fig. 2a-c)**, which made this seem plausible. Nevertheless, many lesions were still yellow brown and soft on probing (signs of active caries). The teeth still did not show any signs of pulpal or periapical involvement. The boy seemed calmer, as compared to the first visit, which also indicated that rebrushing was done at home and the child felt less uncomfortable at the dental clinic. As discussed at the first visit, the boy was once again briefly prepared for the use of a "magic varnish", which was to be photographically documented (his mother had agreed). Then Riva Star® was prepared **(Fig. 3)** and applied (silver and green capsules). **Fig. 4ac** shows the intra oral situation during the application of the second component (green capsule): A creamy white precipitate is formed when the two solutions chemically react **(Fig. 4a-c)**.



(Photos: M. Khole)

Fig. 1: Part of an orthopantomogram (OPG) of the referred four year old child, taken at the first visit. The OPG shows the germs of all permanent teeth, except the two lower second premolars and the four wisdom teeth, which will develop at a later time. Almost all deciduous teeth show signs of caries in this Xray; this is a classic example of severe ECC. Pain was not reported in the case history, so no apical or interradicular ostitis was diagnosed, and numerous teeth with carious defects showed clear pulpal regression, so that well marked dentin layers were visible between the deep lesions and the pulps.

Fig. 2a-c: Front view of the dentition (a), maxillary (b) and mandibular (c) teeth at the second visit, prior to the application of Riva Star®. Oral hygiene had substantially improved, as compared to the first visit. Moreover, a few lesions already showed the first signs of caries arrest. Nevertheless, many lesions were still yellow brown and soft on probing.

Fig. 3: Before applying Riva Star®, the silver capsule with the silver diamine fluoride component and the green capsule with the potassium iodide component should be ready at hand. To facilitate application, brushes in the same colours are included in the system.

Fig. 4a-c: Teeth of the four year old boy with EEC at the second visit; frontal view (a), occlusal views of the maxillary (b) and mandibular (c) teeth during the application of the second component (green capsule) of Riva Star®.

Follow Up Appointment

At the follow-up appointment, about four weeks after the silver diammine fluoride (SDF) application, the parents reported that a paediatrician had confirmed the ADHD diagnosis and their son now received ADHD medication. Regarding his teeth, the boy still had not experienced any pain symptoms. The intraoral situation had clinically changed to a great extent; all lesions showed distinct dark/black discolorations and had a relatively hard surface on probing, i.e. well on the way to arrest or already arrested **(Fig. 5a–c)**.

At that point, it had to be re-evaluated what kind of treatment, if any, was still needed (particularly from an aesthetic point of view) and whether or not certain procedures, such as treatment under general anaesthesia, were still justifiable. As a result of the patient's improved cooperation and oral hygiene, it was jointly decided to restore the carious teeth step by step: With an informed consent, the Hall[9-11] and Atraumatic Restorative Treatment (ART)[12,13] techniques were suggested to be used for the molars, and the caries arrest strategy involving the use of a fluoride toothpaste at home and, if necessary, a second silver fluoride application for caries arrest the anterior teeth. Provided that the boy was still cooperative and wished an aesthetic improvement, compomer restorations were offered, where necessary in the form of strip crowns.[14]

Discussion

Although there are various options for the management and treatment of carious lesions in children with ECC, this diagnosis poses a considerable challenge to paediatric dentists.[15] The two main reasons are:

1. Large numbers of carious lesions needing immediate treatment,
2. Insufficient or non-existent co-operatively of the children affected.

When treating these children, it may be useful to simply apply SDF to the lesions, because it helps to quickly arrest caries and buy time for improving the children's attitude towards dentists. This allows clinicians to follow a step by step approach to dental treatments with their young patients and avoid the use of general anaesthetics in certain cases.

Silver compounds have long been used not only in general medicine but also in dentistry, thanks to their antimicrobial effects.[4] In 2014, the US Food and Drug Administration (FDA) approved the use of SDF for the treatment of (hyper) sensitive teeth. In Germany, SDF has been available for some years to desensitise teeth and arrest root caries in adults. Off label use of SDF can help to arrest caries in children and, as a result, possibly spare children the necessity of undergoing dental treatment under general anaesthesia. **Table 1** summarises the advantages and disadvantages of SDF. **Table 2** is an overview of indications and contraindications.

1. Hohe Anzahl an kariösen Läsionen mit sofortigem Behandlungsbedarf,
2. Die mangelnde oder geringe Kooperation des Kindes.

(Photos: M. Khole)

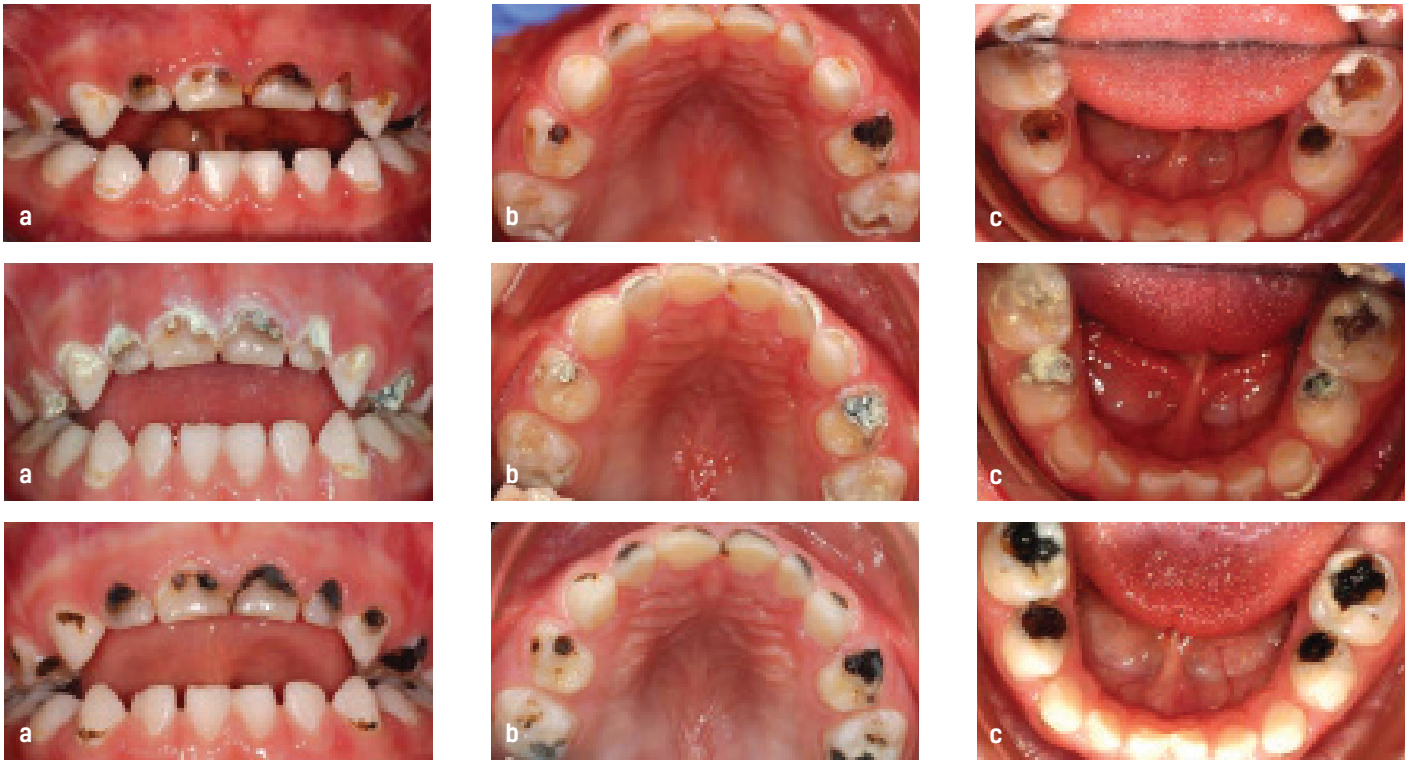


Fig. 6a–c (from top to bottom): Overview of the intraoral findings in the four year old child with ECC in the course of the caries arresting process; frontal views and occlusal views of maxillary and mandibular teeth. The top row shows the situation prior to the application of Riva Star® at the second visit; the middle row shows the findings during Riva Star® application at the second visit; and the bottom row shows the situation about four weeks later. The initial arrest of carious lesions that had already been visible at the second visit was considerably accelerated by the application of Riva Star®, as compared to the steps taken at home to arrest the caries.

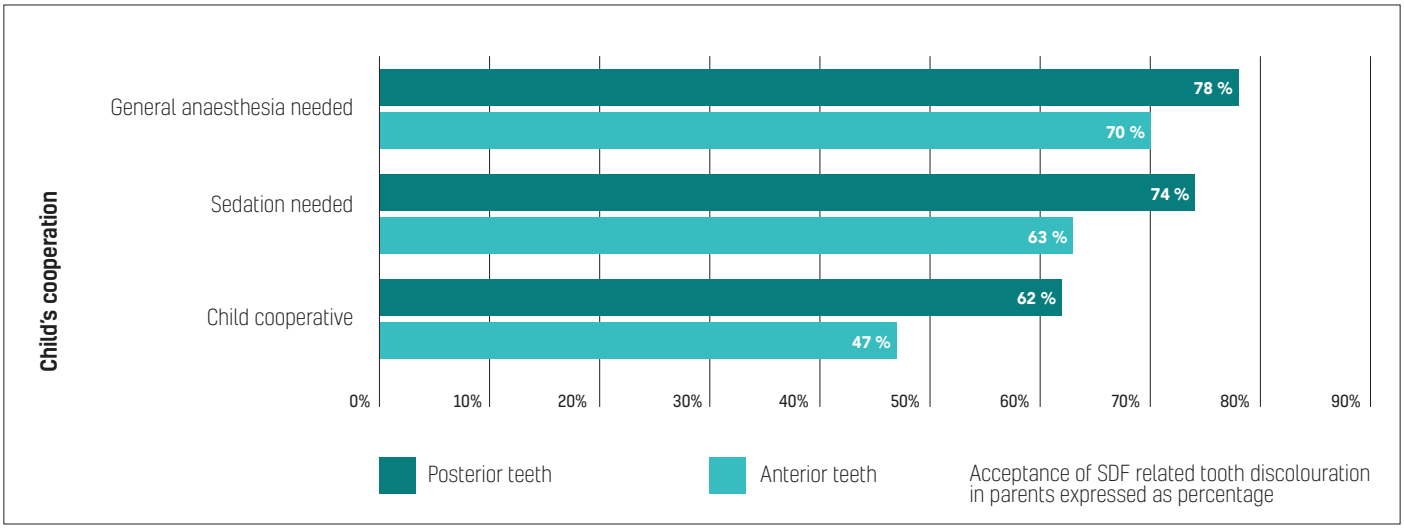


Fig. 7 Acceptance of SDF related tooth discoloration by parents, depending on their child's cooperation and the tooth regions affected. Data from Reference 5.

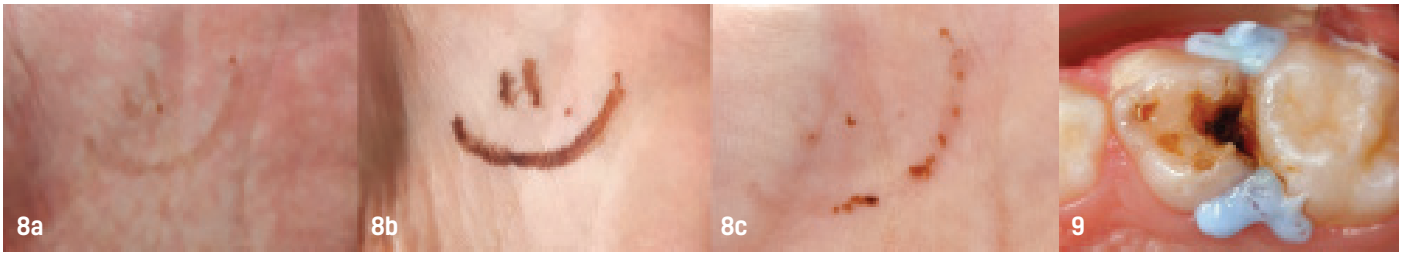


Fig. 8a–c: Skin discoloration after contact with SDF: a) Five minutes after use, b) two hours after use, and c) two days after use. (Photos: Mhd Said Mourad)
Fig. 9: It is advisable to isolate the gingiva with a liquid rubber dam; this helps to avoid discolorations of gingival tissues. (Photo: Mhd Said Mourad)

Caries as an Economic Challenge

Caries is not only the most widespread chronic disease,[16,17] but also an enormous burden on society and economy.[18,19] On the primary, secondary and tertiary levels of caries prevention, various strategies have been implemented to reduce the overall burden on both society and economy. In general, these include the use of fluoride toothpastes, the fluoridation of drinking water and table salt, the application of fluoride varnishes, gels and mouthwashes, pit and fissure sealants, and also the use of sugar substitutes like xylitol.[20] Carious defects may be subdivided into active carious lesions and inactive/arrested lesions (Tab. 3).

BACKGROUND OF SDF

Composition

SDF is an important addition to the "fluoride family" and was introduced in Japan in 1970 by Drs Nishino and Yamaga.[21] The product combined the antimicrobial action of silver with the remineralising effect of fluoride to desensitise teeth and inhibit caries. 38 % SDF is a colourless, high fluoride solution, containing approx. 5 %[20] or 44,800 ppm fluoride ions[7,21], 25% by weight/volume silver ions and 8% ammonia in water.[20]

Effectiveness Testing

The effectiveness of SDF in the arrest of caries was investigated in the form of various systematic reviews and meta analyses of clinical studies on SDF. According to a systematic review conducted by Rosenblatt et al. in 2009,[4] the effectiveness of SDF in terms of caries arrest and caries prevention was 96.1 percent after annual application to deciduous maxillary anterior teeth over a 30-month period,[22] and 70.3 percent after annual application to deciduous molars or first permanent molars over a 36month period.[23] Caries arrest after SDF application, be it observed separately at various times[7] or in comparison with active materials or placebos used as controls, or no treatment, placebos, sodium fluoride varnish and GIC, in deciduous and permanent teeth was consistent in the studies included in several meta analyses.[7,24,25] Horst et al. concluded in a systematic review conducted in 2016 that SDF shows remarkable caries preventive and caries inhibitive properties. They stated that although one application alone may not provide sustained effects, annual application shows significant success, which can even be improved by semiannual application.[26]

Advantages	Disadvantages
Easy and quick to use	Unaesthetic due to black discoloration
No need for complex equipment	Acceptance of the product by parents depends on the tooth region affected and the child's cooperation
Quick caries arrest	
High effectiveness, scientifically proven at highest level of evidence	
Inexpensive	Costs not covered by statutory health insurances in Germany

Tab. 1: Key advantages and disadvantages of silver diamine fluoride (SDF).

Indications	Contraindications
Caries arrest in patients with high caries risk and active, (cavitated) carious lesions	Teeth with pulpal and/or periapical pathosis and associated signs and symptoms
Cavitated carious lesions in patients with behavioural problems or general health problems	Allergies to any of the ingredients
Patients with multiple cavitated carious lesions which cannot be treated in one appointment	Patients undergoing thyroid gland therapy (see Instructions for Use, Riva Star®, SDI)
Cavitated carious lesions in locations making them difficult to treat	Aesthetic concerns
Patients without or with difficult access to dental care	Financial concerns, as costs are not covered by statutory health insurances in Germany
Active, cavitated carious lesions without clinical signs of pulpal involvement	
Hypersensitivity	
Root caries	

Tab. 2: Overview of indications and contraindications for the use of silver diamine fluoride (SDF), based on various studies and publications

Active Carious Lesion	Inactive Carious Lesion
Demineralising activity of the biofilm, mature dental plaque usually present	Microbial activity has been inhibited
May progress and change over time	Development has been slowed down, there is no progression
Clinically visible as a whitish/yellowish stain (often chalky white)	Clinical appearances may range from whitish to brown, brown/black or black stains, depending on lesion depth
The surface texture of the lesion in the enamel layer is dull, loses its lustre and becomes rough on gentle probing	Hard, smooth or shiny texture
The presence of undermined enamel and softened dentin due to caries activity can be detected with a probe	No undermined enamel or softened floor detectable on probing
Requires management/treatment	From a cariological point of view usually no need for action, only checkups
Treatment by restoration or various caries arresting methods, such as application of SDF, fluoride varnish etc.	Observation in the course of preventive measures and regular followups

Tab. 3: Overview of important differences between active and inactive carious lesions, based on various sources.[37-39]

Indications and Acceptance of SDF Treatments

SDF allows clinicians to not only inhibit caries in children, but also, for example, arrest root caries, remineralise deep occlusal lesions and reduce hypersensitivity in adults.[27] Another systematic review[28] also concludes that there are still not sufficient randomised controlled studies of SDF, but clear indications of the effectiveness of SDF in the arrest of coronal carious lesions in deciduous teeth of children and the arrest and prevention of root caries lesions in older adults. The most important side effect of the use of SDF is a dark discoloration of carious tooth structure. A study conducted in Hong Kong, in which 799 children from 37 kindergartens took part[29], showed that although black discolorations of carious lesions by 38 % SDF solution occurred quite frequently (65 to 76 percent), 62 to 71 percent of the parents were satisfied with the appearances of their children's teeth after 30 months. In a webbased survey conducted in the USA, in which photos of carious teeth taken before and after SDF treatments were shown, parents considered the discolorations of posterior teeth much more acceptable than those of anterior teeth. However, even a significant number of those parents who regarded discoloured anterior teeth as unsightly would accept the use of SDF to avoid a treatment under sedation or general anaesthesia **(Fig. 7)**.

SDF may temporarily discolour the skin and the gingiva, so any contact with these tissues should be avoided during application **(Fig. 8)**. Isolation with products like liquid rubber dam is advisable **(Fig. 9)**. Since young children are not always cooperative, at least their lips should be covered with petroleum jelly before application to avoid any inadvertent extraoral discolorations.

Step by Step Application of SDF in Clinical Practice

- **Patient information (approval and discolorations):** The product has been approved only for tooth desensitisation in Germany; caries therapy is not an official indication for use. During application a creamy white precipitate is formed, after a short time the carious lesions turn dark, and after a few days the lesions are usually black. Patients may perhaps experience a strange smell or taste in their mouths.
- **Cleaning:** All tooth surfaces are professionally cleaned with a rubber cup and fluoride free toothpaste, so that they are not covered with food debris or plaque and effective application of the solution to the areas to be treated is ensured.
- **Isolation:** The surfaces are air dried to avoid any saliva contamination. The teeth should be isolated with the gingival barrier or liquid rubber dam included in the Kit. Additionally, cotton rolls and suction can be used. Petroleum jelly should be applied to the lips and other surfaces that may come into contact with the solution.
- **Application:** First, the foil of the silver capsule, Step 1, is pierced, and the brush is dipped into the solution, which is then applied to the carious lesion. This is repeated with the green capsule, Step 2, containing potassium iodide solution. One capsule each (silver and green) is usually sufficient for the treatment of up to five teeth. The two solutions react to form a creamy white precipitate, which can be blot dried (with a cotton pellet). Caution: The SDF solution will discolour everything, including clothes, dental chairs etc.
- **Finalisation:** All the isolation materials used are removed, and a followup appointment is scheduled.

Use of Potassium Iodide in SDF Treatments

The use of potassium iodide after SDF to control or reverse the discolorations has been suggested in numerous studies. Riva Star® (SDI, Bayswater, Victoria) offers both substances. In one of the studies with adult participants, however, the use of potassium iodide did not have any influence on the reduction of the black discolorations in cases of root caries, especially not in the long term.[30] So, for children whose parents have aesthetic concerns, (subsequent) restorations with GIC, composites or tooth coloured crowns at least in the aesthetic zone may be taken into consideration as an additional treatment option.

Bonding to Dentin and SDF Solutions

The most widely used materials for tooth coloured restorations are composite resins and glass ionomer cements.[31] Several studies were conducted to investigate the influence of SDF application on the bond strengths of these restoratives to dentin. The variations in bond strengths found have recently been published in a systematic review.[32] The bond strength of GIC to dentin treated with SDF was not reduced, according to a systematic review by Fröhlich et al., 2020.[33] A universal adhesive used after phosphoric acid etching did not show any decrease in bond strength, either, when applied to dentin treated with SDF.[34] However, the use of potassium iodide (to reduce discoloration) seems to lead to lower bond strengths.[33,35,36] This should be taken into account when planning restorations with the aid of adhesives at a later time.

CONCLUSION

This patient case shows that caries management in young and rather uncooperative children should include effective rebrushing with fluoride toothpaste at home, compliance with dietary guidelines and, as appropriate to the clinical indication, the use of silver fluoride products. These caries arresting methods may help to avoid restorative (invasive) treatments under general anaesthesia, which would involve more risks, effort, time and costs.

Note

The treatment option described in this article is not a dental service covered by statutory health insurances in Germany, but, based on the Patient Rights Law, still to be considered as an alternative when managing caries and subject to the duty to properly inform the patients or their parents.

Conflict of Interests

The Department of Paediatric Dentistry received Riva Star® free of charge, as well as financial support from SDI, to conduct an observational study of this product in clinical use.

Illustrations/Photos

INFORMATION

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