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Clinical Technique/Case Report

Potassium Iodide Reversal of Silver Diamine Fluoride Staining: A Case Report

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Clinical Relevance

The major drawback with silver diamine fluoride (SDF) application is the dark staining of teeth and restorative materials. Therefore, SDF use on adult dentition is limited. Improving the esthetic outcome by stain reduction would greatly enhance the opportunity for its universal use.

SUMMARY

This article describes the clinical protocol of using potassium iodide (KI) to reverse staining caused by silver diamine fluoride (SDF). SDF contains silver, fluoride, and ammonia. It has been used to arrest dental caries mainly in pediatric applications. The major drawback of SDF application is the dark staining of both teeth and restorative materials. Hence, its use on adult dentition is limited. Improving the esthetic outcome by stain reduction would greatly enhance the opportunity for SDF's universal use. This case demonstrates how KI can effectively reverse the staining.

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INTRODUCTION

Silver diamine fluoride (SDF) has been used to reduce the incidence and progression of caries in primary dentition and the results have been well documented.[1-3] SDF was first developed in Japan.[4] Other countries, such as Brazil, England, and Hong Kong, have also been using it to arrest caries in children. Initially, SDF was not approved in the United States partly due to the dark staining of carious teeth. The US Food and Drug Administration, however, approved SDF in August 2014 to reduce tooth sensitivity for those who are 21 years of age or older, and SDF became available in the US market one year later.[5] It is used off-label for the arrest of dental caries.

Despite its great potential for arresting caries, the SDF concept is not taught extensively in the standard restorative dentistry curriculum at US dental schools.[6] At the University of Washington School of Dentistry's predoctoral program, our involvement with SDF started as student-initiated requests after their rotation in pediatric dentistry, where the subject of SDF was introduced. The students questioned why the Department of Restorative Dentistry did not use SDF to control decay in our adult patient population. In response to the

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students' queries, we began a series of research projects and clinical protocols trying to embrace the use of SDF for our adult population.[7-9] We are confident at this time that the esthetic outcome of SDF application through stain reduction would greatly enhance the opportunity for its universal use.

Clinical Case Report

Medical and Dental Background—The patient in this case was a 32-year-old healthy male who suffered from severe decay of the maxillary anterior teeth. His chief complaint was "chipped and broken teeth." The patient's medical history was noncontributory. His dental history included no regular visits to the dentist for more than a decade. The patient also admitted he was a heavy smoker, having smoked a pack of cigarettes per day for the past 15 years but quitting two years ago. He had recently gotten a new job and subsequently dental insurance. Hence, he presented to our dental clinic for a comprehensive dental examination.

The extraoral exam revealed asymptomatic clicking of the left temporomandibular joint during jaw opening. The intraoral examination found generalized gingivitis with severe calculus deposition. There were retained root tips of #1 and #16; #32 was partially erupted, and #17 was impacted. The examination further revealed advanced occlusal carious lesions on teeth #15 and #18.

The most striking finding was the grossly decayed maxillary anterior teeth (Figure 1a,b). We conducted detailed interviews to find out the possible etiology. The patient had normal saliva flow, and no relevant medical information was found to be the possible cause for his dental condition. We ascribed the gross decay to his excessive sugar consumption, lack of dental hygiene, and avoiding care due to dental and medical anxiety. The caries risk assessment indicated that the caries risk was high because of the multiple advanced caries lesions.

All the carious maxillary anterior teeth tested vital to pulp testing, except for #7. Radiographic examination revealed a 3 × 4-mm periapical radiolucency on #7, although the patient was asymptomatic (Figure 2).

For #7, an initial differential diagnosis of necrotic pulp, asymptomatic apical periodontitis was made, and the patient was referred for root canal treatment, followed by scaling and root planing. Another referral was presented to the Department of Oral Surgery for third-molar extractions.

Figure 1. *(a): Preoperative picture of the maxillary teeth before #7 root canal treatment. (b): Preoperative picture of the maxillary teeth after #7 root canal treatment and resin-modified glass ionomer interim restoration.*

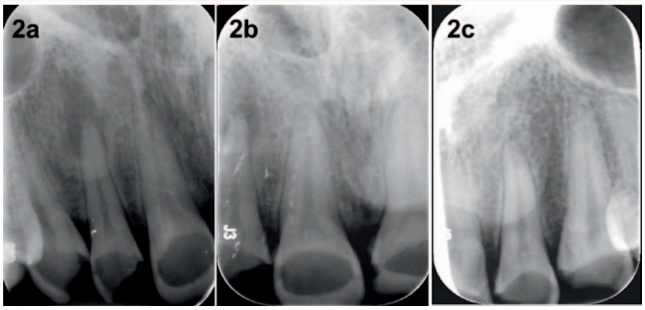

Figure 2. *(a), (b), and (c): Preoperative radiographs of the maxillary front teeth.*

Interim Restorations for Maxillary Anterior Teeth With SDF and Potassium Iodide Application—After discussing the findings with the patient, he was aware of the condition of his maxillary anterior teeth and was motivated to improve his dental health. Since caries risk was high, our immediate treatment phase was to control the caries progression after scaling and root planing. Dietary counseling was done with complete oral hygiene instructions. SDF with potassium iodide (KI) treatment protocols were explained to the patient along with the advantages and disadvantages of such treatments. Decay was removed mainly from the cavity margins using large round burs with a slow-speed hand piece (Figure 3). The removal of soft and infected dentin is crucial to adequate bonding for subsequent restoration. It would also improve the penetration of SDF into the remaining carious dentin and provide a better substrate for application of the glass ionomer restorative material. Additionally, the demineralized enamel would pick up a significant amount of SDF staining at the margins of the restoration and look stained.

The preparations were cleaned and dried, and SDF was applied followed by KI. SDF treatment can

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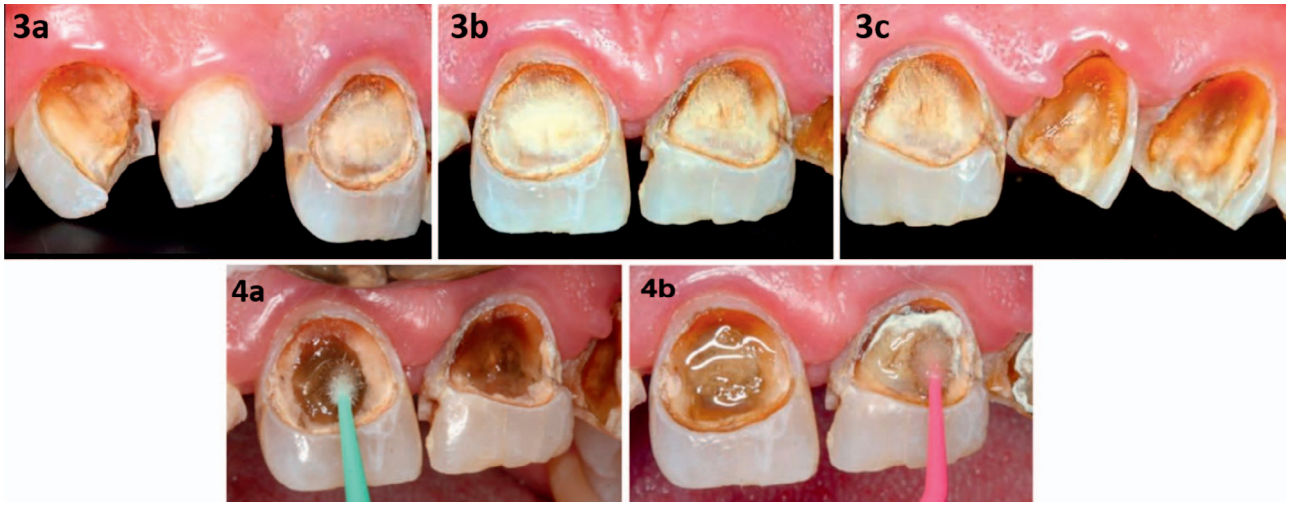

Figure 3. *(a), (b), and (c): Finished cavity preparations.*

Figure 4. *(a): Application of silver diamine fluoride (SDF) with black stain already appearing. SDF treatment can increase the microhardness of carious lesions in dentine and the mineral density of carious lesions in enamel. (b): Application of potassium iodide (KI) showing immediate formation of tripotassium phosphate, K_3PO_4, a white delinquent powder, and silver iodide, also a white powder.*

increase the microhardness of carious lesions in dentin and the mineral density of carious lesions in enamel. Figure 4a,b shows the staining caused by SDF before and after KI application.

Since five of the six anterior teeth tested vital, we prescribed interim glass ionomer restorations for the anterior teeth after SDF and KI treatment (Figure 5a,b). Application of KI returns the SDF-treated dentin to a lighter substrate more amenable to esthetic restorations. This step was deemed important since the interim glass ionomer restorations were to be in place for a few months and patient acceptance and confidence was ensured. Later, these glass ionomer restorations were also to serve as buildups for permanent crowns or veneers. Resin-modified glass ionomer (RMGI) is a highly translucent restorative material because of its high glass filler content. Application of RMGI over SDF-treated dark dentin would unlikely be able to cover the color completely. Final restorations were to be done three to six months later, after all the symptoms, including gingivitis, subsided. The patient was informed to follow all the oral hygiene instructions and improve his gingival health to receive final restorations. Further, at the six-month follow-up appointment, all the restorations were evaluated, touched up with flowable composite, and polished (Figure 6). This helped smoothen the rough surfaces caused by long-term RMGI exposure to oral cavity. The treatment protocol is detailed in Table 1.

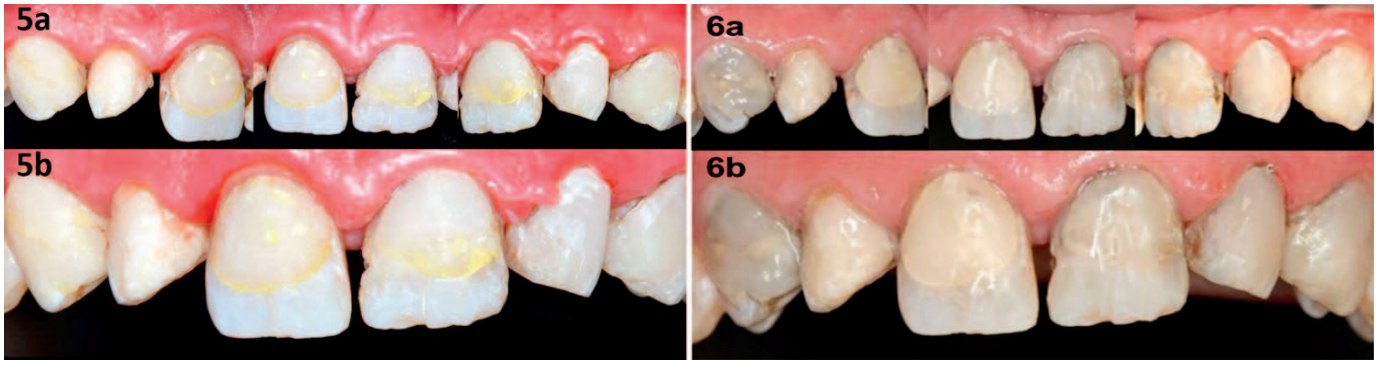

Figure 5. *(a): Interim resin-modified glass ionomer restorations. (b): Formation of yellowish margin on the incisal of the central incisors believed to be a precipitate of silver iodide. Silver iodide is highly photosensitive and can turn dark with exposure to light.*

Figure 6. *(a) and (b): Finished and polished restorations with flowable composite touch-up at six-month follow-up. Note the improved gingival health and slight dark staining of teeth.*

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Table 1: *Recommended Protocol for Potassium Iodide (KI) Staining Reversal*

• Dispense appropriate amount of silver diamine fluoride (SDF) into disposable medicine cup (one drop can be applied to at least five teeth with moderate-size cavities).
• Apply petroleum jelly or use rubber dam to protect soft tissue near affected areas.
• Dry affected tooth surfaces as much as possible with air syringe or with cotton pellets.
• Use a microbrush saturated with SDF to paint directly onto the tooth surface.
• Avoid cavity margins or soft tissues.
• Allow to absorb for one minute, then remove excess with cotton pellets.
• Dispense appropriate amount of KI into disposable medicine cup.
• Use a microbrush saturated with KI to paint directly onto the tooth surface, like SDF application. Reaction products form immediately.
• Restore areas with resin-modified glass ionomer or composite restoration as indicated.

DISCUSSION

SDF is available in an 8-mL bottle (Advantage Arrest Silver Diamine Fluoride 38%, Elevate Oral Care, West Palm Beach, FL, USA) and indicated primarily for the treatment of dentinal hypersensitivity. Each bottle can treat up to 125 sites, with a site defined as up to five teeth.

Medically, KI is known as an expectorant and is prescribed to loosen and break up mucus in the airways. The loosened mucus can then be coughed up, so one can breathe more easily if one has long-term lung problems (eg, asthma, chronic bronchitis, emphysema). KI is also used along with antithyroid medicines and in radiation emergency.

SSKI (potassium iodide oral solution, USP) is a saturated solution of potassium iodide containing 1 g of potassium iodide per milliliter. The SSKI used in this case was manufactured by Upsher-Smith Laboratories, Inc (Maple Grove, MN, USA). The normal dosage for adults is about 0.3 mL (300 mg) or 0.6 mL (600 mg) diluted in one glassful of water, fruit juice, or milk three or four times daily. For stain reversal purpose, the KI dosage used is comparable to 0.3 mL of the saturated KI (1 g/mL) solution. However, the amount applied immediately reacts to form other reaction products. A small, safe amount of KI may reach the saliva.

The combination effect of a SDF and KI treatment on the permeability of demineralized dentin to *Streptococcus mutans* was investigated more than a decade ago;[10] however, only recently was KI suggested to manage the staining problem.[5,7,9,11] It was suggested that discoloration of the carious lesion can be avoided without affecting the caries-arresting effect of SDF. The suggested explanation is that the silver ions from the SDF solution will react with the iodide ions from the KI solution to form silver iodide. We further elucidate the proposed chemical reactions between silver compounds and the major tooth components, hydroxyapatite, as follows:

$$Ca_{10}(PO_4)_6(OH)_2 + Ag(NH_3)_2F \rightarrow CaF_2 + Ag_3PO_4 + NH_4OH$$

The formation of CaF_2 and Ag_3PO_4 was confirmed by *in vitro* studies, and they are considered the major products of the reaction of SDF with tooth tissue.

For the stain reduction, we are proposing that the following reaction occurred where tripotassium phosphate, a white delinquent powder, is formed.[9] The white powder is the main reason for the stain reduction. Another double-reaction product, silver iodide, is a yellowish-white powder but considered to be photosensitive and can turn dark with exposure to light:

$$Ag_3PO_4 + 3KI \rightarrow 3AgI + K_3PO_4$$

Our case report confirms laboratory findings that the restoration margin may still be at risk of discoloration. Yet overall staining compared to that of SDF alone was greatly reduced. It was reported that SDF + KI treatment inhibited development of secondary caries on GIC restorations but was not as effective as SDF treatment alone. Therefore, it seems that the use of KI should be justified for cases where esthetics are important, such as the case presented in the current report.

Potential Risk Associated With SDF and KI

There have been no adverse reports of SDF after around 50 years of use in Japan.[4] Silver allergy would be a contraindication. If soft tissue is not protected with petroleum or rubber dam, desquamate processes, such as ulcerative gingivitis (Figure 7b) can occur. The symptom will go away in 48 hours, but the patient needs to be informed if that happens. Use of KI solution should be avoided in pregnant and lactating women. Potassium iodide can cause fetal harm, abnormal thyroid function, and goiter when administered to a pregnant woman. The patient ought to be informed of the potential hazard. KI can also cause the desquamate process if in contact with soft tissue (Figure 7d) unless the soft tissue has been protected before SDF application, in which case the desquamate process will not occur. SDF has been

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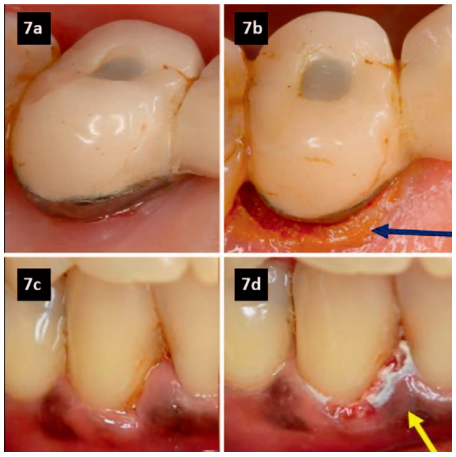

Figure 7. *Application of silver diamine fluoride (SDF) to arrest caries at a defective crown margin (a) resulted in soft tissue reaction (b). Gingival tissue before (c) and after (d) application of potassium iodide (KI). Minor reactions can occur even after protection of soft tissue by petroleum jelly.*

approved as a desensitizer, and it has been reported in the literature that SDF causes minimal adverse effects; however, further data on the effects of SDF and KI on pulpal complex are needed.

Restoration Following Treatment of Dentin

While it was reported that the application of SDF did not affect the bond strength of RMGI to dentin, others reported that the application of SDF may significantly decrease the bond strength of composite to dentin, depending on the protocol and adhesive system used.[10] Rinsing with water spray for 15 seconds improved bond strength, but superficial refreshing of SDF treated dentin prior to bonding showed the highest bond strength. In the previously mentioned report, a two-step self-etch adhesive and a universal adhesive used after phosphoric acid etching showed better performance than universal adhesive alone on SDF treated dentin. It was also reported that the application of SDF + KI to dentin surfaces before the placement of GIC restorations did not affect the bond strength of GIC to dentin and did not adversely interfere with the fluoride uptake into the adjacent demineralized dentin. In this case, a resin-modified glass ionomer was used as the restorative material, which has the advantages of GIC with improved mechanical properties and esthetics.

Clinical Aspects and Benefits

Rampant caries control treatments, such as the case reported here on anterior teeth, have been suggested to quickly increase patients' self-esteem and motivate them to improve their oral health.[12] Since these procedures typically involve minimal tooth structure removal (drilling), they cause little discomfort and anxiety for the patients avoiding dental care. These treatments also bear the advantage of quickly providing access to much-needed care and reducing caries progression.

The SDF has multiple aspects that make it a unique choice for such a case; it is a bactericidal agent and reduces the growth of cariogenic bacteria.[10,11,13] SDF not only inhibits demineralization and promotes the remineralization of demineralized enamel and dentin but also hampers degradation of the dentin collagen in caries-affected dentin.[13-15] In experimental animal model studies, pulp histology was not significantly altered in the molar cavities exposed to SDF, concluding that SDF caused minimal adverse effects.[16] Further, SDF has a strong preventive effect that is comparable to or stronger than fluoride varnish. Studies show that a single application of SDF can significantly increase the resistance of dentin against demineralization.

SDF + KI has both the antibacterial and caries-arresting properties, and its remineralization potential is expected to improve in combination with the RMGI. The suggested treatment also benefits the long-term treatment planning goals by providing a basis for treatment prognosis in each individual patient. A current dental terminology code was approved in 2016 for such caries arresting treatments (code D1354), allowing reimbursement for off-label use of SDF. We anticipate that dentists will be using more of such treatments as SDF + KI for caries in the adult population following the approach presented in this report.

Alternate Treatment

As an alternate treatment to control decay, the American Dental Association recommends application of fluoride varnish every six months as an effective measure in the primary and permanent dentition of children and adolescents.[17] As a precaution, fluoride varnish may decrease the bond strength of composite restorations to dentin.[18] The atraumatic restorative technique is another viable alternative; however, it does not involve the use of SDF, while SDF has shown strong caries-arresting, collagen-preserving, and antibacterial effects that might not be achieved by RMGI alone. In this case, arresting active dentin caries was a primary goal; therefore, this technique was selected. Further clinical studies should compare the results of both techniques.

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CONCLUSIONS

Our case report confirms that the application of KI helps reverse staining caused by SDF to a large extent. Restoration margins may still be at risk of discoloration. KI can help enhance the esthetic outcome by stain reduction, thus making SDF a mainstream choice for preventing caries. With the approval of a current dental terminology code in 2016 for caries-arresting treatments, we anticipate that dentists will be using more of SDF to help prevent caries in the adult population. We encourage that SDF be taught in the standard restorative dentistry curriculum of dental schools as a viable caries control tool. Dentists should also be acquainted with the products and clinical protocols to be able to help their high-caries-risk patients.

Disclaimer

The clinical pictures were digitally cropped and oriented for comparison.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the University of Washington.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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