

**ORIGINAL ARTICLE****Journal Section**

Impact of Potassium Iodide Solution on Silver Diamine Fluoride Black Staining - In Vitro Investigation

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Abstract

Dental caries is a prevalent global oral health issue, necessitating effective preventive and treatment strategies. Silver diamine fluoride has emerged as a valuable tool for arresting carious lesions, but its drawback of causing permanent black staining raises concerns. This study explores the potential of potassium iodide to mitigate silver diamine fluoride-induced staining through repeated applications at different intervals. Sixty carious permanent teeth were divided into three groups: silver diamine fluoride alone, silver diamine fluoride with daily potassium iodide application, and silver diamine fluoride with weekly potassium iodide application. Color assessments were conducted using mean grey values at baseline, immediately post-application, and at 2 and 4 weeks. Results demonstrated that potassium iodide significantly reduced black staining when applied immediately after silver diamine fluoride. Daily potassium iodide application yielded the whitest color, surpassing weekly application. The findings suggest that integrating potassium iodide with silver diamine fluoride, particularly through daily application, offers a promising approach for minimizing staining associated with silver diamine fluoride treatment, enhancing its acceptability and clinical utility.

KEYWORDS

Silver Diamine Fluoride; Potassium Iodide; Prevention; Dental caries

1 | INTRODUCTION

Dental caries is one of the most prevalent oral health issues in the world. Host factors are the etiology of this complex illness, bacterial agent and oral environment. The bacteria convert sugar into acids through metabolism, and demineralization occurs in the enamel.¹ To avoid this

issue, demineralization ought to be addressed while it's still in its early stages, using fluoride application, xylitol or casein products.² When the caries lesion becomes a cavity, taking out the damaged tooth tissue and replacing it with a restorative material is the most popular method of treating dental caries.² Sometimes Caries removal and restoration cannot be used to manage carious lesions,

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when there is insufficient tooth structure left for a restorative procedure to be feasible, or the patient refuses to cooperate and general anesthesia is required. Furthermore, in the fields of pediatric and special care dentistry, it is frequently necessary to halt the advancement of lesions so that patients can better tolerate restorative procedures. Applying silver diamine fluoride (SDF) is one of the recommended dental therapies in these circumstances rather than removing carious tissue.³ SDF is a colorless and odorless solution composed of ammonium ions, fluoride, and silver ions. Ammonia acts as a stabilizer in the solution. SDF contains a high concentration of fluoride ions (38%), reaching 44,800 ppm. Upon application to decayed tooth tissue, a series of chemical processes ensue, leading to tooth desensitization and the halting of carious lesions. These processes involve the occlusion of dentinal tubules, remineralization, prevention of dentinal collagen breakdown, and bacterial elimination. Nevertheless, a significant drawback of SDF is its tendency to permanently stain carious lesions black.⁴ To mitigate this concern, potassium iodide (KI) is promptly applied following the administration of SDF to minimize the extent of black staining within the carious lesion. KI, a salt comprising 23% potassium and 76% iodine, instigates a reaction with SDF, resulting in the precipitation of yellow silver iodide, which can be readily rinsed away. Importantly, the application of KI does not compromise SDF's efficacy in arresting caries.⁵ In a study aimed at identifying the optimal concentration of KI, ranging from 7.5% to saturated solutions for reducing black staining post-SDF application, it was found that the saturated KI group exhibited the most pronounced reduction in black staining immediately after KI application.⁶ Unfortunately, there is no study to demonstrate the effectiveness of SDF+ KI (saturated) application more than once in different intervals. So, the purpose of this study was to investigate the impact of applying KI repeatedly at various time intervals.

2 | METHOD

Design

The study was an experimental design conducted in vitro, it was carried out with permission from the Pharos University research ethics committee, with registration number (02-2023-3-39-4-080). The research adhered to

the recommendations of the Checklist for Reporting In-vitro Studies (CIRS).⁷

Study Sample

Based on the mean difference between SDF and SDF+KI color outcome of 50 %⁶, and precision of 5%. A 95% confidence level calculation indicated that 60 teeth would be the minimal sample needed. The study included 60 human extracted teeth, the selected teeth were carious permanent teeth with occlusal or proximal caries extending to dentine and if there is the presence of restoration or caries extending to pulp, the tooth was excluded.

Teeth and Materials Preparation

The teeth were cleaned, and debris was removed from the decayed cavity using a sharp excavator to ensure optimal contact of the tested materials with the dentin. Subsequently, the teeth were immersed in artificial saliva, formulated by mixing 500 milliliters of distilled water with 1.2 grams of potassium chloride, 0.843 grams of sodium chloride, 0.051 grams of magnesium chloride, 20 milliliters of tricalcium phosphate (1%), and 6.8% carboxymethylcellulose.⁸ Saturated KI solution was prepared dissolving 1 g of KI in 0.5 mL boiling water.⁹ Artificial Saliva and saturated KI solution were prepared in the Department of Pharmacology, Faculty of Pharmacy, Pharos University. SDF with a concentration of 38% (Elevate Oral Care, LLC, USA) was used.

Grouping

Teeth with similar carious lesion size and location were divided randomly into 3 groups; group 1 (20 teeth): SDF, group 2 (20 teeth): SDF with KI applied every day, and group 3 (20 teeth): SDF plus KI applied once a week.

Treatment

SDF was applied to the carious lesions of the three groups for 2 minute using a micro sponge brush.¹⁰ KI solution was applied to the carious lesions of groups 2 & 3 immediately after SDF application using a micro sponge brush for 2 min. The application of KI was repeated once daily to the caries lesions of group 2, and once weekly for group 3.

Evaluation

To capture images for color assessment, teeth were photographed under consistent lighting conditions at baseline, immediately after application, and subsequently

at two and four weeks following the use of the evaluated materials (Fig. 1). Throughout the four weeks, teeth from all three groups were stored in artificial saliva. After each imaging session, the artificial saliva was replenished. Using ImageJ software (WS Rasband, National Institute of Health, Bethesda, MD, USA), teeth images were imported and calibrated, and the carious area was isolated before being examined for the mean grey values. The gray value ranges from 0-225 (0: black, 255: white).

Statistical Analysis

The collected data were organized and tabulated, and statistical analysis was performed using IBM SPSS Statistics software, version 25, by IBM Corp., Armonk, NY, USA. Group comparisons were conducted using One-Way ANOVA tests, followed by post hoc tests for pairwise comparisons. Repeated measures ANOVA was employed to compare different follow-up measures within the same group. Graphical representations of the data were created using Microsoft Excel.

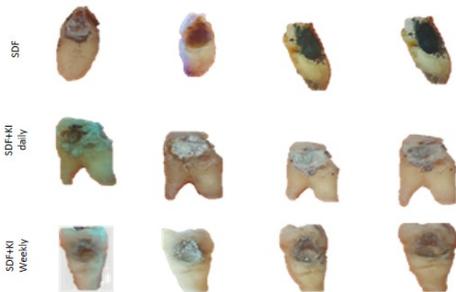


FIGURE 1 Images at different follow-up times among the 3 groups

3 | RESULTS

It was found as shown in Table 1 that at baseline before SDF application there was no significant difference between group 1, 2, and 3 regarding mean grey value (99.3 ± 2.3), (100.0 ± 2.2), and (99.5 ± 2.3), respectively ($p > 0.05$). After immediate application of tested materials, there was a high significant difference between the 3 groups in mean grey value (71.5 ± 4.1), (170.3 ± 4.4) and (171.1 ± 9.3) respectively, group 2 and 3 were significantly whiter than group 1 ($p = 0.000$). At the two

follow-up periods, there were significant differences between the 3 groups with mean grey values of 45.6 ± 1.7 , 171.3 ± 5.7 , and 154.9 ± 3.4 after 2 weeks, and 26.9 ± 1.5 , 138.2 ± 4.3 , and 94.2 ± 4.0 after 4 weeks, respectively, the group 2 was the closest to the hue white.

The mean grey values were compared between baseline, immediate and the 2 follow-up periods in different groups (Table 1 and Fig. 2). The results found that for group 1, the mean grey values decreased significantly with time to be 71.5 ± 4.1 (immediately), 45.6 ± 1.7 (2 weeks) and 26.9 ± 1.5 (4 weeks) when compared with the mean grey value at baseline (99.3 ± 2.3). the teeth became significantly darker in color ($p=0.000$). Regarding group 2, the color became significantly whiter after the immediate application of SDF+KI (170.3 ± 4.4) and at the two follow-up periods (171.3 ± 5.7 and 138.2 ± 4.3) respectively when compared with baseline (100 ± 2.2). Also, as regards, group 3 had a significant difference between baseline (99.5 ± 2.3), immediate (171.1 ± 9.3) and at the two follow-up periods (154.9 ± 3.4 and 94.2 ± 4.0) respectively. The highest mean grey values were after immediate application then decreased significantly with time ($p= 0.000$).

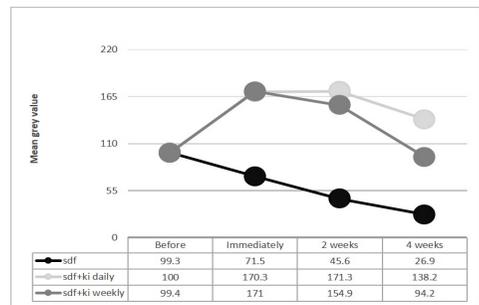


FIGURE 2 Comparison of mean grey values at different follow-up times among the 3 groups

4 | DISCUSSION

SDF can arrest dental caries in patients who cannot be treated with regular dental care as; uncooperative children, elderly patients, physical or cognitive disabilities, and immunocompromised patients.¹¹ To increase the acceptance of SDF among patients, parents and clinicians,

there is a need to modify SDF which will result in no or negligible staining, while retaining the benefits of all the properties of SDF.¹²

In the medical field, KI is recognized as an expectorant, often recommended to aid in the loosening and dispersion of mucus within the airways. This property makes it particularly beneficial for individuals with chronic lung conditions such as asthma, chronic bronchitis, or emphysema, facilitating easier breathing by enabling the expulsion of mucus through coughing. Additionally, potassium iodide is utilized in conjunction with antithyroid medications and is a component of emergency protocols for radiation exposure. On the other hand, KI has the potential to induce desquamation upon contact with soft tissue, unless appropriate protective measures have been taken before the application of SDF and KI, in which case desquamation can be prevented.¹³

The results of the current study found that when saturated KI was applied to 38% SDF, the black staining decreased significantly after immediate application and during the 2 follow-up periods. but when SDF was applied alone, the staining continued to be darker until the end of the study. This finding is in agreement with a study conducted in 2017 to evaluate the effect of KI and SDF treatment, it was found that KI treatment showed minimal to no staining after 4 weeks, and the teeth treated with SDF alone were noticeably darker.¹⁴ Another study conducted in 2022, used topical application of SDF and KI treatment, the color change was detected, and it was concluded that the application of SDF followed directly by KI treatment produced a significant reduction in teeth staining than the application of SDF alone.¹⁵

In disagreement with the current results, Garg et al. reported that the reduction in the staining with the application of KI once immediately after SDF occurred only at the time of the placement, however, black staining was reported to increase from day 7 to day 14.⁵ This may be due to the excess unreacted silver ions precipitated as silver sulfide, inducing discoloration.^{16,17} This may explain why the daily application of KI gave better color at the end of the current study. The daily application of KI reacts with the remaining silver giving a better outcome.

The current study demonstrates several strengths

that enhance its scientific rigor. Firstly, the experimental design incorporated a randomized allocation of teeth into different groups, ensuring a robust investigation into the effects of KI on SDF staining. Moreover, meticulous sample size calculation was methodically conducted, thereby bolstering the statistical power of the study. Additionally, the utilization of ImageJ software for teeth image analysis and calibration further enhances the objectivity of color assessment.

However, it is crucial to acknowledge certain limitations inherent in the study design. Firstly, the *in vitro* nature of the investigation may restrict the generalizability of findings to the complex oral environment *in vivo*. Additionally, while the use of artificial saliva is a common practice, it introduces a potential discrepancy when compared to natural saliva. Furthermore, the short-term follow-up of only 4 weeks restricts the assessment of color stability over an extended period. Lastly, the utilization of simplified mean grey values for color assessment may not fully capture the intricacies of color changes.

5 | CONCLUSION

Applying saturated KI after SDF treatment proved effective in diminishing the severity of black staining caused by SDF. Furthermore, the daily application of KI resulted in a notably whiter color compared to the weekly application. Future *in vivo* research is advised to overcome the limitations of the present study, offering a deeper insight into the effects of SDF and KI treatment across various clinical scenarios. Such studies can furnish evidence-based recommendations regarding the optimal concentrations and dosages of SDF and KI for routine clinical application. Long-term follow-up investigations are essential to assess the sustained efficacy and safety of these treatments in clinical practice.

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Nil

Conflict of interest

The authors have no conflicts of interest to declare.

Availability of data and materials

The corresponding author can provide the datasets used and/or analyzed in the current work upon reason-

able request.

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TABLE 1 Comparison between the three groups at baseline, immediately after application and the two follow-up periods

Group	Baseline (mean±SD)	Immediately (mean±SD)	After 2 weeks (mean±SD)	After 4 weeks (mean±SD)	P value
Group 1 (SDF)	99.3±2.3 ¹	71.5±4.1 ^{a2}	45.6±1.7 ^{a3}	26.9±1.5 ^{a4}	0.000*
Group 2 (SDF+KI daily)	100.0±2.2 ¹	170.3±4.4 ^{b2}	171.3±5.7 ^{b3}	138.2±4.3 ^{b4}	0.000*
Group 3 (SDF+KI weekly)	99.5±2.3 ¹	171.1±9.3 ^{b2}	154.9±3.4 ^{c3}	94.2±4.0 ^{c4}	0.000*
P value	>0.05	0.000*	0.000*	0.000*	

*Statistically significant difference ≤ 0.05 . Different superscript letters denote significant pairwise comparisons between different groups. Different superscript numbers denote significant pairwise comparisons between different follow-up periods within the same group.