# Evaluation of the Masking Effect of Different Glass Ionomer Restorations following Silver Diamine fluoride and Potassium Iodide Application: An In Vitro Study

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Eur J Gen Dent 2022;11:195–200.

## Abstract

**Objectives** This is an *in vitro* study that aimed to evaluate the ability of different glass ionomer restorations to mask the discoloration produced following silver diamine fluoride (SDF) only and after potassium iodide (KI) application.

**Materials and Methods** Thirty-six extracted human adult posterior teeth were collected. Box-shaped cavities ($4 \times 2 \times 2\,mm^3$) were prepared along the cementoenamel junction. Specimens were randomly divided into two major groups according to the materials applied under the restorations group (A) 38% silver diamine fluoride (SDF) followed by immediate application of potassium iodide (KI), group (B) 38% silver diamine fluoride (SDF) only. Each group was further subdivided according to the restorative material applied as follows ($n = 6$): subgroup (I) zirconia reinforced glass ionomer, subgroup (II) resin-modified glass ionomer restoration, and subgroup (III) high viscous glass ionomer restoration. Color assessment of all specimens was performed using a reflective spectrophotometer. Specimens' color was assessed color of normal dentin then assessed immediately after application of SDF (group A) and after application SDF + KI (group B) with the respective restorative material used.

**Statistical Analysis** Data showed parametric distribution and variance homogeneity and were analyzed using one-way analysis of variance followed by Tukey's post hoc test.

**Results** Intergroup comparisons showed that for SDF and SDF + KI samples, there was a significant difference between the different restorative materials ($p < 0.001$). For glass ionomer, SDF samples had significantly higher color change value than SDF + KI ($p < 0.001$), while for RMGI and zirconia reinforced glass ionomer, SDF + KI samples had significantly higher value ($p < 0.001$) although zirconia reinforced glass ionomer showed the least color change following SDF ($6.00 \pm 2.74$).

**Conclusion** Within the limitations of this study, we could conclude that using zirconia reinforced glass ionomer could have a good masking effect on discoloration produced by SDF. While the resin-modified glass ionomer restoration showed more discoloration and darkening effect even after using of KI. Also, using KI in combination with SDF had a good masking effect on discoloration that produced by SDF.

**Keywords**
- laboratory research
- potassium iodide
- silver diamine fluoride
- resin-modified glass ionomer
- zirconia reinforced glass ionomer

**DOI** https://doi.org/10.1055/s-0042-1759753.
**ISSN** 2320-4753.



Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

## Introduction

Dental caries is one of the most prevalent diseases worldwide with higher rates, especially in patients with lower socioeconomic status and those with special health care needs.[1] Untreated carious lesions can lead to pain, loss of tooth function, and infection that may develop leading to serious complications. These effects have an impact on patients' oral health as well as their overall health, including growth, cognitive development, and quality of life.[2]

Silver diamine fluoride (SDF) is a non-invasive, low-cost, antibacterial solution that has been introduced to potentially arrest active carious lesions due to its remineralization potential especially in patients with special needs, uncooperative very young children, or medically compromised patients. It had shown a proven effect in the biomodification of inner repairable carious dentine increasing its elastic modulus and microhardness of caries affected dentine also limiting secondary caries development in adult, which was reported to be the reason for replacement of 25% of amalgam and resin composite restorations.[3–5] Unfortunately, poor aesthetics is the main significant disadvantage of using SDF, as it causes black staining on treated teeth also because the tooth cavities are not restored, the chewing efficiency of the cavitated teeth may not be improved.[2,6,7]

To overcome these drawbacks, a saturated potassium iodide (KI) solution was suggested to be applied immediately following SDF application, allowing the reaction between silver ions and iodide ions resulting in silver iodide that reduces black staining. Also, different restorative materials such as glass ionomer restorations have been proposed to restore the lesions after SDF and to help in masking the black color of SDF. They were tested for bonding and performance after the application of SDF and resulted that there was no adverse effect of the SDF on their bonding to tooth structure.[2,8] Furthermore, using SDF under glass ionomer cement restorations results in a positive pulpal response and helps the formation of secondary reparative dentine and increases the resistance of cavity margins to secondary caries development.[6]

The quest for better glass ionomer restorative materials has led to the development of new classes with higher properties, e.g., resin-modified glass ionomer and recently zirconia reinforced glass ionomer (Zirconomer Improved, Shofu Inc., Japan), which was named "White Amalgam" due to its high strength and long durability. It also has fluoride-releasing ability and reasonable translucency that mimic natural tooth shade.[9] Detailed search in the literature was done to find that no study reported testing the performance of zirconia reinforced glass ionomer following the application of SDF. The effective role of SDF in preventing and arresting secondary caries combined with high strength properties, fluoride release, and translucency of Zirconomer was suggested to result in a promising restorative option. This in vitro study was proposed to evaluate the ability of different glass ionomer restorations to mask any resulted discoloration following SDF and also after potassium iodide (KI) application to SDF. The null hypothesis proposed was that there would be no difference between the performance of different glass ionomer restorations in masking any discoloration following (SDF) and (KI) application.

## Materials and Methods

Thirty-six extracted human premolar teeth were collected following the regulations of human teeth reuse in research work by the Research Ethics Committee of Faculty of Dentistry, Cairo University. They were washed properly under running water, cleaned from any tissue debris, and stored in distilled water until use.

The sample size ($n = 6$) was calculated based on the specified outcome; the mean difference in the color change in a previous study[6]; to be able to reject the null hypothesis with Effect size d = 5.4154633, $\alpha$ error probability = 0.05 and power (1-$\beta$ error probability) = 0.90 using the G Power software version 3.1.9.6.

Box-shaped cavities ($4 \times 2 \times 2\ mm^3$) were prepared along the cemento-enamel junction.[6] The cavities were then prepared with a tungsten carbide bur (FG 245; SS White, United Sates) under copious air–water cooling. All cavities were conditioned with 10% polyacrylic acid.[10] Specimens were randomly divided into two major groups according to the materials applied under the restorations with an allocation ratio of 1:1. Group (A) 38% SDF followed by immediate application of KI, (Riva Star, SDI, Bayswater, Australia), group (B) 38% SDF only. Each group was further subdivided according to the restorative material applied as follows ($n = 6$): subgroup (I) Zirconia reinforced glass ionomer (Zirconomer Improved, Shofu Inc., Japan), subgroup (II) resin-modified glass ionomer restoration (Fuji II LC, GC, Tokyo, Japan), and subgroup (III) high viscous glass ionomer restoration (Fuji IX, GC, Tokyo, Japan; ►**Table 1**).

**Table 1** Brand names, manufacturers, and composition of used materials

| Material | Composition |
|---|---|
| Zirconomer Improved (Shofu Inc., Japan) | Powder: glass powder, zirconium oxide, tartaric acid (1–10%), polyacrylic acid (20–50%), liquid: deionized water |
| Fuji II LC (GC, Tokyo, Japan) | Powder: aluminosilicate glass, pigments<br>Liquid: polyacrylic acids, distilled water, Hydroxyethyl Methacrylate (HEMA; 17%), dimethacrylate monomer, camphorquinone |
| Fuji IX (GC, Tokyo, Japan) | Powder: Fluoroaluminosilicate glass (70–80%)<br>Liquid: Polyacrylic acid 10–15%, distilled water 10–15% |
| SDF/KI Riva Star (SDI, Bayswater, Australia) | 1st liquid: 38% silver diamine fluoride<br>2nd liquid: potassium iodide (KI) |

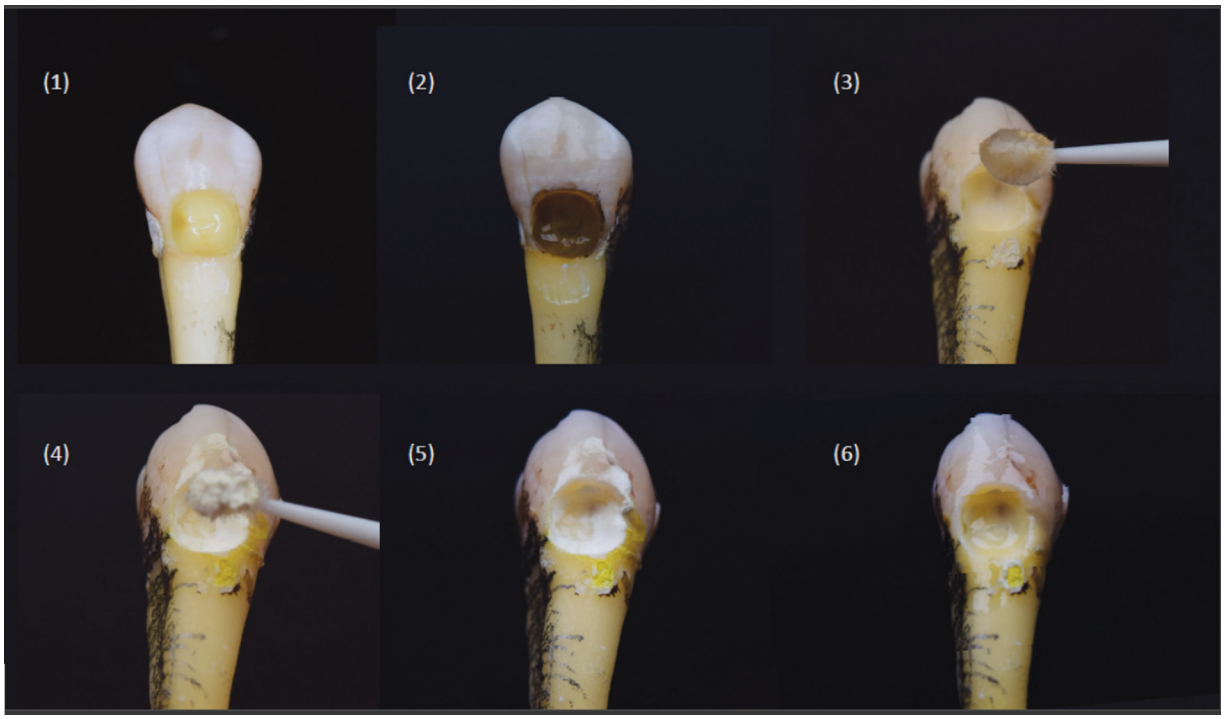


**Fig. 1** Application of SDF plus KI. (1) Sound dentine (2) application of SDF (3, 4) application of SDF followed by KI immediately using a bond brush (5) the reactionary creamy white precipitate was formed (6) the specimen was washed properly with water.

As per the manufacturer's instructions, SDF was applied to the cavities using a micro-brush. Only in group (A), KI was applied immediately following SDF application using bond brush until the white reactionary precipitate was formed. After precipitate removal through washing by water, specimens were restored with the restorative material according to the allocated group. Specimens were finally finished, polished, and became ready for color change evaluation (►**Fig. 1**).

### Assessment of the Baseline Color

The specimens' color was assessed using a reflective spectrophotometer with 4 mm aperture size (RM200QC, X-Rite, Germany). Each Specimen was positioned at the center of the measurement area. A white colored background was used, and the measurements were taken according to the CIE $L^*a^*b^*$ color space related to the standard illuminant D65 of Commission Internationale de l'Eclairage (CIE; $L^* = 88.81$, $a^* = -4.98$, $b^* = 6.09$), where $L^*$ is the degree of color lightness (0–100), $a^*$ is the color on the red/green axis and $b^*$ is the color along the yellow/blue axis. Before each measurement, the spectrophotometer was recalibrated. Three measurements were done for each specimen and the average was calculated.

### Color Change (ΔE) Assessment

Specimens' color was assessed first for the sound dentin for the baseline measurements then after application of SDF and finally after application of KI with the respective restorative material. Color change (ΔE) of each specimen was calculated using the following formula:

$$\Delta E = [(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2]^{1/2}$$

### Statistical Analysis

Mean and standard deviation (SD) values were used to represent numerical data. To test for normality, Shapiro–Wilk test was used. Levene's test was used for homogeneity of variances testing. Data showed variance homogeneity, and parametric distribution was also analyzed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test. The significance level was set at $p < 0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.1.1 for Windows.[a]

## Results

Results of intergroup comparisons presented in ►**Table 2** and in ►**Figs. 2** and **3** showed that for SDF and SDF + KI samples, there was a significant difference between different restorative materials ($p < 0.001$). For SDF samples, the highest value was found in resin-modified glass ionomer restoration ($11.57 \pm 4.17$), followed by glass ionomer ($11.02 \pm 3.02$), while the lowest value was found in zirconia reinforced glass ionomer ($6.00 \pm 2.74$) and post hoc pairwise comparisons showed value of zirconia reinforced glass ionomer to be significantly lower than other restorative materials ($p < 0.001$).

For SDF + KI samples, the highest value was found in RMGI ($31.57 \pm 6.33$), followed by zirconia reinforced glass ionomer ($10.84 \pm 3.78$), while the lowest value was found in glass ionomer ($6.60 \pm 3.06$) and post hoc pairwise comparisons showed values of different materials to be significantly

[a] R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

**Table 2** Inter and intragroup comparisons

| Material | Color change (Mean ± SD) | | | *p*-Value |
|---|---|---|---|---|
| | High viscous glass ionomer | resin-modified glass ionomer restoration | Zirconia-reinforced glass ionomer | |
| SDF | $11.02 \pm 3.02^{a}$ | $11.57 \pm 4.17^{a}$ | $6.00 \pm 2.74^{b}$ | $<0.001^{d}$ |
| SDF + KI | $6.60 \pm 3.06^{c}$ | $31.57 \pm 6.33^{a}$ | $10.84 \pm 3.78^{b}$ | $<0.001^{d}$ |
| *p*-Value | $<0.001^{d}$ | $<0.001^{d}$ | $<0.001^{d}$ | |

Abbreviations: KI, potassium iodide; SD, standard deviation; SDF, silver diamine fluoride.
Note: Different superscript letters a, b, c indicate a statistically significant difference within the same horizontal row.
[d]significant ($p < 0.05$).

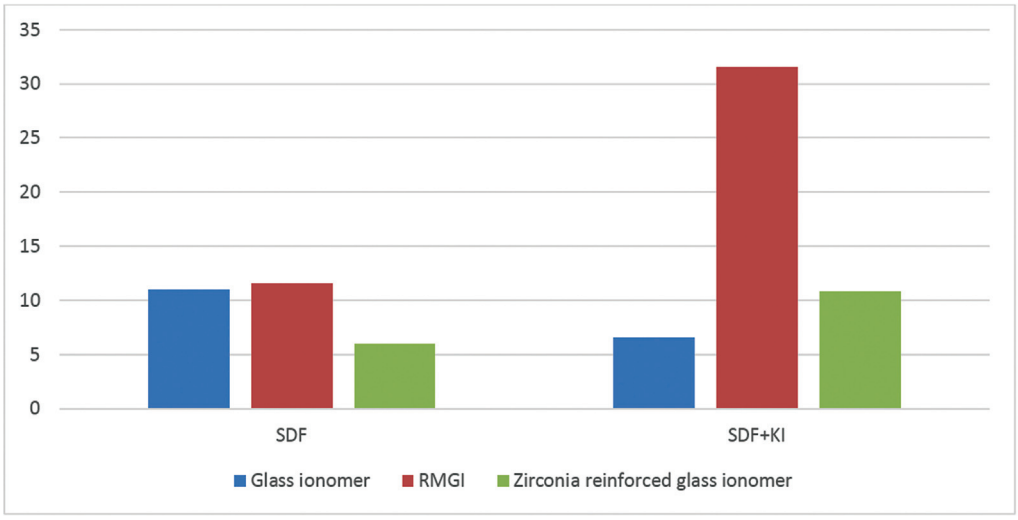


**Fig. 2** Bar chart showing average color change in different restorative materials (A).

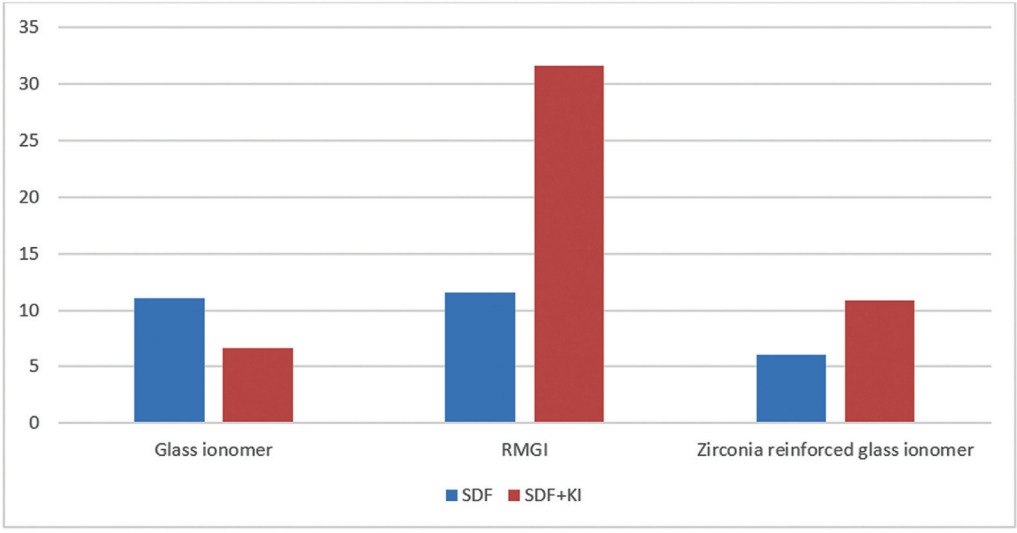


**Fig. 3** Bar chart showing average color change in different restorative materials (B).

different from each other ($p < 0.001$). For glass ionomer, SDF samples had significantly higher value than SDF + KI ($p < 0.001$), while for RMGI and zirconia reinforced glass ionomer, SDF + KI samples had significantly higher value ($p < 0.001$).

## Discussion

Lots of scientific literature support the safety and efficiency of SDF as a caries arresting agent.[3,11–13] However, significant aesthetic barriers limit its widespread acceptance by adults.

Especially there has been a paradigm shift in expectations from advanced dental care focusing highly on aesthetic outcomes.[14,15] In this study, SDF at a concentration of 38% was used due to its profound effect in preventing and arresting dental caries.[16,17] However, using SDF as a caries arresting agent can cause black staining of tooth structure that may not be acceptable for many patients from the esthetic point of view. The color acceptance remains a very crucial factor when using of any preventive or restorative material. A promising approach is used to solve this problem by applying the KI solution immediately after SDF treatment[6] to decrease the resultant black color. Variety of different restorative materials have been introduced to restore the cavitated teeth following SDF application (with or without KI), such as glass ionomer restoration which is the most commonly used material due to its fluoride release and good marginal sealing with tooth structure, resin-modified GI (RMGI) and resin composite restorations.[10] In the current study, we used different modifications of glass ionomer restorations, zirconia-reinforced glass ionomer, resin-modified glass ionomer restoration, and the conventional glass ionomer restoration. In this study, before starting the experiment, the specimens were stored in a distilled water, then dry specimens were used to show the actual staining potential of SDF to prevent any adverse reactions between SDF and the storage solution, according to Patel et al.[18] Randomization was performed but blinding could not be attained due to the evident color change produced by the SDF. Furthermore, different compositions of used restorative materials allow them to be easily discernible from each other. A reflective spectrophotometer was utilized for color assessment in this study, as it depends on the low light intensity to determine the full visible spectrum of the LABORATORY system with strong data consistency and good repeatability.[19]

The resultant dentin discoloration after SDF application in all experimental groups could be attributed to this chemical reaction, as shown in Eq. (1)

$$Ag(NH_3)_2F(aq) \rightarrow Ag(s) + 2NH3\ g\text{-} + F.$$

Also, this chemical reaction between the silver compounds and the hydroxyapatite tooth component occurs as follows in Eq. (2):

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

According to these equations, SDF produces not only the free fluoride ions and $CaF_2$ responsible for the remineralization of tooth structures but also a black silver precipitate of Ag(s) causing discoloration of dentin[6] and this was in agreement with the finding of many laboratory trials.[7–9] However, there was statistically significant difference between the different glass ionomer restorations applied in this study following SDF only as the highest ΔE value was for (RMGI) indicating poor masking effect, followed by (GI) then the lowest ΔE was recorded for the zirconia-reinforced glass ionomer indicating good masking effect. This could be attributed to that (RMGI) contains resin translucent material that reflects the discoloration of the underlying SDF more easily as compared with the zirconia-reinforced glass ionomer, which considered more opaque material in comparison to (RMGI) that helped a little in masking the discoloration caused by the application of SDF and this was in agreement with Zhao et al.[6] While in the groups treated with SDF + KI, we observed that generally the staining effect of the assessed groups was decreased as the compared with the groups of SDF alone. This effect of KI is shown in Equation '3' as KI reverts the discoloration effect of SDF by reacting with the excess silver ions to produce silver iodide, which is yellowish creamy in color and easily rinsed away with water.[14]

$$Ag(NH_3)_2F(aq) + 3KI(aq) \rightarrow 3AgI(s) + 2NH3\ g\text{-} + F.$$

Besides, the KI has a creamy white color when applied the tooth structure, which may also help in mask the SDF discoloration effect.[11] It was reported by Zhao et al[6] that the reproduction of the black metallic silver ions was enhanced by the exposure to light, which was obvious after light curing of resin-modified glass ionomer group in accordance to our result. Lou et al[20] also reported that the silver iodide is considered photosensitive and further dissociates by the long exposure to light into its respective ions recreating the dark silver ions and this could clarify why the KI-SDF treated group also displayed some discoloration and darkening. Meanwhile, Roberts et al[11] found that light-cured restorative materials such as resin composites and resin-modified glass ionomers, demonstrated a grayish discoloration immediately when applied after SDF. Yet, in conflict with our results, the color changes of these materials were minimum over time, which could be attributed to using different aging methods other than light sources.[11] According to current results, the null hypothesis proposed was rejected. Clinical research is highly recommended to correlate these results with the real clinical conditions inside the oral cavity as the oral environment may alternate these findings.

## Conclusion

Within the limitations of this study, we could conclude that using zirconia-reinforced glass ionomer could have a good masking effect on discoloration produced by SDF. While the resin-modified glass ionomer restoration showed more discoloration and darkening effect even after using of KI. Also, using KI in combination with SDF had a good masking effect on discoloration that produced by SDF.

**Conflict of Interest**
None declared.

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