ORIGINAL RESEARCH

Effect of Silver Diamine Fluoride and Potassium Iodide on Microleakage of Composite Resin in Anterior Primary Teeth

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Abstract

Aim: One of the preventive interventions for early childhood caries is the use of silver diamine fluoride (SDF), which works uniquely in the prevention of caries. The suggested method to minimize the discoloration of SDF is the use of potassium iodide (KI). However, there are concerns about the bonding properties of dentin after the application of SDF-KI. Therefore, this study aimed to investigate how SDF-KI affects composite resin microleakage in primary teeth.

Materials and methods: In this *in vitro* study, class V cavities were created on the buccal surfaces of 60 extracted primary canines. The samples were divided into three groups: Group I: 38% SDF solution was applied to the cavity; Group II: SDF-KI solution was applied to the cavity; and group III: the cavities were irrigated with distilled water. All cavities were filled with composite resin and subjected to a thermocycling regime (500 cycles). The dye penetration of samples was evaluated following a 24-h immersion in 1% methylene blue. Microleakage at the occlusal and gingival margins was evaluated using a stereomicroscope at 40× magnification. Data were analyzed using the Chi-squared test ($p < 0.05$).

Results: There was no statistically significant difference between microleakage scores at the occlusal margin ($p = 0.128$). At the cervical margin, the SDF-KI group had significantly more microleakage than the SDF and control groups ($p = 0.001$).

Conclusion: Applying the SDF-KI significantly increased microleakage in the cervical margin but had no significant effect on the occlusal margin.

Clinical significance: Regarding the beneficial effects of SDF in preventing and arresting dental caries, application of it before composite resin is suggested in controlling caries without the negative effects on microleakage.

Keywords: Caries, Microleakage, Potassium iodide, Primary teeth, Silver diamine fluoride.

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Introduction

Early childhood caries (ECC), which is the presence of one or more decayed tooth surfaces as well as missing or filled tooth surfaces in each primary tooth of a preschool child, is considered by the American Dental Association to be a significant public health concern.[1] The ECC prevalence varied between countries and ranged from 16% (Singapore) to 89% (China).[2] A systematic review with a sample size of 80,405 children showed the prevalence of dental caries in primary teeth was 46.2% (95% CI: 41.6–50.8%).[3] Numerous behavioral and socioeconomic risk factors for caries have been identified, including oral colonization with elevated levels of cariogenic bacteria, especially *Streptococcus mutans*, prolonged bottle feeding, frequent snacking and sugary beverage consumption, and inadequate toothbrushing.[4] The negative impact of ECC can range from difficulty performing daily activities, such as pain in eating, to problems in their growth and development, weight loss, and low self-esteem.[5,6]

Behavioral control issues typically complicate the restorative treatment of ECC and often require hospitalizations or emergency room visits. However, if this disease is not treated, it progresses and negatively affects the quality of life, and in severe cases, it can even threaten the child's life.[7] On the other hand, preventive measures to control ECC are more cost-effective than seeking emergency care or restorative treatments when severe caries occur.[8]

For non-cavitated carious lesions, use of professional fluoride associated with sealants on occlusal surfaces is considered a standard for arresting or reversing lesions in ECC.[9]

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The use of silver and fluoride compounds has been approved as safe for clinical use, which act uniquely in destroying bacteria and strengthening the teeth by stopping and preventing caries.[10] This material is more effective in controlling caries when used with fluoride varnish and is an alternative treatment for the carious teeth of uncooperative children until they become mature enough to comply with advanced treatment procedures.[10,11] Research has shown that silver diamine fluoride (SDF) can be used for treating tooth hypersensitivity, making dentin desensitized, and disinfecting in root canal treatment.[12,13] Silver diamine fluoride prevents the reduction of collagen in the dentin, limits demineralization, causes the progress of remineralization in the dentin and enamel, and finally stops caries.[14,15]

When using an SDF solution, there is no need to remove decayed dentin beforehand.[16] According to the findings of a clinical trial, SDF with a concentration of 38% can perform better compared to the interim glass ionomer restorative treatment in preventing ECC.[17] Similarly, in Gao et al.'s systematic review, it was shown that SDF with a concentration of 38% can effectively arrest dentin caries in primary teeth in childhood.[18]

The only obvious drawback of this material is that the deposition of silver particles in the caries lesion causes the color of the lesions to turn black.[19] Since SDF was not widely accepted by patients due to esthetic issues, an alternative was proposed to minimize the side effect of discoloration through the use of potassium iodide (KI), which reacts with residual silver ions and destroys their color effects.[19] Through this, the staining that is associated with SDF can be avoided without reducing its effectiveness in preventing caries.[20] However, there is controversy regarding the negative effects of SDF on bonding when used on damaged dentin.[21,22] Zhao et al.[23] reported that if the KI solution is applied immediately after SDF treatment, it can reduce discoloration without any negative effects on the adhesion of glass ionomers to artificial caries-affected dentin. Due to the lack of studies and contradictory research results in this field, the present study aims to find out how SDF and KI affect the microleakage of composite resin in primary teeth.

Materials and Methods

This experimental study was approved by the Ethics Committee of Ardabil University of Medical Sciences, Ardabil, Iran (IR.ARUMS.REC.1401.103). In this study, 60 extracted maxillary anterior primary teeth were selected from Ardabil dentists over a period of four months. In this *in vitro* study, the desired sample size was calculated using the following formula with 80% test power:

$$\frac{\left(z_{1-\alpha_2} + z_{1-\beta}\right)^2 \times \left(s_1{}^2 + s_2{}^2\right)}{\left(\mu_1 - \mu_2\right)}$$

These teeth were not in any points restored or cracked and did not have any enamel defects or developmental abnormalities. The remaining soft tissue and other debris were cleaned by using a hand scaler. Disinfection of the teeth was done with a 0.1% timolol solution for 48 h followed by storage in distilled water until used.

Class V cavities of 1.5 × 2 × 3 mm (occlusogingival height = 3.0 mm, cavity depth = 1.5 mm, and mesiodistal width = 2.0 mm) were created on the middle third of the buccal surface of the teeth. This was done by a #330 diamond fissure with a high-speed water-cooled handpiece. In order to prevent the slowness of the bur, it was replaced every 10 teeth. The specimens were randomly distributed across the three groups, as shown in the following:

- Group I (experimental; $n = 20$): The prepared cavities were treated with 38% SDF (Riva Star, Aqua, SDI Limited, Australia) solution with a microbrush for 3 min, and then the cavity was washed for 30 s.
- Group II (experimental; $n = 20$): The prepared cavities were treated with 38% SDF and KI (Riva Star, Aqua, SDI Limited, Australia) solutions. SDF was used with a microbrush for 3 min, and right after that, a saturated KI solution was applied to the treatment site until creamy white turned clear, and then the cavity was washed for 30 s.
- Group III (control; $n = 20$): Distilled water was used to treat the prepared cavities for 3 min, and then they were washed for 30 s.

Table 1: Comparison of percentage of occlusal microleakage between the study groups

	Microleakage score N (%)				
Group	*Score 0*	*Score 1*	*Score 2*	*Score 3*	*p-value*
SDF +KI	11 (18.3%)	9 (15.0%)	0 (0.0%)	0 (0.0%)	0.128*
SDF	14 (23.3%)	5 (8.3%)	1 (1.7%)	0 (0.0%)	
Control	15 (25.0%)	5 (8.3%)	0 (0.0%)	0 (0.0%)	

*Chi-square

The cavity walls of three groups were covered by a bonding layer (G-bond: 7th generation bonding agent, GC Corp., Tokyo, Japan) and agitated for 20 s by a microbrush. After that, air spray was used for 5 s to evaporate the solvent, which was then light-cured for 10 s.

Tetric Evo Ceram (Nano-Hybrid Composite, Ivoclar-Vivadent, Schaan, Liechtenstein) was located in the cavities in layers and cured for 20 s with a light-emitting diode at a light power of 1200 mW/cm2. One operator conducted the procedure of matching and all its steps. The samples were stored in distilled water at 37°C for 24 h.

The samples underwent 500 thermal cycles in different water baths (5°C and 55°C) using a 60-s dwell time and a 3-s transfer time. After that, each tooth was completely covered by nail varnish, except for 1 mm around the edges of the restoration cavity. The samples were immersed in a 1% methylene blue solution for 24 h.

The surface color of the teeth was washed with pumice slurry solution. The samples were transversely sectioned using a low-speed diamond saw. A stereomicroscope (Olympus SZ1145, Olympus Optical Co., Ltd., Tokyo, Japan) with 40× magnification was utilized for evaluating the level of dye penetration on the occlusal and cervical surfaces. The amount of penetration in the occlusal and cervical edges was recorded in each dental section, and the highest amount was recorded as the tooth microleakage. The scoring of the microleakage was conducted following an ordinal ranking system, as follows:

- Score 0 = no leakage,
- Score I = leakage up to half the depth of the cavity,
- Score II = leakage more than half the depth of the cavity, and
- Score III = leakage to the bottom of the cavity (Flowchart 1).

Data were analyzed with SPSS software (version 25; SPSS AG, Schneckenmannstrasse, Zürich) using the Chi-squared test at a 5% level of significance.

Results

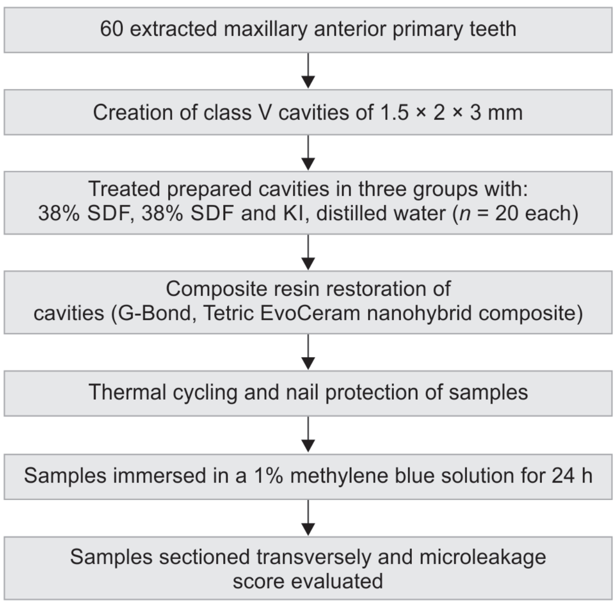
Table 1 displays the distribution frequency of occlusal microleakage scores in the groups. Microleakage scores at the occlusal level did not show any significant difference between the three groups (p-value = 0.128). However, the control group showed the best seal and the least microleakage. It was found that in all groups, 0 was the most prevalent score at the occlusal margin, and no group showed occlusal microleakage at the level of score III.

Table 2: Comparison of percentage of cervical microleakage between the study groups

	Microleakage score N (%)				
Group	*Score 0*	*Score 1*	*Score 2*	*Score 3*	*p-value*
SDF +KI	0 (0.0%)	12 (20.0%)	6 (10.0%)	2 (1.7%)	0.001*
SDF	9 (15.0%)	11 (18.3%)	0 (0.0%)	0 (0.0%)	
Control	9 (15.0%)	11 (18.3%)	0 (0.0%)	0 (0.0%)	

*Chi-square

Flowchart 1: Experimental procedure plan



All cervical microleakage values are presented in Table 2. According to the Chi-squared test, the SDF + KI groups were significantly different ($p = 0.001$) from one another in cervical microleakage. At the cervical microleakage, a score of 1 was the most frequent score in all groups. SDF and control groups showed similar cervical microleakage, with a frequency of 9% in score 0 and 11% in score 1.

The microleakage scores of cervical margins were significantly greater compared to the occlusal margins in all the study groups ($p < 0.05$).

Discussion

The Food and Drug Administration, United States, approved SDF as a commercial product for dental use in August 2014.[24] Silver diamine fluoride is available on the market in various concentrations. The present study used the 38% concentration since Fung et al. found that this concentration could more effectively prevent and arrest caries than the 12% concentration.[25] Potassium iodide prevents the staining of SDF through the precipitation of excess silver ions as a white silver iodide deposit; however, arrested carious lesions have a tendency to darken with time.[26,27] For esthetic issues, it is necessary to seal the cavity properly after SDF-KI is applied. An optimal marginal seal is an essential factor for the longevity of the restorations. The performance of SDF and KI on dental cavities and their effect on sealing ability could be tested through microleakage, which is widely accepted and cheap. Therefore, the present study investigated the effectiveness of SDF and SDF-KI cavity pretreatment on the marginal seal of the Class V restorations.

In occlusal microleakage, the frequency distribution of 0, 1, 2, and 3 scores was approximately the same in the SDF group and the control group. The findings of the present study corroborated the findings of Uzet et al., revealing that the microleakage between the tooth structure in class V cavities and composite resin was not impacted by pretreating sound permanent molars with SDF at 38% concentration.[28] The primer's penetration and bonding into the intertubular and peritubular dentin can be interfered with by SDF, as a result of which a less hybrid layer is formed with the lower collagen matrix. How SDF is applied determines how severe this effect can be, in that an increased use of SDF can create a better bond.[21] In this study, by rinsing all samples for 30 s after they were treated with SDF, the negative effect of SDF was removed. Soliman et al.[29] revealed that the pretreatment of primary dentin with 38% SDF did not negatively affect the marginal seal of resin-modified glass ionomer cement.

This result was inconsistent with the findings of the study by Pérez et al.[30] which revealed significantly greater microleakage in the application of fissure sealant without pretreating with SDF (81.66%), compared to the sealant with SDF pretreatment. The lack of agreement between the findings of the two studies can be attributed to the different techniques of applying SDF. In this study, SDF was applied two times, with an interval of two weeks in between, for treating the fissure, whereas the current study applied SDF only once. The samples were treated with a 38% SDF solution with a microbrush for 3 min, and then the cavity was washed for 30 s.

The microleakage in the cervical margins is at a higher level than the occlusal margins, and the number of cavities with a score of zero in the cervical microleakage was less in all three groups. It could be due to the more permeable structure of dentin tissue than enamel.[31] Results showed that there was no statistically significant difference in the cervical and occlusal margin readings for microleakage between the SDF-pretreated group and the control group. Results of this study came in accordance with Gupta et al.[32] SDF-pretreated premolar teeth did not have a significant difference in microleakage between resin-modified glass ionomer and tooth structure. Uzel et al.[33] reported no significant difference in microleakage scores between the group of noncarious third molar teeth treated with SDF (38%) before the application of resin composite and the control group. On the other hand, Osama[34] found that SDF 38% treatment does not adversely affect the microleakage of resin composite and glass ionomer restorations bound to carious primary dentin.

In cervical microleakage, a significant difference was exhibited between the groups. The SDF-KI group exhibited the highest number of microleakages compared to the control and SDF groups. Lee reported increasing microhardness and remineralization was more effective in the SDF than SDF-KI, due to the high concentration of fluoride and silver ions in the SDF.[35] It appears that when SDF-KI is applied, a higher concentration of AgI precipitates on the surface, which has low water solubility.[36] Silver ions form the dentinal tubules occluded by protein precipitation.[37] In addition, a precipitation of calcium fluoride is formed as a result of fluoride ions reacting with calcium ions, which then plug dentinal tubules.[38] The application of SDF to the acid-treated carious dentin surface leads to the infiltration of the zone of exposed collagen with silver particles.[39] According to the findings of the study, treating samples with the G-bond agent leads to the complete diffusion of the adhesive under wet-bonding conditions, and added to that, collagen fibers are not exposed, and there can be a slight decalcification at dentin.[40]

Consistent with our findings, Gupta et al.[32] showed there is no statistically significant difference in the microleakage of resin-modified glass ionomer in the SDF-KI group, compared to the chlorhexidine gluconate and saline groups. This could be attributed to the variation in the application procedures of SDF-KI, wherein prior to the placement of resin-modified glass ionomer, the cavity surface was not treated with an adhesive following SDF-KI treatment.

Farahat et al.[37] showed that the strength of the universal, etch, and rinse adhesive bonds was reduced by SDF-KI, which was not the case in the control group. Some studies found that rinsing away SDF-KI residues can remove the effect on the bond strength.[26,37] Koizumi et al.[38] revealed that using SDF-KI leads to a reduction in the dentin bond strength; however, SDF-KI was not rinsed in the study. On the other hand, it was found that after applying SDF or SDF-KI, if 35% phosphoric acid is used for etching and rinsing, the SDF density can be removed in the most superficial dentin layer, and there will be fewer negative effects on bonding. After rinsing, the residuals of SDF, which were used for treating the surface with a scanning electron micrograph and were not absorbed by the tooth, were removed from the peri and intertubular dentin. Removing the remaining superficial SDF after treatment can be viewed as a positive attribute of SDF because a therapeutic effect may still be achieved even after rinsing.[21]

The current study used universal adhesive on the dentin surface without etching, which can be effective against the microleakage of SDF-KI groups. The benefits of one-step bonding systems are various, as they can simplify, shorten procedural steps, and decrease technique sensitivity. For this reason, many consider them the best way to restore composite resin in uncooperative or younger children. It was recommended that following a self-etching method is more effective when applying universal adhesive to the dentin surface.[39,41] Phosphoric acid was hypothesized to be the cause of removing the deposit that SDF-KI produced. Lutgen et al.[21] found that the application of SDF can improve the performance of two-step self-etch adhesive and universal adhesive in a selective etch compared to only applying universal adhesive.

On the other hand, Van Duker et al.[42] indicated that before the application of adhesive, deposits rinsing the bond strength were low for the removal of excess SDF-KI. RL Quack et al.[43] observed that the bonding of the two-step self-etch adhesive did not significantly differ from the three-step etch and rinse adhesive in the control and 38% SDF groups. As opposed to the current study, RL Quack et al.[43] did not investigate the effects of the application of KI following SDF, yet rinsing was conducted for 30 s.

Moreover, light curing of the adhesive and composite resin may have an effect on the microleakage of dentin and composite, which received SDF pretreatment primarily. The findings indicated that the light curing of the SDF darkened the dentin surface more, showing that as the precipitation of more metallic silver increases, the ionic interaction between restoration material and dentin increases as well.[44] Wang et al.[45,46] found that the shear bond strength of the demineralized dentin receiving treatment with SDF and then being light cured was higher compared to that of the demineralized dentin that received treatment with SDF but was not light cured. According to Toopchi,[38] if SDF undergoes another round of dental light curing for 40 s after it is applied, this leads to a decrease in the penetration depth of the SDF in healthy dentin and an increase in the hardness of the infected dentin. Hence, there is a need for further studies to identify the best way for the application of SDF or SDF-KI with adhesive restorative materials.

The limitation of this study was the difficulty of simulating the oral conditions regarding the biological aspects of many factors that may contribute to composite resin microleakage in primary teeth, so long-term clinical trials are needed to confirm SDF or SDF-KI. In addition, further studies should evaluate microleakage in carious dentin treated with SDF or SDF-KI.

Conclusion

Based on the results obtained in this study, SDF pretreatment does not affect the microleakage of the composite resin restoration, and it can be suggested as an acceptable and practical agent for caries prevention. Applying the SDF-KI significantly increased microleakage in the cervical margin but had no significant effect on the occlusal margin.

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