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ORIGINAL RESEARCH

Effect of silver diamine fluoride and potassium iodide on nano leakage and micro tensile bond strength of composite to demineralized dentin in primary teeth

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Abstract

Background: Conservative treatment of adhesive dentistry considers demineralized dentin as a bonding substrate, and utilizing silver diamine fluoride (SDF) on demineralized dentin before composite restoration, probably can be beneficial.The aim of this study to evaluate the effect of SDF and potassium iodide (KI) on nano leakage plus the micro tensile bond strength of composite to demineralized dentin in primary teeth.

Materials and Methods: In this experimental- laboratory study, seventy-eight teeth in the micro tensile group and ninety teeth in the nano leakage group were divided into two groups with sound and demineralized dentin. Each group of teeth was divided into three separate groups. In the first group, bonding was used without pre-treatment. In the second group, the SDF was used before the bonding agent and SDF and, KI was used in the third group. Two-way ANOVA, Bonferroni's post hoc test, Mann-Whitney test and Fisher's exact test were used for data analysis. ($\alpha<0.05$)

Results: The lowest mean bond strength was in the SDF and KI groups in both sound (10.0 ± 1.9) and demineralized (6.8 ± 2.3) dentin groups. Using KI significantly reduced bond strength ($P<0.05$). Nano leakage in teeth with sound and demineralized dentin in both SDF and SDF and KI groups was significantly lower than in the control groups ($P<0.05$).

Conclusion: **Using SDF does not harm composite bond strength to primary teeth, but using KI after SDF reduces composite bond strength. The use of SDF and KI significantly reduces composite nano leakage.**

Keywords: silver diamine fluoride; potassium iodide; Tooth, Deciduous

Introduction

Silver Diamine Fluoride (SDF) is a topical drug that was introduced as a reducing dental sensitivity material by the food and drug administration (FDA) (1). Many clinical studies have mentioned SDF as a safe and effective substance in controlling dental caries in children (2). Obviously, without critical pulp damage (3). Early childhood caries (ECC) is a common infectious disease but a serious health problem affecting the quality of life (4). Using SDF simply and economically can be effective in managing this caries. Some studies have also shown that this material is more effective than sodium fluoride in stopping dentinal caries (6).SDF is a bactericidal agent that reduces the growth of cariogenic bacteria, prevents demineralization and promotes enamel and dentin remineralization. It has fluoride and silver. Silver has antibacterial properties, and fluoride prevents and stops caries (7). SDF inhibits the activity of some metalloproteinase matrix enzymes such as MMP-2, MMP-8, and MMP-9 and prevents collagen degradation (8). This effect is due to the preservation of collagen as this scaffold improves remineralization (9). Preparation of cavity with SDF 38% increases the resistance of glass ionomer cement and resin composite to secondary caries. In restorative treatments, SDF can improve the success of direct restorations (10). A commonly observed complication in treatment with SDF is the formation of a black spot (11). The black colour created after the application of SDF is due to the genesis of a silver phosphate layer on dentin (12). In the presence of light, the Silver ions in the SDF become metal silver, which can cause black colour changes (13).

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A solution for this problem is using potassium iodide solution (KI) after using SDF, which reduces the colour intensity while not affecting the anti-caries properties of SDF (14). The potassium iodide reacts with silver-free ions and creates a creamy white sediment from silver iodide, which reduces the black colour (12, 15). Therefore, SDF and KI could be applied simultaneously on demineralized dentin to have both the antibacterial effect of SDF and the black colour prevention of KI. (16, 17). Due to the anti-cariogenic characteristics of SDF and KI, using this substance can help as a cavity cleaner on demineralized dentin. Different results from similar studies on the effect of SDF and KI application on composite bond strength are available. (13, 15, 18). Selveraj's study showed that the application of SDF and KI has no undesirable effect on the bond strength of composite resin to dentin. (15) However, in the study of Van Duker, the addition of KI reduced the bond strength (13). Considering the different results there are not enough studies on the bond strength of the composite when the dentin adhesive substrate is affected or demineralized. According to the theory of minimal invasion, in many cases, affected dentin is the substrate of the adhesive material (19). Recently, the effect of SDF and KI on the bond strength of dentin in permanent teeth was investigated (13). However, to our knowledge, there is no study on the effect of the simultaneous application of these two substances on the dentin bond strength of deciduous teeth when the adhesive substrate is demineralized dentin. Studies have shown that due to the difference in the dentin structure of deciduous and permanent teeth, the bond strength of composite to dentin in deciduous teeth is different (20). This study aimed to investigate the effect of the SDF and KI on nano leakage and bond strength of composite on demineralized dentin in primary teeth.

Materials and Methods

The present experimental-laboratory study (ethics ID IR.IAU.KHUISF.REC.1399.153) used 168 healthy human deciduous canine teeth without caries, earlier restoration and hypoplasia that had been extracted due to orthodontic reasons and collected within six months. After keeping the teeth in 0.1% w/w thymol solution (13) to expose the dentine, the outer enamel of the buccal surface was removed using a slow-moving diamond cutter (CNC cutting machine, Nemo, Mashhad, Iran) with a stream of cooling water. The dentin surface was polished with 600-grit silicon carbide paper under wet conditions to create a smooth surface. The prepared samples were divided into two groups of teeth with sound dentin (S) and teeth with demineralized dentin (D).

For obtaining demineralized dentin, each sample was placed in 15 ml of demineralizing solution (containing 1.5 mM $CaCl2$, 0.9 mM $KH2Po4$, 50 mM acetic acid and a pH regulator at 4.5 using NaOH) at 37 ° C for seven days to create artificial demineralized dentin. The surface of the demineralized dentin was then slightly polished with 600-grit silicon carbide paper to form a smear layer without removing the demineralized dentin layer (13). Each of the groups S and D was divided into three subgroups (15 samples in each group): (control) without dentin surface preparation, (SDF) dentin surface preparation with SDF and (SDF and KI) surface preparation with SDF and KI. In the control group, the dentin surface was washed with deionized water for 30 seconds before applying the adhesive. In the SDF group, silver diamine fluoride (caries stop 30%, Biodinamica, Brazil) was applied using a micro brush on dentin then after one minute, it was washed for 30 seconds (13). In SDF and KI groups, after SDF application, KI saturated solution (consisting of 7100mg KI in 5ml deionized water) was applied to the dentin surface using a micro brush until forming a white precipitate and finally washed off after 1 minute. Universal bonding (Universal, G-Premio Bond, Gc Corporation Tokyo, Japan) was used with the Total etch technique using 37% phosphoric acid (21). We used the bonding agent based on the factory instruction: the dentin was etched for 10 seconds and then rinsed and dried, G-Premio bond was applied and waited for 10 seconds, dried for 5 seconds, and light cured for 10 seconds. We placed Composite (Gradia direct, shade A2, Gc Corporation Tokyo, Japan) on each sample with a thickness of 4 mm in consecutive 2 mm layers using plastic moulds mm in height and diameter (made with transparent plastic tube) as a matrix to hold the composite.

Seventy-eight prepared samples were immersed in deionized water at 37 ° C for 24 hours. Then the samples were mounted inside a transparent resin inside a plastic mould. In the next step, the teeth were transferred to a fully automatic cutting machine (CNC cutting machine, Nemo, Mashhad, Iran) and cut to make 1×1 mm pieces. A large number of sections were obtained from the samples, and finally, fifteen healthy sections were selected in each group to evaluate the bond strength (one to two samples from each tooth). Samples of each group were kept separately in the incubator at 37 ° C for 24 hours before evaluation in the micro tensile bond strength measuring machine.

For performing the bond strength test, the parts were attached to the plates of a micro tensile bond strength measuring device (Micro tensile machine, MTD-500 plus-SD Mechatronik, Germany) using a cyanoacrylate adhesive. The tensile force was applied at a speed of 1 mm per minute until the failure of the bond. The load at which the failure occurred was recorded with the Newton unit. The amount of micro tensile bond strength was obtained by dividing the force among Newton by the cross-sectional area of the specimens. The fracture was examined using an electron microscope and recorded as adhesive or cohesive failure in dentin or cohesive in resin or as a combination.

For the nano leakage test, all dental surfaces up to one millimetre of the restoration margin were covered with two coats of varnish. 50% w / w ammoniacal silver nitrate solution was prepared according to the method of Tay et al. (2002) (22). Samples were immersed in 50% wt. ammoniacal silver nitrate, tracer solution, for 24 h. The samples were then washed with distilled water for 5 minutes and then placed in the developer solution under fluorescent light for 8 hours to convert silver diamine ions to silver metal grains (23). Then samples were washed with distilled water for 5 minutes and placed in an automatic cutting machine for buccolingual cutting. Each tooth was divided into two halves, and one half was selected randomly for examination under an electron microscope (Philips XL30 SEM, Netherlands). Images with a magnification of 800 were taken in the backscatter mode with a 180 KV voltage. The penetration of silver particles into the resin-dentin interface was graded from 0 to 4. (0, without nano leakage - 1, 25%> nano leakage - 2, 50-25% nano leakage - 3, 75-50% nano leakage - 4, 75% <Nano leakage) (24) (Figure 1).

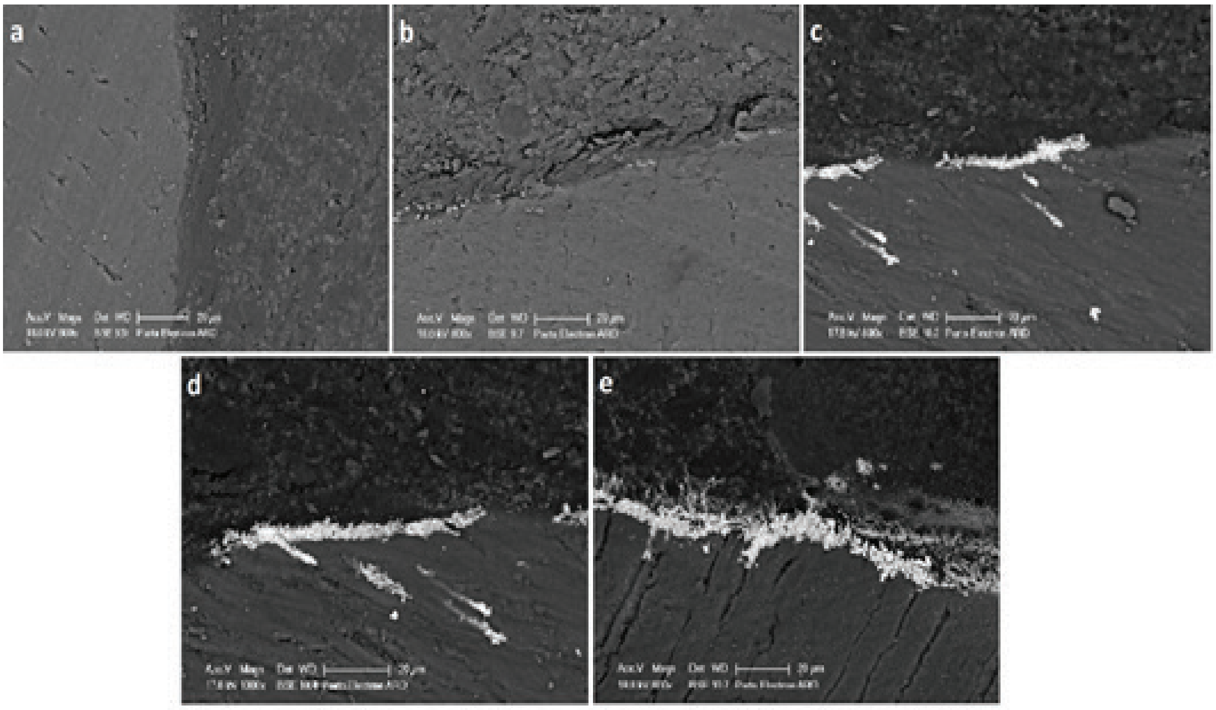

Figure 1.(a) Grade 0 nanoleakage, **(b)** Grade 1 nanoleakage, **(c)** Grade 2 nanoleakage, **(d)** Grade 3 nanoleakage, **(e)** Grade 4 nanoleakage

Differences between groups were analyzed statistically according to the number of samples for each group and degree by two-way analysis of variance (ANOVA), Bonferroni post hoc test, Mann-Whitney test and Fisher's exact test in SPSS version 22.

Results

In the present study, fifteen samples in six distinct

Table 1. Mean and standard deviation of microtensile strength of composite bond to healthy and demineralized dentin with and without surface preparation

Dentin	Type of preparation	Number	Mean	Standard deviation	Minimum	Maximum
Healthy	No preparation	15	16.23	3.87	9.20	23.90
	Preparation with SDF	15	15.20	2.16	12.40	20.90
	Preparation with SDF and KI	15	10.07	1.96	6.70	13.20
Demineralized	No preparation	15	14.20	1.31	12.20	17.30
	Preparation with SDF	15	12.94	2.16	8.30	17.20
	Preparation with SDF and KI	15	6.84	2.39	3.10	11.90

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groups were examined. The results of the amount of the micro tensile bond strength of the composite are mentioned in table 1.

The normality of distribution was assessed by the Shapiro-Wilk test, and the test of homogeneity of variances between groups was performed by Levene's test.

According to the results of the two-way analysis of variance, the effect of dentin type (sound and demineralized) and kind of preparation (without preparation, preparation with SDF and with SDF and KI) on the micro tensile bond strength of the composite was significant ($p < 0.05$).

According to the results of the Bonferroni post hoc test, in teeth without preparation, in teeth with surface preparation with SDF and in teeth with surface preparation with SDF and KI, the mean level of micro tensile bond strength of composite in sound dentin was significantly higher than demineralized dentin ($p < 0.05$). Based on the results of the Bonferroni post hoc test, the mean of micro tensile bond strength of composite in teeth with surface preparation with SDF and teeth without surface preparation in teeth with sound dentin ($p > 0.05$) and teeth with demineralized dentin ($p > 0.05$) had no significant difference. In both sound and demineralized dentin groups, the mean micro tensile bond strength of the composite in teeth with surface preparation with SDF and KI was significantly lower than the teeth without surface preparation and the teeth with surface preparation with SDF ($p < 0.05$).

Table 2. Frequency distribution of fracture pattern in teeth with healthy dentin and demineralized with and without surface preparation. A (adhesive failure), M Table 3: (composite failure), CC (cohesive failure in composite), CD (cohesive failure in dentin

Dentin	Fracture pattern	No preparation		Preparation with SDF		Preparation with SDF and KI		P Value
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	
Healthy	A	13	86.7	15	100.0	14	93.3	.762
	CC	1	6.7	0	0.0	0	0.0	
	M	1	6.7	0	0.0	1	6.7	
	Total	15	100.0	15	100.0	15	100.0	
Demineralized	A	14	93.3	13	86.7	12	80.0	.858
	CD	1	6.7	2	13.3	2	13.3	
	M	0	0.0	0	0.0	1	6.7	
	Total	15	100.0	15	100.0	15	100.0	
p Value		1.000		0.483		0.732		

Based on the result of Fisher's exact test, there were no significant differences in the fracture pattern between the groups ($p > 0.05$) (Table 2).

According to the results, in teeth with sound dentin in the group without surface preparation, the highest frequency of nano leakage grade was 3 (53.3%) (table 3).

In the SDF group, the highest frequency of nano leakage grade was zero (53.3%) (Table 3).

In SDF and KI group, the highest frequency of nano leakage grade was zero (46.7%) (Table 3).

In teeth with demineralized dentin in the group without surface preparation, the highest frequency of nano leakage grade was 4 (33.3%) (Table 3).

In the SDF group, the highest frequency of nano leakage grade was one (0.40%) (table 3).

In the SDF and KI group, the highest frequency of nano leakage grade was one (46.7%) (Table 3).

Based on the Mann-Whitney test modulated by Bonferroni, in both sound and demineralized dentin groups, nano leakage grade in teeth with surface preparation with SDF and in teeth with surface preparation with SDF and KI was significantly lower than in teeth without surface preparation ($p < 0.05$).

Discussion

According to the results of this study, the research hypothesis that there is no difference in the average micro tensile bond strength of composite between demineralized and sound dentin was rejected. The results of this study showed that in all groups, the bond strength of composite to sound dentin was higher than the bond strength for demineralized dentin. A similar finding was reported in earlier studies (25-28). It seems that the reduced bond strength in demineralized dentin can be due to its reduced hardness and interference

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Table 3. Frequency distribution of nanoleakage grade in teeth with healthy dentin and demineralized with and without surface preparation.

Dentin	Nanoleakage grade	No preparation		Preparation with SDF		Preparation with SDF and KI	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Healthy	Zero	2	13.3	8	53.3	7	46.7
	One	0	0.0	4	26.7	4	26.7
	Two	4	26.7	1	6.7	2	13.3
	Three	8	53.3	2	13.3	0	0.0
	Four	1	6.7	0	0.0	2	13.3
	Total	15	100.0	15	100.0	15	100.0
Demineralized	Zero	1	6.7	5	33.3	4	26.7
	One	1	6.7	6	40.0	7	46.7
	Two	4	26.7	2	13.3	1	6.7
	Three	4	26.7	0	0.0	1	6.7
	Four	5	33.3	2	13.3	2	13.3
	Total	15	100.0	15	100.0	15	100.0

with the penetration of resin monomers (27, 29). The reduction of calcium, phosphate and magnesium content due to demineralization makes porous hypo-mineralized dentin and reduces its mechanical properties (28). In affected dentine, mineral crystals fill the dentin tubules. This obstruction of dentinal tubules with acid-resistant crystals can prevent the formation of resin-resistant tags and can be associated with this result (30).

The results of this study confirmed our hypothesis that there is no difference in the bond strength of composite to dentin in teeth with and without surface preparation with SDF, but in the case of tooth preparation with SDF and KI, our hypothesis was rejected. In this study, the micro tensile bond strength of composite to dentin in the teeth of the control group and teeth with surface preparation with SDF was not statistically significant. This result was similar in both groups of sound and demineralized dentin. There are studies similar to the results of this study that have shown that the application of SDF on dentin does not harm the bond strength of composite to dentin (13, 15, 31-33). Van Duker's study suggests that one explanation for this observation is that when the bond to the demineralized dentin is limited by the strength of the cohesive substrate, the potential adverse effect of SDF is not reflected (13).

In the Lutgen study, contrary to the results of this study, the use of SDF on dentin reduced the bond strength of the composite. In this study, self-etch adhesive was used (21). SDF is a solution with an approximate pH of 10. Therefore, it can have a significant adverse effect on the acidity of weak self-etch adhesives (13). On the other hand, washing after SDF application can strengthen the bond strength by a considerable amount. Washing removes only the surface layer of SDF while silver and fluoride ions penetrate to a depth of 450 µm (21). Also, when using SDF, due to the connection of silver nitrate with dentin, cubic crystals holding phosphate, silver and calcium are formed, which are not separated by washing (34). In this study, universal adhesive was used by the Total etch method, which can explain the difference between our result and the results of the mentioned study.

According to the results of this study, the application of KI after SDF reduces the micro tensile bond strength compared to the control group and the group prepared with SDF. This result was similar in teeth with sound and demineralized dentin. The penetration of the resin into the dentin tubules and its branches creates a mechanical trap resulting from the resin tags, which generates the best possible bond to the etched dentin (35). The formation of silver iodide from the reaction between fluoride and potassium iodide is responsible for reducing the permeability of dentinal tubules (16). This white-yellow deposit on the dentin surface does not disappear during etching and washing (13). It seems that the reduction in the permeability of dentin tubules and the consequent depletion in the formation of resin tags can explain the reduced bond strength. The study by Van Duker and Koizami also showed that the application of potassium iodide after SDF reduces the bond strength of the composite to dentin (13, 36). In the study of Koizami et al. (36), the micromorphological analysis of the surface of the samples using SEM microscopy showed that the application of phosphoric acid generally removes sediments caused by SDF and KI from the dentin, thus opening the dentinal tubules. But the deposits of the rest of the material are still enough to affect the bond strength adversely. However, in the study of Selvaraj (15) and Sakr (33), no negative effect was observed after using KI. It seems that more studies are needed.

The failure pattern of the samples showed that in all studied groups the predominant failure pattern was of the adhesive failure type, and no significant difference was observed between the different groups.

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In Selvaraj's (15) and Quock's (31) study, the dominant failure pattern was observed as an adhesive failure.

In this study, the effect of SDF and KI on nano leakage was also investigated. The results of this study rejected the research hypothesis that there is no difference in the frequency distribution of nano leakage grade in teeth with surface preparation with SDF or SDF and KI and without surface preparation. Our study showed that the application of SDF and KI reduces nano leakage in both groups of teeth with sound and demineralized dentin. This finding is similar to the result of Selvaraj's study (15). Silver nitrate occupies nanometer-sized water-filled spaces around exposed collagen fibrils, affecting the resin penetration or the replacement of remaining water by adhesive or even incomplete monomer conversion(37). Complete removal of water from dentin tubules using air can be difficult (38) and this inadequate drying with air can cause water to remain in dentin tubules (39).

SDF and KI deposits may prevent water from escaping from the dentin tubules by closing the dentin tubules. Karthik Selvaraj, in his study, explains the reduction of nano leakage following the application of SDF and KI and points out that the penetration of silver particles stands for water-filled resin blisters that osmotically draw water from dentin and adhesives into hypertonic regions created by solubilized calcium and phosphate. Reduced silver penetration when using SDF and KI may be related to SDF's ability to block dentin tubules (15). Previous studies show anti-sensitive agents block dentin tubules by creating sediments and reducing dentin permeability and fluid contamination of the lower dentin tubules when using adhesives, resulting in reduced nano leakage (15, 36). However,
more studies are required to study this effect more accurately with the presence of hydrostatic force.

The results showed that the application of SDF can reduce the nano leakage of composite resin while not harming the bond strength of the composite. Some studies show nano leakage does not affect bond strength (40-42). In other words, these porous areas and the lack of resin in the adhesive bonding area will not affect the micro tensile bond strength. Nano leakage-related porosities that are nanometer in size appear to be too small to initiate failure (41). However, these spaces are suitable pathways for enzymes and acidic products and over a long duration of time can affect the bond strength of the composite and the durability of the restoration (42). Therefore, it seems that the reduction of nano leakage following the use of SDF and KI, over time can have positive effects on the durability of composite restorations, which requires more long-term clinical studies for more accurate conclusions.

Conclusion

The results of this study showed that the application of SDF on sound and demineralized dentin in deciduous teeth before the application of composite resin did not harm the bond strength of the composite while adding KI to reduce the black colour caused by SDF reduces the bond strength of the composite. The application of SDF and KI also reduces the amount of nano leakage in teeth with sound and demineralized dentin.

Conflicts of interest: none

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