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Original Article

The effect of silver diamine fluoride on the bond strength of glass ionomer to the enamel of primary teeth

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ABSTRACT

Background: Dental caries is a disease which is caused by the acidic by-products of the metabolic processes of dental plaque. Silver components are one of the clinical solutions to prevent caries. This study aimed to investigate the effect of silver diamine fluoride (SDF) application on the shear bond strength of glass ionomer to primary teeth enamel.

Materials and Methods: In this *in vitro* study, a total of 48 anterior sound primary teeth were randomly divided into four groups (n = 12). The control group (G1) consisted of healthy primary teeth, and the three experimental groups (G2–G4) were composed of demineralized primary teeth. The second group did not undergo SDF treatment, the third group underwent SDF treatment, and the fourth group underwent SDF treatment plus polishing. Glass ionomer cylinders were bonded to all specimens and subsequently tested by a universal testing machine to measure the glass ionomer shear bond strength. The type of fracture was examined by a stereomicroscope. Data analysis was carried out using the SPSS 22 statistical software. Data were analyzed by one-way analysis of variance and *posthoc* Tukey tests (α =0.05).

Results: The mean shear bond strength of the glass ionomer was significantly higher in the control group than in the other three groups ($P < 0.05$). The mean shear bond strength of glass ionomer was significantly higher in the SDF-treated group than in the non-SDF treated and SDF-treated and polished groups ($P < 0.05$).

Conclusion: Although the glass ionomer bond strength to sound enamel was higher than other groups by a significant margin, the application of SDF increases the shear bond strength of the glass ionomer to remineralized white spot enamel in primary teeth.

Key Words: Deciduous tooth, dental enamel, glass ionomer, shear strength, silver diamine fluoride

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INTRODUCTION

Dental caries is a biofilm-induced disease that dissolves the tooth mineral content, which is caused by the acidic by-products of the metabolic processes of the dental plaque. Silver components are one of the clinical solutions to prevent caries. Silver diamine fluoride (SDF) has been clinically used to

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prevent and arrest dental caries in both permanent and primary teeth.[1] SDF is especially effective in arresting dentin caries in primary teeth.[2] The use of AgF beneath glass ionomer cement (GIC) restorations in primary teeth has been shown to result in a healing pulpal response and to be effective in promoting the formation of reparative dentin.[3] SDF is used for the management of dental caries in young children to arrest root caries, to prevent pits and fissures and secondary caries, to desensitize the sensitive teeth, to treat infected root canals, and to prevent the fracture of endodontically treated teeth.[4] The caries trend can be changed from the acute state to the chronic state or can be terminated by the application of SDF in children with too many caries. The teeth requiring functional and esthetic restoration can be treated under controlled conditions after arresting the acute phase of the disease with SDF.[1,5] SDF is an inexpensive and cost-effective treatment which is easy to use on young children. SDF does have some disadvantages, mainly to the black staining of the lesions, which is not esthetically pleasing.[4]

Among the common materials used for the restoration of primary teeth, the demand for resin composite restorations has increased in esthetic dentistry. However, these materials have their disadvantages, including polymerization shrinkage, volume change, and gap formation between the tooth and restoration. Microleakage of fluid and bacteria can be caused by the gap which results in hypersensitivity and discomfort for the patients, pulpal irritation, and recurrent caries.[6] On the other hand, GICs have been developed with improved working time, easy handling, increased shear bond strength, less brittleness, and less sensitivity to moisture to prevent problems such as microleakage while acting as a fluoride reservoir.[5,7] The application of these materials in pediatric dentistry is on the rise. The purpose of this study was to investigate whether the use of SDF underneath glass ionomer restorations in primary teeth affects the shear bond strength of the material.

MATERIALS AND METHODS

Preparation of specimens

In this *in vitro* study, 48 anterior primary teeth that were extracted in a 3-month period prior to the study and were free of any crack, wear, decay, filling, fluorosis, calcification, or enamel defects were selected. The teeth were stored in the 0.2% thymol solution. After cleaning the debris using a hand curette and rinsing under normal saline, tooth surfaces were cleaned using a slow-speed handpiece and a rubber cup. Each specimen was mounted in the self-curing acryl so that the tooth would be submerged under its cementoenamel junction and only the crown would be left out. Specimens were randomly divided into four groups of 12 teeth each. A pencil was used to map out a rectangular area (5 mm × 5 mm) in the center of the labial enamel surface of each tooth, which was used as the test area. The outside areas of the mapped window were sealed with acid-resistant nail varnish.

Demineralization and surface treatments

The teeth were divided into four groups (G1–G4) and three groups (G2–G4) of specimens were immersed in a demineralizing solution (containing 2.2 mM of $CaCl_{2,}$ 2.2 mM of $KH_2PO_{4,}$ 0.05 M of acetic acid; PH = 4/4) at 37 Celsius for 96 h[8] to demineralize the enamel surface, which simulated whitespot lesion formation in a wet environment. The demineralizing solutions were changed every day for refreshing.

Group 2 specimens were demineralized but did not undergo treatment with SDF. Groups 3 and 4 were treated with Advantage Arrest SDF 38% solution for 10 s and were air-dried for 5 s before incubating. After the SDF treatments, the superficial enamel of group 4 specimens was polished off in 50 cycles of figure-eight repetitions using #600 grit polishing discs (3M ESPE USA) and was then briefly rinsed and air-dried for 5 s.[9]

Compositions, specifications, and manufacturers of the materials used in this study are displayed in Table 1.

The Control Group (G1) specimens, which did not undergo a demineralization phase, were stored

Table 1: Compositions, specifications and manufacturers of the materials used in this study

Material	Manufacturer	Lot number
Advantage arrest SDF	Oral Science, Quebec, Canada	19021
GC Fuji II light-cured universal restorative (glass ionomer)	GC Corporation, Tokyo, Japan	1808271
Demineralizing agent	Merck, Germany	1.02382.1000
Demineralizing agent	Merck, Germany	1.04873.1000
Demineralizing agent	Merck, Germany	1.00056.2500
Self-curing acryl	Acropars 2000, Malic, Industries Co, Tehran, Iran	PST 6021-1

SDF: Silver diamine fluoride

in artificial saliva during the entire study. All the experimental groups (G2-G4) were stored in artificial saliva and kept in the incubator at 37°C after surface treatment for 1 week before bonding the glass ionomer to dental tissues. After surface conditioning using polyacrylic acid, glass ionomer (GC Fuji II Light-Cured Universal Restorative) was bonded to each of the prepared tooth surfaces. A transparent plastic tube was used to apply the glass ionomer to the specimens (2.6 mm diameter and 5 mm length). The tube was placed on the tooth surface and filled with light-cured universal restorative glass ionomer. The material was light-cured with a halogen curing light, with a power density of 1000 mW/cm2 (Demi Kerr, USA) from the top, right, and left sides of the rod for 40 s each. After curing was completed, the transparent plastic tubes were carefully cut and removed gently. After the glass ionomer was set, the transparent plastic tubes were cut away from the rod.

The specimens were placed in artificial saliva, stored at 37°C for 24 h. Before the shear test, all samples were checked under an optical microscope (magnification = ×28) for defects. The samples that showed any gaps in the tooth-restoration interface or any bubbles on the cylinder were excluded at this stage.

The specimens underwent the shear bond strength testing in a universal testing machine (Zwick ROELL Z2.5 MA 18-1-3/7, Germany). A knife-edge blade (0.5 mm in terminal thickness) was utilized to direct the shearing force as close as possible and perpendicular to the glass ionomer-enamel interface. Each specimen was placed in the testing jig of the universal testing machine at a crosshead speed of 0.5 mm/min. The force required to fracture each specimen was recorded by the machine. Failure loads were recorded in N and converted to MPa to present the shear bond strengths. The shear bond strength (MPa) was calculated as: F/pr2 where F was load and r was composite sample radius (5.3 mm^2). Data analysis was carried out using the SPSS 22 Statistical Software (IBM Co., Armonk, NY, USA). One-way analysis of variance (ANOVA) and *posthoc* Tukey tests were performed to compare the effects of SDF on the shear bond strengths. Statistical significance was defined at $P < 0.05$ for all tests. The fracture modes of glass ionomer-enamel surfaces were evaluated at × 28 magnification using a stereomicroscope (LeicaMS5, Wetzlar, Germany) and recorded as adhesive and mixed-mode.

RESULTS

The mean and standard deviation of each group are displayed in Table 2.

The results of one-way ANOVA showed a significant difference between the mean shear bond strength of the four groups ($P < 0.001$). The results of the *posthoc* Tukey test showed the mean shear bond strength was significantly higher in the control group than in the three experimental groups. The mean shear bond strength was significantly higher in group 3 (demineralized teeth treated with SDF) than in groups 2 ($P = 0.01$) and 4 ($P = 0.04$). No statistically significant difference was observed between groups 2 and 4 ($P = 0.42$).

The fracture modes are presented in Figure 1. The results of the Chi-square test showed no significant differences between the frequency of fracture modes ($P = 0.27$). The frequency of fracture modes in Groups 2 and 3 was very similar. No statistically significant difference was observed between these two groups and the other groups.

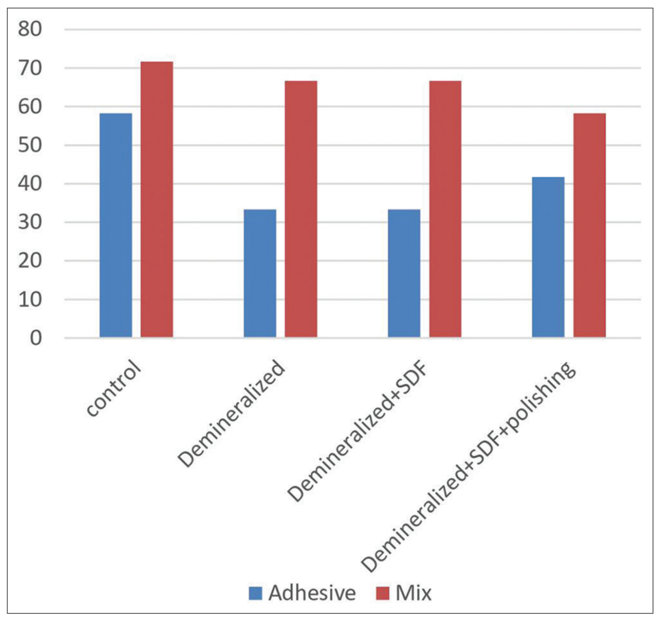

Figure 1: Frequency distribution of fracture mode.

Table 2: Mean shear bond strength (MPa) and standard deviation of each group

Groups	Mean (MPa)	SD	*P*
1. Control[a]	12.1	1.4	<0.001
2. Demineralized[b]	7.9	1.9	
3. Demineralized + SDF[c]	10.1	1.5	
4. Demineralized + SDF + polishing[b]	8.4	1.8	

[a,b] and [c] are statistically significant different. Means with the same superscript are not statistically significant different (*P*>0.05); SD: Standard deviation, SDF: Silver diamine fluoride

DISCUSSION

This study sought to examine whether pretreating demineralized enamel with SDF could affect the bond strength of glass ionomer to the enamel. Although the glass ionomer bond strength to sound enamel was higher than other groups by a significant margin, the results of this research showed an increase in the GIC bond strength when SDF pretreatment was used on demineralized Enamel groups (G2-G4).

The use of SDF in children has several advantages. Ease of use and eliminating the need for local anesthesia or drilling means that SDF can be used in children with intense dental fear.[7] SDF reduces the growth of cariogenic bacteria. Clinical studies have reported that SDF has a significant antimicrobial effect against *Streptococcus mutans* and *Actinomyces naeslundii* biofilms and can also inhibit matrix metalloproteinase activity.[10] Therefore, the use of SDF in children with caries, especially in uncooperative children, is a great and practical strategy for caries control.

Restoration of SDF-treated teeth is sometimes performed by dentists, and the appliance of glass ionomers is necessary due to their numerous advantages.[11] So far, many studies have investigated the effect of SDF on dentin and its consequences on the shear bond strength of adhesives and direct restorative materials such as glass ionomers and composite resins. It has been shown that SDF inhibits demineralization and preserves collagen degradation. It can keep hydroxyapatite and fluorapatite in the organic matrix, which may result in increased bond strengths.[12] This may also increase surface microhardness and improve the chemical bonding of GIC.[13] SDF reduces the loss of calcium and phosphate ions, remineralizes the carious dentin, and increases the surface microhardness.[10] SDF also protects dentine collagen. Applying SDF reduces the release of hydroxyproline, which is a result of collagen degradation.[14] Using immunolabeling methods, a study revealed that a larger amount of intact collagen remained on the dentin surface after treatment with SDF.[15] The activities of cathepsins, which are proteolytic enzymes that contribute to dentin collagen degradation, were also inhibited by SDF.[14] SDF causes calcium and phosphate sedimentation on the demineralized dental hard tissue. It has been shown that SDF had a higher effect on dentinal carious lesions because dentinal tissue contains a higher amount of protein, carbonate, and phosphate for reaction with silver.[2,16-18] Conversely, these compounds are rarely found in the enamel tissue.[10]

Unlike dentin, few studies have examined the effect of SDF on enamel and its consequences on the shear bond strength of different adhesives and direct restorative materials such as glass ionomers and composite resins. However, the demineralized enamel is often found around the cavities, enamel bond strength is highly important. Based on the present study results, SDF affects the shear bond strength between glass ionomer and demineralized enamel on the primary teeth. Further, the shear bond strength of glass ionomer to the SDF-treated demineralized enamel was significantly higher than that of the untreated demineralized tooth, which can be due to the increased surface hardness following SDF treatment. Mohammadi and Farahmand Far indicated that reduced enamel hardness of primary teeth during pH cycling in SDF-treated enamel samples was lower than the healthy teeth, and the effect of SDF on the increased hardness of enamel demineralized tissue can be one of the reasons for the increased shear bond strength of glass ionomer to the SDF-treated enamel demineralized tissue.[7] The Surface Micro Hardness decrease (%) was numerically higher in the control group than in other groups, and the SDF group indicated the maximum resistance to mineral loss.[7]

It has been shown that the application of SDF elevates the mineral density of the dental demineralized tissue,[19] which can increase the shear bond strength of glass to the tooth surface by increasing the hardness and providing calcium. Moreover, the carboxylic acid of light-cured resin-modified glass ionomer (RMGI) can bond to the silver phosphate (formed after reaction between the tooth surface and SDF) and silver iodide deposition (formed after reaction between SDF and potassium iodide) and increase the shear bond strength of glass ionomer to the SDF-treated demineralized enamel compared to the untreated surface.[20]

However, the results showed the shear bond strength of glass ionomer to healthy enamel surface was significantly higher than that of the SDF-treated demineralized surfaces, which can be due to the presence of more calcium ions of the healthy tooth surface for replacing the carboxylic acid OH in glass ionomer.[21] In addition, the presence of HEMA in the composition of light-cured glass ionomer used in this study increased the wetting of glass ionomer on the incompletely dried enamel surface and induced a higher shear bond strength, while the surface energy was reduced in the treated demineralized teeth due to bonding to SDF, and its wetting by glass ionomer was followed by more problems.[19,21]

In a study done by Lutgen *et al*.,[9] the positive impact of polishing on the bond strength of composite to SDF-treated dentin was shown. In our study, the SDF-treated demineralized surface enamel on which the polishing was performed had lower bond strength to glass ionomer compared to that of an unpolished surface. Since surface polishing is a clinical process, polishing was done in one group to evaluate the effect of this process on the bond strength of glass ionomer. The results showed this process significantly reduced the bond strength compared to the unpolished group and elevated the shear bond strength to the surface of untreated demineralized teeth. It seems that surface roughness after SDF treatment can affect the mechanical retention of the enamel surface. Polishing reduces the roughness and mechanical gear. It has been shown that the bonding of glass ionomer to the sandblasted enamel is higher than that of unprepared enamel, which indicates the positive effect of surface roughness on the glass retention.

Another factor that can impact the bond strength of RMGI to the SDF-treated demineralized enamel is the time passed between the application of SDF and the RMGI bonding. In this study, 1 week was passed after SDF treatment and then RMGI was bonded. This time interval can impact the bond strength. Other studies have already considered the impact of this time interval on the bond strength of RMGI to the SDF-treated dentin,[22,23] however, such studies are lacking with regards to the SDF-treated enamel. Therefore, more studies are needed to further elucidate the impact of this time factor on the RMGI bond strength to enamel and more accurately mimic the clinical settings.

As RMGI has an opaque appearance, it can easily mask the discoloration caused by SDF application on tooth structure and facilitate an acceptable esthetic appearance for pediatric patients with a high risk of caries. RMGI would be indeed preferred over composite resin for esthetic restorations in these patients as it would not only require less removal of tooth structure, but also it is less technique sensitive and plaque retentive restorative material.

CONCLUSION

We can conclude that

1. SDF-treated demineralized enamel surface could significantly increase the shear bond strength of light-cured glass ionomer compared to the untreated demineralized enamel surface
2. This increase in bond strength was not comparable to the shear bond strength to healthy enamel.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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