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Efficacy of Silver Diamine Fluoride on Immediate and Delayed Adhesive Strength of Resin Composite to Sound Dentin of Permanent Teeth: An In Vitro Study

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Abstract

Aim of the study: How silver diamine fluoride affected the immediate and prolonged adhesive resin composite's resistance to sound dentin of permanent premolars.

Material and method: Three groups were identified (total number=30). The manufacturer's recommendations were followed while applying adhesive resin to the dentin surfaces in Group A after they had been etched. In Group B and C, dentin surfaces were treated with silver diamine fluoride and 0.05% NaF respectively. Then etched and bonded as for the control group. Then resin composite build-ups were created. Following this, each group was divided into two subgroups (for each group n=5), subgroup 1 underwent a shear bond strength test by universal test machine after 24 hrs, subgroups 2 the test was done after thermocycling process (300 cycles). The mode of failure was also examined.

Results: The type of dentin surface treated with SDF solution was significantly affect shear bond strength (p=0.000) for both periods (immediate and prolonged). However, there were no significant difference between NaF group and control group on shear bond strength (p>0.05) in immediate and prolong periods. On other hand there were statistically no significant differences between immediate and prolonged shear bond strength in SDF group (p=0.850), NaF group (p=0.637) and control group(p=0.794) When dentin surfaces were treated with silver diamine fluoride, there were more adhesive failures not as 0.05% NaF and control group which showed more mixed failures.

Conclusion: silver diamine fluoride significantly reduced bond strength of etch and rinse adhesive system. Pretreatment with NaF maintained the shear bond strength of the adhesive to dentin after 300 thermal cycles.

Keywords: Universal test machine, silver diamine fluoride, sodium fluoride, shear bond strength

Introduction

The stability of the hybrid layer has a direct impact on how long resin composite restorations last. Methacrylate polymers used in adhesive systems may be subject to metalloproteinases' enzymatic degradation and chemical hydrolysis. Cavity pretreatments, esterase-resistant adhesive systems, or inhibitors of the collagen lytic enzyme must be used to stop the activity of metalloproteinases and stop the deterioration of the hybrid layer (Surendranath, Krishnappa and Srinath, 2022).

The US FDA approved the chemical name silver diamine fluoride (SDF) and the formula (Ag (NH3)2F), as a drug that inhibits tooth decay in 2016, SDF's constituent parts are responsible for its beneficial benefits. Silver nitrate destroys germs, silver salt promotes dentin sclerosis and calcification, and fluoride slows the process of demineralization and encourages

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demineralization, Previous research has shown that SDF is the fluoride-containing substance that prevents collagen deterioration and demineralization the best (Surendranath, Krishnappa and Srinath, 2022).SDF is not typically used before to a composite restoration, though, for two reasons: (Surendranath, Krishnappa and Srinath, 2022) it darkens the color of the tooth and the restoration, and (Knight and McIntyre, 2006) it doesn't offer a suitable procedure before putting the restoration in place that won't weaken the bond (Surendranath, Krishnappa and Srinath, 2022). Using salts that react with the free silver ion include potassium iodide (KI), for example created following the application of SDF, is the suggested solution for the first issue. This reaction produces white silver iodide, which seals the tooth's surface from changing color (Knight and McIntyre, 2006). There is still disagreement over the implications of a particular strategy for the second issue, despite the fact that various solutions have been put forth. Additionally, the impact of KI use has not been examined in the majority of studies, except in Selvaraj et al study that included the presence of KI in SDF and its effect on bond strength (Selvaraj et al., 2016).

The research is conducted to investigate how adding SDF affects the bond strength of adhesive are erratic. According to two researches, using SDF has no detrimental effects on the bond strength (Selvaraj et al., 2016). In contrast to the findings of the aforementioned investigation, one study, demonstrated that using SDF prior to using universal adhesives and self-etch adhesives with and without selective etch can weaken the connection to the dentin in comparison to control group (Lutgen, Chan and Sadr, 2018). Furthermore, other one demonstrated that KI/SDF can weaken the connection between the three different adhesives and bond strength reduction persists when KI is used after SDF (Koizumi, Hamama and Burrow, 2016).

Yet, all research about SDF assessed the initial connection strength. Case day case in clinical settings, thermocycling stimulates temperature changes. According to several studies, thermocycling has the ability to hasten the development of dentin and restorative interface contact deterioration (Daneshkazemi et al., 2013).

This study sought to assess and contrast immediate and prolonged effects of silver diamine fluoride and sodium fluoride on the Bond strength of resin composite to sound dentin.

Materials and Methods

Ethical approval was received from the College of Dentistry institutional ethics committee board at the University of Baghdad (approval number and date: 571322 on 17/05/2022).

Mold fabrication and sample preparation

Thirty freshly extracted caries free unrestored human premolar were selected for use in this study. A need for orthodontic treatment led to the extraction of healthy human premolar teeth. Teeth were stored in thymolsolution (0.02%) till the time of the study to stop the growth of germs and fungi. Each tooth's occlusal surface was sliced 1 mm below the

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mesial pit with an electric diamond saw (Gamberini, Italy) while it was submerged in water (Khalil, and Al-Shamma, 2015).

Sample grouping, thermocycling procedure

Specimens were divided into 3main groups of 10 teeth as follows: Group A specimens of control group in which the surface was noticeably damp after being etched for 15 seconds with 37% phosphoric acid (Dline, EU), followed by a 15-second water wash. With a disposable applicator, Single Bond Universal was applied for 20 seconds, and then gently blasted with air by a triple syringe for around 5 seconds, until it stopped moving and the solvent had entirely evaporated. The adhesive was harden with a commonly used curing light for 10 seconds .Group B specimens were rewetted with SDF that was applied according to manufacturer instruction, Riva Star Step 1: one (1) drop of solution (sdf: grey lable) was dispensed on to non-absorbent mixing pad and carefully applied the solution to treatment site only, a medium sized micro brush was used, Riva Star Step 2: Immediately after dispensing two (2) drops of the green-labeled solution onto a brand-new, non-absorbent mixing pad, a medium-sized microbrush generously applied the solution to the treatment site. The treatment surface initially had a creamy white appearance. Riva Star Step 2 solution (KI: green label) was administered continuously until it turned clear, at which point it was Blot dried, and adhesive agent was used as in the control group. Group C specimens were treated with 0.05% sodium flouride that was prepared by adding 0.05 gram sodium fluoride powder to 100 ml of de-ionized water, the solution was rubbed on dentin surface which were then dried with absorbent paper and handled as with the control group for 60 seconds (Neri et al., 2017). Using a LED light curing apparatus, for composite build-ups that were inserted in a single step of 2 mm thickness, Filtek Z350 resin composite (3M ESPE, USA) was used (SDI, Australia). Each group was separated into two additional subgroups (n = 5), the first of which conducted after 24 hours, to test shear bond strength, and the second of which went through a thermocycling process. In the thermocycling apparatus, the specimens underwent 300 heat cycles at 5 and 55 with a 30 second dowel time (Iraq, Baghdad, custume made). The samples were then dried, and their shear bond strength was determined by using a universal testing machine (Instron machine, WDW-50, LARYEE, and China) at crosshead speed of 1 mm/min.

Mode of failure

Following shear bond strength testing, the sample pieces analyzed after being viewed under stereo microscope at 20 x and classified as adhesive, mixed (partially adhesive) /partially cohesive) or cohesive failure.

Statistical analysis Data were analysed by using: Shapiro Wilk, Levene test, One Way Analysis Of variance (ANOVA) with Tukey's HSD using Statistical Package for social Science (SPSS version -22, Chicago, Illionis, USA).

Results

The type of dentin surface treated with SDF solution was significantly affect shear bond strength($p=0.000$) for both periods

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(immediate and prolonged)However, there were no significant difference between NaF group and control group on shear bond strength ($p<0.05$)in immediate and prolong periods(Table 1).On other hand there were statistically no significant differences between immediate and prolonged shear bond strength in SDF group($p=0.850$),NaF group ($p=0.637$) and control group($p=0.794$)(Table 1) , (Figure 1) . SDF was the lowest shear bond strength value of the other groups and the significance of differences in shear bond strength between materials was caused by the lowest value obtained from SDF group (Table 2).When dentin surfaces were treated with silver diamine fluoride, there were more adhesive failures not as 0.05% NaF and control group which showed more mixed failures (Table 3), (Figure 2).

Table 1: Descriptive and statistical analysis of Shear bond strength among SDF, NaF and control groups between immediate and delayed periods. From Table (1) it can be seen that mean value of adhesive strength was not affected by thermocycling within each group. Significance was found between the groups when comparing adhesive strength at immediate and prolonged times.

Groups		**Period**		**F**	**P value**
		Immediate	**Delayed**		
SDF	Min.	12.420	12.220	0.038	0.850
	Max.	17.038	17.038		
	Mean	15.096	14.856		
	±SD	1.817	2.054		
	±SE	0.813	0.919		
NAF	Min.	23.408	23.408	0.241	0.637
	Max.	26.522	25.930		
	Mean	25.153	24.753		
	±SD	1.449	1.106		
	±SE	0.648	0.495		
Control	Min.	25.318	25.118	0.073	0.794
	Max.	27.707	27.592		
	Mean	26.633	26.433		
	±SD	1.154	1.189		
	±SE	0.516	0.532		
F		87.803	85.625		
P value		**0.000**	**0.000**		

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Table 2: Multiple pairwise comparisons of Shear bond strength among SDF, NaF and control groups by period using Tukey Honestly Significant difference (Tukey's HSD). In Table (2) a comparison between shear bond strength of groups found that the SDF was the lowest of the other groups. The significance of differences in shear bond strength between materials was caused by the lowest value obtained from SDF group.

Period	Groups		Mean Difference	p value	Upper bound 95% CI	Lower bound 95% CI
Immediate	SDF	NAF	-10.057*	**0.000**	-12.585	-7.530
		Control	-11.538*	**0.000**	-14.065	-9.010
	NAF	Control	-1.480	0.299	-4.008	1.047
Delayed	SDF	NAF	-9.897*	**0.000**	-12.448	-7.347
		Control	-11.578*	**0.000**	-14.128	-9.027
	NAF	Control	-1.680	0.225	-4.231	0.871

Table 3: Distribution of failure mode among period and groups. As illustrated in Table (3) it was found for both periods that there was a percent of failure in adhesive and mixed types for all groups. For NaF and control groups the mixed failure was predominant while there was increase in adhesive failure among the SDF group in comparison to other groups.

Period		**Failure**			
		Adhesive		**Mixed**	
		N.	**%**	**N.**	**%**
Immediate	SDF	2	40.00	3	60.00
	NAF	1	20.00	4	80.00
	Control	1	20.00	4	80.00
	Total	5	25.00	15	75.00
Delayed	SDF	2	40.00	3	60.00
	NAF	1	20.00	4	80.00
	Control	1	20.00	4	80.00
	Total	5	25.00	15	75.00

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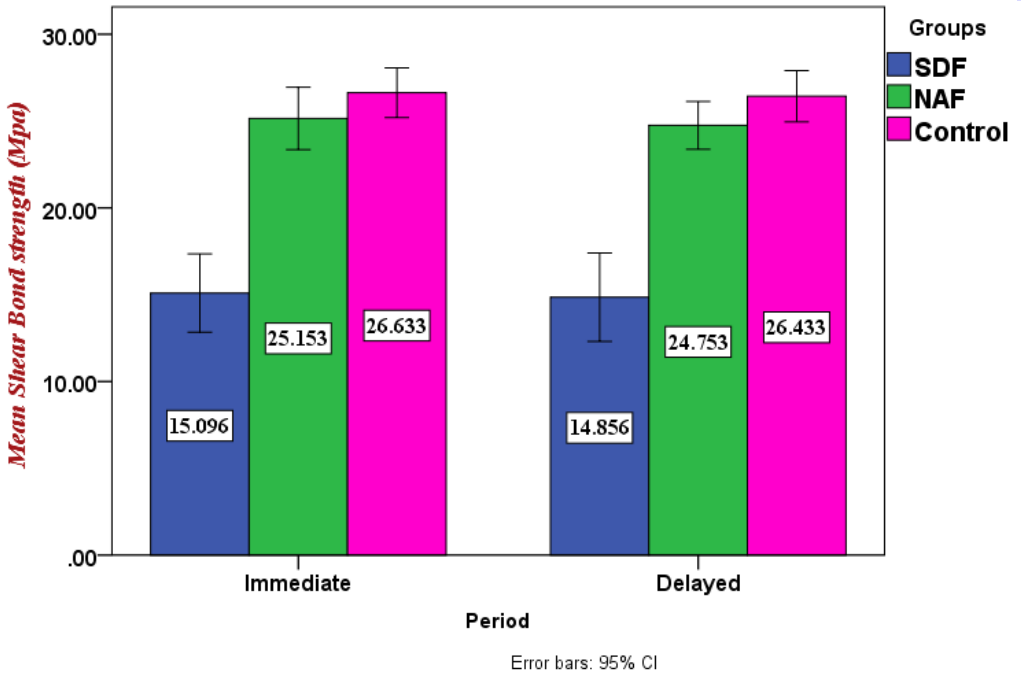

Figure 1: Bar-chart showing the comparison between groups at immediate and prolonged groups of adhesive strength.

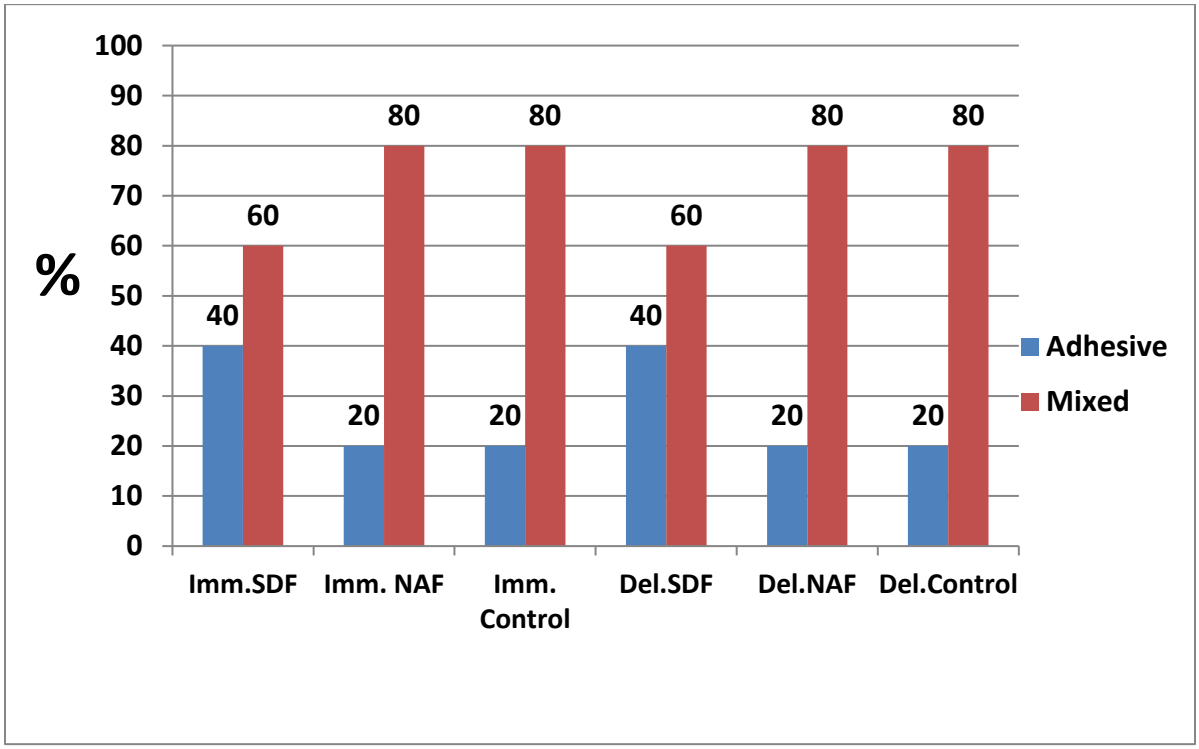

Figure 2: Bar-chart showing the distribution of failure mode among period and groups.

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Discussion

The hybrid layer has been identified to be the weakest link in bond formed between the adhesive agent and the dentin substrate and is highly dependent on adhesive penetration capacity (Al-Shamma and Al-Abbas, 2020). The key step for good infiltration and penetration of adhesive resin monomers into the demineralized dentin matrix exposed by acid etching is essential components of high-quality hybrid layers and resin tags, which are required for good micromechanical retention of adhesive resin monomers into the dentin substrate (Al-Qrimli and Al-Shamma, 2016). The effects of the materials tested in this study have shown they do not have similar effect on the immediate adhesive strength of resin composite. Sodium fluoride had an effect that was almost equal to the control group in which no material was used before the single bond adhesive was applied, the enhanced mechanical qualities of this adhesive, which led to higher adhesion, may be due to hydroxyethyl methacrylate-2 inclusion in SBU bond strength, water-based adhesives result in lower bond strengths than the adhesive with acetone or ethanol (Al-Qrimli and Al-Shamma, 2016).

The SDF group, after successive comparisons revealed to be the cause of the difference between the groups' importance. SDF had the impact of weakening the resin composite's shear bond strength. This was in line with (Koizumi, Hamama and Burrow, 2016), who made the argument that SDF can prevent primer from penetrating into the intertubular and peritubular dentin and from bonding there, which results in the production of fewer hybrid layers with reduced collagen matrix. According to a study (Farahat, Davari and Karami, 2022), using KI/SDF weakens the dentin connection, which is consistent with the findings of the current investigation.

Furthermore, in a study it was demonstrated that using SDF could weaken bonds, but added that how severely this effect is impacted relies on how SDF is applied, with rinsing the SDF having the greatest impact (which was not done in this study) resulted in the development of a stronger bond (Farahat, Davari and Karami, 2022). The pH of SDF is around 10. If SDF is applied without first washing very alkaline, interfering with the self-etch adhesive on the surface, and weakens the bond. In order to achieve the best bond for a composite restoration, the anticaries material left on the surface must be rinsed (Farahat, Davari and Karami, 2022). Beside the effect of SDF in occluding dentinal tubules by the explain why microleakage reduced especially with an interval that SDF had more time to work and occlude dentinal tubules (Khalaf and Jasim, 2022) that may interfere the penetration of resin tags into dentin. Three studies have shown that if KI/SDF residues were rinsed away, they did not affect the bond strength (Gupta et al., 2019). On the other hand, one study showed that the bond strength remained low despite running the rinsing process (Van Duker et al., 2019). The not rinsing approach followed in the present study may probably be the reason for the reduced bond strength.

Concerning sodium fluoride, the process by which calcium fluoride crystals are formed and then deposited on the apertures of dentinal tubules as a result of the reaction between sodium fluoride and calcium ions

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(Habeeb and Mahmood, 2021). The results of this investigation were in line with those of other studies, which demonstrated that the bond strength does not appear to be adversely affected by the presence of sodium fluoride in self-etching monomers (Costa et al., 2014, Pinto et al., 2015). These studies compared sodium fluoride to distilled water and chlorhexidine and indicated that the CHX and distilled water had a greater impact on the initial composite-dentin bond strength than did the application of NaF.

Studying the prolonged effect of the materials on adhesive strength of resin composite was done by thermocycling to expose the bonded specimens to extreme temperatures which simulate intraoral conditions. In this study aging of the samples did not show an effect on the adhesive strength for each group. While when comparing between groups, SDF was again the reason for the significance of difference between groups. This finding indicates that thermal aging did not affect the properties of the three materials and that each material maintained the same bond strength. This came in agreement with some studies ;) for SDF (Farahat, Davari and Karami, 2022) and for NaF (Al-Qrimli and Al-Shamma, 2016). While when comparing between the materials, SDF showed the weakest bond strength. The reason for this weakened bond strength may be due to the application protocol of SDF as mentioned earlier, concerning rinsing the SDF before applying the adhesive agents. While however, a study found that even after the rinsing procedure, the binding strength remained poor (Van Duker, 2019).

Mode of failure

Clinical failure of adhesive restorations happens more often due to insufficient sealing of cavity walls rather than complete loss of retention (Al-Shamma and Maryoosh, 2020). The microscopic features of specimen surfaces were analyzed using a stereo microscope at 20 x) to categorize the fracture patterns. It was observed that the predominant failure was the mixed failure, while adhesive failure was low in each group except for the SDF group which showed a slightly higher number of adhesive failures. There was no loss of cohesiveness in resin composite. Unlike the collapse of cohesive systems types, when the dentin wall is entirely coated with resin composite, adhesive failure types are characterized by the absence of any residual resin composite. The mixed failure type is distinguished by sections of exposed and covered dentin, as its name suggests (Steiner et al., 2019). However, the main disadvantage of one-step self-etch adhesives is related to their high hydrophilicity, which makes the adhesive layer more prone to take water from the substrate's surface inherent moisture (Sofan et al., 2017). These one-step adhesives have been found to function as semi-permeable membranes even after polymerization as a result of their increased water affinity, allowing water to pass from the substrate through the adhesive layer (Cevik et al., 2020). Resin polymer hydrolysis, and subsequent deterioration of the tooth-resin connection over time appear to be caused by the adhesive layer's permeability (Gomes et al., 2020).

For total-etch systems (used in this study), The dentin and enamel surfaces are modified

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using a phosphoric acid etching procedure so that the adhesives can penetrate the tooth surfaces and form a mechanical bond. A strong acid with a pH of roughly less than 0.5 is phosphoric acid. It works wonders at removing the smear layer, the mineral found in the dentin's collagen matrix, and to display the prismatic crystal structure, the mineral in the enamel. Enamel made with phosphoric acid has extremely stable and strong adhesion to both uncut and cut (prepared) surfaces. The phosphoric acid therapy fully dissolves the smear layer from dentin, exposing the tubules. Also demineralized is the collagen matrix. Demineralized collagen should be kept wet in some systems to avoid the collapse of the collagen fibers and subsequent loss of binding strength. To avoid sensitivity in this situation, it is essential to thoroughly seal the tubules (Abbood and Al-Hashimi, 2016).

Taken the above in consideration and the similar results obtained from the NaF and control group, the cause of the adhesive and mixed failure may be considered indifferent. As for the SDF group the failure confirms the previously mentioned findings concerning the role of SDF in decreasing adhesive bond strength. The application of SDF which did not include the rinse step may be the cause of reduced bond strength. Because there was probably too much SDF present, the bonding was unable to create a strong bind with the dentin. The rinse procedure may be what makes SDF application techniques unique in terms of bonding effectiveness. SDF may prevent the primer and bonding agent from impregnating the peritubular and intratubular dentin necessary to create a meshwork with the collagen matrix beneath. The lifetime of composite restorations depends on ensuring adequate bonding, which is achieved by rinsing excess SDF away. It is noteworthy that the manufacturer's instructions for the SDF product used in this study do not recommend rinsing after application, in contrast to the published SDF application protocol (Cevik et al., 2020) and the original SDF product instructions (Saforide, Bee Brand Medico Dental, Osaka, Japan), which both specify a rinsing step in the application protocol. It's also important to know that the manufacturer estimates SDF's pH to be about 10. When SDF is applied without being rinsed, the surface may become too basic, which will interfere with phosphoric acid etching and the self-etching adhesive's ability to etch, weakening the connection (Chan and Sadr, 2018).

Sound dentin was the subject of this study. This can be viewed as a restriction. The adhesion to the carious dentin was shown to be less successful than the sound dentin (Alhabdan, 2022). Dentin also experiences structural alterations with time. Thus, it is advised that additional research be done test various surface preparation methods and adhesives in sclerotic dentin treated with SDF, as well as their effects on adhesion to carious dentin. In order to combine SDF in the presence of adhesive restoration materials best way possible and preserve the advantages of both, further adjustments to the application process are required.

Conclusion:

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1- In Immediate period, silver diamine fluoride solution reduced shear bond strength of composite to dentin.

2- Thermocycling did not change the effect of silver diamine fuoride significantly that still reduce shear bond strength of composite to dentin as its effect immediately.

Supplementary Material

None.

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Data Availability Statement

Data are available from the authors upon reasonable request.

Conflict of interest

The authors reported that they have no conflicts of interest.

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