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Assessment of Microleakage of Resin Composite Restorations Following Silver Diamine Fluoride Pretreatment in Primary Molars: An In Vitro Study

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ABSTRACT

Background: In recent years, silver diamine fluoride (SDF), a topical fluoride formulation containing metal ions, has attracted growing attention for its effectiveness in preventing further progression of dental caries.
Objectives: To evaluate the effect of silver diamine fluoride pretreatment on microleakage of resin composite to the dentin in primary molars.
Method: For microleakage test, Class V cavities were prepared on the buccal surface of 34 extracted primary molars. The teeth were assigned into two groups, Group A: Experimental group (SDF) and Group B: Control group. The cavities were filled with composite restoration. The specimens were then submitted to 1000 thermocycles and immersed in 0.5% basic fuchsin and sectioned in a buccolingual plane. The depth of dye penetration was evaluated under stereomicroscope at 10X magnification.
Result: Chi square test and Independent t- test were used. Group A showed mean microleakage value and standard deviation of 0.81±0.91 while, Group B showed 0.63±0.79. No statistically significant difference was found between Group A & Group B.
Conclusion: From the present study it could be concluded that pretreating dentin with 38% SDF did not affect the microleakage of composite resin to dentin.

***Keywords**: Silver diamine fluoride, microleakage, composite, class V cavity, primary teeth.*

INTRODUCTION

Although dental caries is largely preventable, it continues to be a major oral health concern among children. The condition significantly affects individuals and populations by causing pain, impairing oral function, and reducing oral health–related quality of life, particularly among socially and economically disadvantaged groups.[1]

Among children in low-income countries, untreated dental caries negatively influences general health, social functioning, and school-related activities. This issue is often exacerbated by financial constraints, restricted access to basic oral healthcare services, and the substantial cost associated with restorative dental care.[2]

The extensive use of fluoride-containing dentifrices has contributed to a marked decline in dental caries prevalence and substantial improvements in the oral health of children. Nevertheless, preschool-aged children continue to exhibit a high prevalence of untreated carious lesions, with the decayed component representing the largest proportion of the deft index compared to other age groups.[1]

According to parental reports, major barriers to obtaining dental care for children include dental anxiety, financial limitations, difficulties in scheduling appointments, and transportation-related challenges.[3]

Conventional dental procedures have gradually been replaced by minimal invasive dentistry (MID), an approach centered on conserving intact tooth structure through noninvasive techniques. Community-based preventive strategies, including the arrest of carious lesions, may be regularly employed to control the advancement of dental caries.[4,5]

Silver diamine fluoride (SDF) has recently gained considerable global attention among clinicians because of its proven effectiveness in arresting the progression of carious lesions. For more than four decades, silver fluoride (AgF) has been successfully used as a preventive agent in both clinical and laboratory-based studies. In the United States, the first dental SDF formulation received clearance from the U.S. Food and Drug Administration (FDA) in August 2014 and became commercially available in April 2015. According to Horst et al., the low cost of SDF makes it suitable for incorporation into community oral health programs, with once- or twice-yearly applications recommended as a preventive measure.[1]

Silver diamine fluoride (SDF) has demonstrated a favorable safety profile, with no serious adverse events reported in clinical trials published globally. It has also shown high effectiveness, arresting approximately 80% of treated carious lesions. Furthermore, SDF is an efficient treatment option, as it can be applied within a minute with minimal training by healthcare professionals across a variety of clinical and community settings.[6]

Stebbins proposed that the reduction in dental caries was associated with the antibacterial effects of silver compounds and the formation of a black protective layer, which promoted sclerosis and secondary dentin formation. Subsequently, Howe employed an ammoniacal silver nitrate solution on carious lesions, leading to the development of a blackened sclerotic dentin layer that appeared to inhibit further caries progression. Howe's solution remained widely used until the 1950s for sterilizing prepared carious lesions and as a root canal disinfectant; however, concerns regarding its clinical effectiveness and potential pulpal adverse effects limited its continued use. Nevertheless, some investigations suggested that silver nitrate could penetrate both sound and carious dentin, as well as vital and non-vital tissues, producing only mild and localized pulpal effects.[7,8]

In the 1970s, silver fluoride (AgF) was introduced in Western Australia as part of minimally invasive approaches within school dental services. Later, in 1969, Nishino first investigated silver diamine fluoride (SDF) during doctoral research at Osaka University, Japan, combining the strong antimicrobial action of silver with the cariostatic benefits of high fluoride concentration. This formulation also produced precipitates capable of occluding dentinal tubules, thereby reducing dentinal hypersensitivity. Subsequently, diammine silver fluoride received approval from Japan's Central Pharmaceutical Council under the Ministry of Health and Welfare as a cariostatic agent and was commercialized as Saforide. Following this, numerous studies explored SDF as an alternative strategy for managing dental caries, particularly in developing countries with limited access to oral healthcare services.[9]

Silver diamine fluoride (SDF) is a colorless ammonia solution containing silver and fluoride ions. Since neutral silver fluoride is unstable, it is commonly dissolved in water containing ammonia to form a more stable complex ion (Mei, Ito, et al. 2013).[10]

The therapeutic effectiveness of silver diamine fluoride (SDF) is attributed to the combined action of silver and fluoride ions. Its role in the prevention and arrest of dental caries is primarily mediated through three mechanisms: antibacterial activity against cariogenic microorganisms, enhancement of remineralization with simultaneous inhibition of enamel and dentin demineralization, and preservation of the dentinal collagen matrix through inhibition of collagenase activity.

SDF interacts with hydroxyapatite to produce compounds such as silver phosphate and calcium fluoride, which act as reservoirs for fluoride and phosphate ions, thereby facilitating remineralization. Silver ions are capable of penetrating carious lesions and remaining within the affected tissues, allowing prolonged antimicrobial and protective effects. Penetration depth varies depending on the tissue involved, extending approximately 25–30 μm into enamel, 200–300 μm into dentin, and up to 2 mm in deep carious lesions. Additionally, the formation of silver-containing compounds, including silver oxide and silver phosphate, contributes to the characteristic black discoloration observed in arrested carious lesions.[1]

In a systematic review and meta-analysis, Oliveira et al. reported that silver diamine fluoride (SDF) was effective in preventing dental caries in primary dentition when compared with placebo, fluoride varnish, or no intervention, concluding that SDF demonstrates substantial preventive benefits across the primary dentition.[11] Similarly, a systematic review by Contreras et al. observed a significant reduction in active carious lesions among children treated with SDF.[12]

Llodra et al. identified 38% SDF as highly effective in reducing caries incidence in primary teeth, reporting an approximately 80% reduction in new carious lesions over a 36-month period when compared with a water control group.

Children receiving SDF developed fewer new lesions than controls, and the difference was statistically significant.[13] Likewise, Chu et al., in a study limited to maxillary anterior teeth in preschool children, demonstrated that the SDF-treated group developed substantially fewer new lesions over 30 months compared to the water control group.[14]

A major limitation of silver diamine fluoride (SDF) in caries arrest is the black discoloration of treated lesions, which may be considered unaesthetic and can reduce acceptance among some children and parents. In addition to staining carious lesions, SDF may also discolor skin and clothing. Skin stains are not easily removed and generally fade gradually over time. The solution may also produce an unpleasant metallic taste. Mild irritation of the gingival and oral mucosal tissues has also been reported; affected areas typically appear whitish temporarily, with healing occurring within 1–2 days.

Additional drawbacks of SDF include its sensitivity to light, necessitating storage in opaque or dark containers. Due to its high fluoride content, accidental ingestion of large quantities may result in toxicity, requiring careful application, particularly in very young children. To address the issue of black staining, potassium iodide (KI) has been suggested as an adjunctive agent, as it reacts with free silver ions to form silver iodide, a creamy white precipitate that may reduce discoloration.[15]

SDF has proven to be effective in preventing secondary caries which results due to microleakage. Microleakage at the tooth restoration interface is considered a major factor influencing the longevity of dental restorations. An effective bond to the enamel and dentin would reduce marginal microleakage, seal the interface to prevent bacterial penetration that leads to recurrent decay and post-operative sensitivity.[15]

Silver diamine fluoride (SDF) represents an effective, affordable, and sustainable approach for arresting dentinal caries in children and adolescents at high caries risk across various age groups. Owing to its strong antimicrobial properties, SDF plays a significant role in inhibiting biofilm formation and preventing dental caries. It is particularly beneficial for individuals who are unable to tolerate conventional restorative procedures, have limited access to dental services, or possess special healthcare needs. Current evidence indicates that biannual application of SDF is more effective in arresting and preventing dental caries when compared with placebo or certain alternative interventions. Continued application of SDF is recommended until definitive restoration is completed or the affected tooth undergoes natural exfoliation.[1]

By considering the above advantages of SDF, this in vitro study was undertaken with an objective to evaluate the effect of silver diamine fluoride pretreatment on microleakage of resin composite of resin composite to the dentin of primary molars.

METHODOLOGY

The study included thirty four non-carious primary molars extracted based on clear clinical indications, such as over-retention, impending exfoliation, or the need for serial extraction. Exclusion criteria comprised deeply carious primary molars, teeth with pulpal exposure, lesions involving proximal surfaces, and previously restored primary molars.

The extracted teeth were cleaned with slurry of pumice and a prophy cup and stored in distilled water with thymol crystals until used for examination. After retrieving from distilled water, Class V cavities (3 mm X 2 mm X 1.5 mm) (Figure 1) were prepared using tungsten carbide burs. The teeth were randomly assigned into two groups consisting of 17 samples each, Group A: Experimental group (SDF) and Group B: Control group.

In the experimental group 38% SDF (FAgaminR TEDEQUIM SRL) solution was applied on the dentin surfaces (Figure 2) using an applicator tip for 3 minutes, followed by a 30 second rinse with distilled water. The prepared cavity was dried with compressed air and etched with 35 percent phosphoric acid (3M Scotchbond Etchant) for 20 seconds. The gel was removed with vigorous distilled water spray for 15 seconds. Excess water was removed from the rinsed surface with a soft blow of air to avoid desiccating the dentin and achieve a moist surface. Dentin bonding agent (Adper Scotchbond Multi-Purpose) was directly dispensed to thoroughly wet the processed dentin surface with a fresh applicator tip. The processed dentin surface remained fully wet for 20 seconds. The surface then received a gentle air-dry for at least five seconds to reach a uniform, glossy appearance, the adhesive was light cured for 20 seconds. Following adhesive application, the cavity was filled with composite resin restoration,[15] (3M ESPE Filtek Z350 XT Universal Syringe Shade) and cured according to manufacturer’s instructions (Figure 3).

In the control group the dentin surfaces were not pretreated with SDF (FAgaminR TEDEQUIM SRL). The prepared area was processed following the same steps as adhesive bonding as described previously.

Once set, the restorations were finished with fine-grit finishing diamond burs and polished with the disc system. The restored teeth were stored in distilled water for 24 hours at 370C. The specimens were then submitted to 1000 thermocycles with 30s baths at temperature 50C and 550C and a dwell time of 10 s in a resting bath at 240C.

Root ends were sealed with a layer of composite resin and double-coated with nail varnish up to 1 mm from the restoration margins (Figure 4). All samples were subsequently immersed in 0.5% basic fuchsin solution for 24 hours (Figure 5). After removal from the dye solution, the teeth were washed and sectioned longitudinally through the centre of the restorations in a buccolingual plane with a diamond saw (Figure 6).4 Marginal leakage, as indicated by the depth of dye penetration at the margins were evaluated under stereomicroscope at 10X magnification given by Prabhakar et al.[16]

- Score 0: No dye penetration
- Score 1: Dye penetration between the restoration and the tooth into enamel only
- Score 2: Dye penetration between the restoration and tooth limited to enamel and dentin.
- Score 3: Dye penetration between the restoration and the tooth extending into the pulp chamber. (Figure 7)

Figure 1: Class V cavity prepared

Figure 2: Application of SDF

Figure 3: Tooth restored with Composite

Figure 4: Nail varnish applied

Figure 5: Samples placed in 0.5% basic fuschin

Figure 6: Tooth sample after buccolingual sectioning

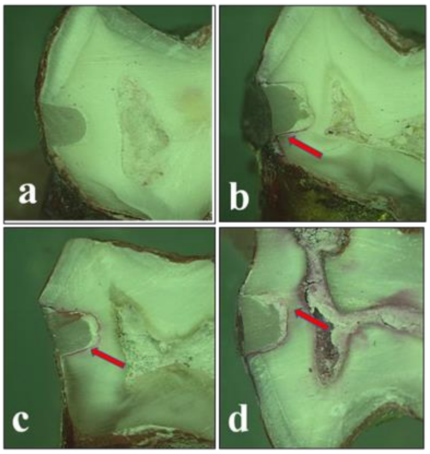


Figure 7: a. Score 0 (No dye penetration);
b. Score 1 (Dye penetration between the restoration and tooth limited to enamel only);
c. Score 2 (Dye penetration between the restoration and tooth limited to enamel and dentin;
d. Score 3 (Dye penetration between the restoration and tooth extending into pulp chamber)

RESULTS

The data obtained was tabulated and subjected to statistical analysis using Chi square test and Independent t- test. Chi square test was performed to check for the homogeneity of distribution. A normal distribution was found in the data in both experimental group (n=34) and control group (n=34). A p-value more than 0.05 was considered for statistical insignificance. SPSS (version 24) software was used for analysis.

On evaluation of microleakage, 41.17% of samples of Group A and 47.05% of Group B had score 0 (no dye penetration). 35.29% of samples of both the groups had score 1 (dye penetration between the restoration and the tooth into enamel only) 17.64 % of samples of both the groups had score 2 (dye penetration between the restoration and tooth limited to enamel and dentin). 5.88 % of samples of Group A had score 3 (dye penetration between the restoration and the tooth extending into the pulp chamber), while none of the samples of Group B had score 3. (Table1, Graph 1). Group A showed mean microleakage value and standard deviation of 0.81±0.91 Group B showed mean microleakage value and standard deviation of 0.63±0.79. (Table 2 & Graph 2) On comparison, statistically insignificant difference was found in mean microleakage values between Group A & Group B with P value of 0.52. (Table 3)

Table 1: Percentage distribution of microleakage scores for Group A & Group B

Microleakage Values			
Score	**Group A**	**Group B**	**Total**
Score 0	7 (41.17%)	8 (47.05%)	15 (88.23%)

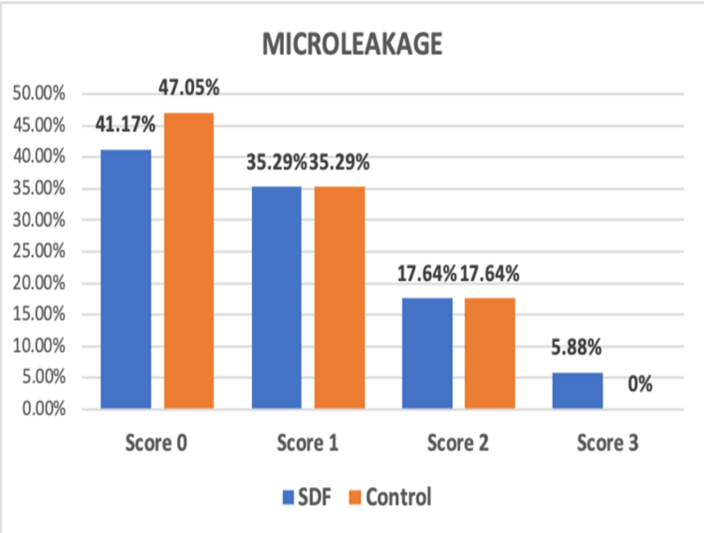
Score 1	6 (35.29%)	6 (35.29%)	12 (70.58%)
Score 2	3 (17.64%)	3 (17.64%)	6 (35.29%)
Score 3	1 (5.88%)	0 (0%)	1 (5.88%)
Total	17	17	34

Table 2: Mean microleakage values of Group A & Group B.

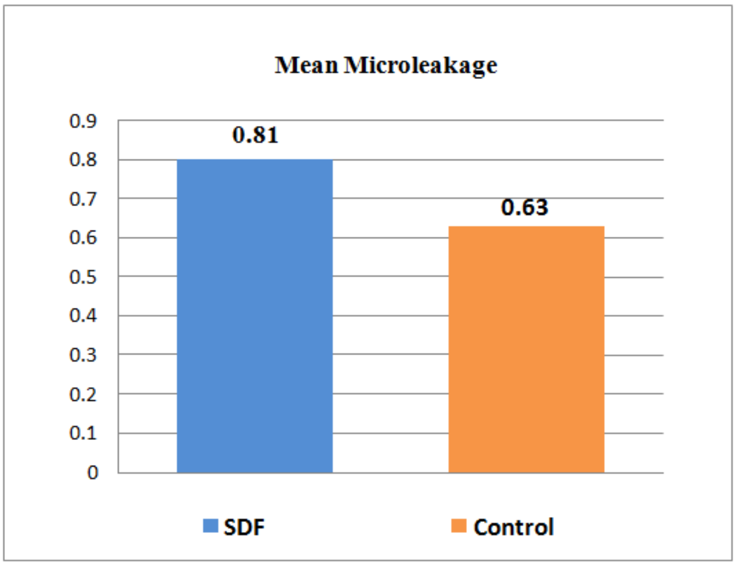
	Group	N	Mean	Std. Deviation	Std. Error Mean
Microleakage	**A**	17	0.81	0.911	0.228
	B	17	0.63	0.719	0.180

Table 3: Comparison of microleakage values of Group A & Group B.

Microleakage	t	p value	Mean Difference	Std. Error	95% Confidence Interval	
					Lower	Upper
Equal variances assumed	0.646	0.523*	0.188	0.290	-0.405	0.780



Graph 1: Percentage distribution of microleakage scores for Group (SDF) & Group B (Control)



Graph 2: Mean microleakage values of Group A (SDF) & Group B (Control)

DISCUSSION

Any agent applied to dentin and enamel substrates prior to restorative procedures could potentially interfere with the ability of hydrophilic monomer resins to wet, diffuse, and polymerize in situ into dentin substrates, resulting in changes of their mechanical properties. The ultimate objective in adhesive dentistry is to establish an effective adhesion to dental tissues.[17]

Dentin bonding agents adhere to dentin substrate by micromechanical hybridization. Formation of a perfect resin infiltrated hybrid layer is essential to provide a durable bond to dentin. The extent of resin infiltration into the demineralized and exposed collagen determines the quality of resin and dentin bond. Loss of integrity of either the resin component or the dentin matrix within this resin dentin interface has been directly related to the loss of stability of the hybrid layer. Incomplete resin infiltration into the hybrid layer not only results in nanoleakage but also degradation of dentin matrix due to matrix metalloproteinases (MMP) activation.[18]

SDF can create an environment of fluoride hypersaturation leading to the formation of fluorapatite crystals in dentin, which are larger in size than hydroxyapatite crystals and, thus, have a closely packed structure with fewer voids and greater microhardness.[19] From this morphological perspective, we would expect a lower bond strength in the SDF-treated group because fluoride hypersaturation and an acid-resistant surface might decrease micromechanical bonding of composite on to the tooth. Therefore the current study was undertaken to evaluate the effect of silver diamine fluoride pretreatment on microleakage of resin composite to the dentin in primary molars.

Microleakage is related to several factors, such as dimensional changes of materials due to polymerisation shrinkage, thermal contraction, absorption of water, mechanical stress and dimensional changes in tooth structure. The polymerisation shrinkage of a composite resin can create contraction forces that may disrupt the bond to the cavity walls, leading to marginal failure and subsequent microleakage. Variation in enamel bonding sites might also influence the bonding ability of composite because of the anisotropic structure of the enamel. An effective bond to the primary enamel and dentin would reduce marginal microleakage, seal the interface to prevent bacterial penetration that leads to recurrent decay and postoperative sensitivity. However, the adhesive failure of composite restoration to deciduous teeth is still a common problem. The shape of the cavity can also challenge the adaptation of the restorative material to the margins. In our present study class V cavities (3 mm X 2 mm X 1.5 mm) was prepared because they have high C- factor and the cervical enamel/dentin/resin composite interface has been reported to be more vulnerable to microleakage than other sites.[20]

The dynamic environment simulating in vivo aging by subjecting bonded materials to cyclic exposures of hot and cold temperatures shows the relationship of coefficient of thermal expansion between the tooth and the restorative material. Thermal cycles ranging between 200 to 5000 are used in many in vitro studies. And hence, in our study 1000 thermal cycles between 5°C and 55°C were applied. Microleakage is usually evaluated by a dye penetration test and subsequent cutting of the specimens. It is widely accepted and preferred method because it is readily available, cheap and non-toxic. The most effective dye for revealing microleakage is 0.5% basic fuchsin. Therefore, in present study 0.5% basic fuchsin was used to assess the depth of dye penetration using stereomicroscopic images. Scoring of these images was done based on criteria given by Prabhakar et al.16 In the present study, 41.17% of samples of Group A and 47.05% of Group B had score 0 (no dye penetration). 35.29% of samples of both the groups had score 1 (dye penetration between the restoration and the tooth into enamel only) 17.64 % of samples of both the groups had score 2 (dye penetration between the restoration and tooth limited to enamel and dentin). 5.88 % of samples of Group A had score 3 (dye penetration between the restoration and the tooth extending into the pulp chamber), while none of the samples of Group B had score 3.

Group A had mean microleakage value of 0.81 while Group B had mean microleakage value of 0.63. Even though SDF group showed microleakage on a slightly higher side it is statistically insignificant. This was in accordance with the study done by Uzel et al on noncarious human mandibular third molar teeth.14 In a study done by Gupta et al, SDF-KI group showed the least microleakage when used as a cavity cleanser followed by RMGIC restoration.15Although the contribution of microleakage to restoration failure remains controversial, microleakage studies are still the most popular test method employed to obtain a preliminary idea about the quality of a new material or combination of materials.20 However, future studies need to investigate: the ultrastructure of dentin treated with SDF and the biological reaction of pulpal cells to SDF, including any cytotoxic effect.

CONCLUSION

It can be concluded that since Group A (SDF) and Group B (Control) showed statistically insignificant difference in the mean microleakage values and considering the possible mode of action of SDF for arresting caries, inhibition of demineralisation, promotion of remineralisation and protection of the collagen matrix from degradation, SDF pretreatment under the composite restoration can be considered as a treatment option in restoring primary teeth in pediatric dentistry.

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