ORIGINAL RESEARCH

Evaluation of Microtensile Bond Strength between SMART Technique and Conventional Glass Ionomer Cement-treated Carious Primary Dentin

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Abstract

Background: Silver diamine fluoride (SDF) solution has been used clinically to prevent and arrest dental caries. To evaluate the microtensile bond strength between silver-modified atraumatic restorative technique (SMART) and glass ionomer cement (GIC) applied to carious primary teeth and also the mode of restoration failure.

Materials and methods: A total of 40 carious primary molars were equally allocated into test and control groups after sectioning through the middle of the carious lesion. The test specimens were treated with one drop of 38% SDF and the control with deionized water. The samples were stored in artificial saliva for 14 days at 37° C and the dentin surfaces were conditioned and restored with Fuji IX GP Extra. After 24 hours storage in artificial saliva, the specimens were prepared for testing of microtensile bond strength. Paired *t*-test was used to compare the mean bond strengths. The mode of failure was assessed with a stereomicroscope under 40× magnification.

Results: The mean microtensile strength for the test group was 7.39 MPa [standard deviation (SD ± 2.3)] and 7.20 MPa (SD ± 1.98) for the control group ($p > 0.05$). The most common mode of failure was the mixed failure mode in both groups.

Conclusion: Silver diamine fluoride (SDF) does not adversely affect the bond strength between GIC applied to carious dentin.

Keywords: Carious primary dentin, Glass ionomer cement, Silver diamine fluoride.

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Introduction

Early childhood caries (ECC) is a significant public health issue. It is one of the most widespread childhood illnesses, affecting 60–90% of children globally. The prevalence of ECC ranges from 1 to 12% in the majority of developed and developing nations, and it can reach up to 70% in less developed nations. Boys are more affected than girls, between the ages of 8 months and 7 years, and the prevalence of ECC is highest in the 3–4-year-old age. In India, the incidence of ECC is about 51.9%.[1] It is more severe in communities with low socioeconomic status, where caries lesions are more frequently left untreated and have a greater negative effect on infants and young children's overall health and quality of life.[2]

The advent of minimal invasive dentistry (MID) resulted in a paradigm change in the management of dental caries, especially in young children. Under MID, techniques like silver diamine fluoride (SDF) and atraumatic restorative treatment (ART) are used to maximize dental structure preservation while minimizing the psychological toll on the patient. These methods are essential for enhancing children's oral health, especially in places where access to regular dental treatment is scarce.[3]

The primary impediment is the price of the glass ionomer Fuji IX, which is more expensive than other materials, especially for underprivileged communities. The very low retention rate in multisurface cavities and caries development in regions where restoration is compromised are two additional drawbacks of ART.[4]

Because sound dentin is left in place after SDF, it can be used with the ART, which uses hand devices to prepare cavities with or without local anesthesia. As part of the silver-modified atraumatic restorative technique (SMART), SDF can be applied right before applying traditional glass ionomer cement (GIC). The SMART technique preserves pulp vitality, promotes the remineralization of the carious lesion, and eliminates cariogenic bacteria by sealing the restoration.[5]

The quality of the dentin is one of the elements that might affect bond strength. Dentin has a low surface energy due to its heterogeneous makeup, which contains around 30% by volume of organic materials. However, because caries-affected dentin has gone through several cycles of demineralization and remineralization, it is less hard than normal dentin. This reduced hardness most likely results from intertubular dentin which naturally contains less mineral content.[6] The bonding to normal and caries-affected dentin, or dentin next to pulp horns, may vary owing to changes in substrate permeability and water content.

SDF is used to stop the progression of caries while also preventing the development of new carious lesions. This cost-efficient topical treatment has been proven to be successful due to

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the synergistic action of fluoride and silver helps in remineralization, antibacterial action, and increase in dentin permeability due to silver phosphate (Ag_3PO_4).[7]

SDF is increasingly being used in the management of caries, making it feasible to treat the dentin surface of cavities before the placement of the restoration. Therefore, the present study aimed to ascertain the impact of SDF on the microtensile bond strength between carious primary dentin and GIC as well as to determine the cause of restoration failure.

Materials and Methods

In collaboration with the Department of Biochemistry, Mamata Medical College and Hospital, Jyothi Spectro Analysis, and Department of Oral Pathology, Mamata Dental College and Hospital, Hyderabad, the current study was carried out at the Department of Pedodontics, Mamata Dental College and Hospital, Khammam, Telangana, India. Ethical clearance was obtained from the institution.

A solution of 0.9% sodium chloride (Lab chem sodium chloride, 0.9% w/v, Grainger industrial supply, United States of America) and 0.2% sodium azide (Spectrum sodium azide, Grainger industrial supply, United States of America) was used to preserve 40 extracted carious primary molars for up to 2 months at room temperature. The only primary teeth that were taken into consideration were those that still had at least two surfaces of tooth structure and dentinal caries that radiographically extended beyond the distance between the pulp chamber and the dentin enamel junction.

Each specimen was randomly divided into two groups after being sectioned through the center of the carious lesion using a slow-speed cutting device. The test group (Saforide Bee Brand Medico Dental Corp Ltd, Osaka, Japan) was treated with 38% SDF and the control group was treated with distilled water.

Using a microbrush, the carious dentin surfaces in the test group were treated for 3 minutes with a 38% SDF solution after being rinsed with water for 30 seconds. For 14 days at 37° C, all specimens were maintained in artificial saliva (Icpa Health Products Ltd., Ankaleshwar). The carious proximal surface of each specimen was reduced occlusal-gingivally with a diamond bur in a high-speed handpiece following storage and the flat surface was subsequently polished with 600-grit silicon carbide paper. In the test samples, just the darker dentin layer remained after they were reduced. With water cooling, the roots were sectioned using a high-speed diamond bur. The specimens were treated with cavity conditioner (GC America Alsip, Illinois, United States of America) for 10 seconds before being rinsed off. As directed by the manufacturer, GIC (Fuji IX GP Extra Capsule, GC America Inc., Alsip, Illinois, United States of America) powder and liquid were dispensed. By utilizing the specimen as a guide, a temporary mold was created by wrapping clear tape over it. After the glass ionomer solidified (which took 5 minutes), the samples were kept in artificial saliva at 37° C for 24 hours. The samples were then cut into slices of about 0.7 mm thickness using a slow-speed water-cooled diamond saw and these slices were trimmed and then formed into an hourglass shape with a 1 mm^2 cross-section using a diamond bur.

The hourglass-shaped test specimens were made so that only the blackened dentin/GIC interface was present in the center. Throughout the shaping and testing processes, the specimens had been kept wet. Each specimen was placed in a universal testing machine's testing jig (Fig. 1) and subjected to tension stress at a crosshead speed of 1 mm/minute until the bond failed. Four types of failure modes were identified after being evaluated with a stereomicroscope at a 40-times magnification (Fig. 2). Cohesive failure within the dentin; adhesive failure between the restorative material and the dentin surface; cohesive failure within the restorative material; and mixed failure, which combines the aforementioned three types of failure. Results were tabulated and subjected to statistical analysis.

Fig. 1: Universal testing machine

Fig. 2: Stereomicroscope

Results

The bond strength between the test and control group was compared using a paired *t*-test with a significance level of 0.05. Under 40× magnification, a stereomicroscope was used to evaluate the failure mode. The mean microtensile bond strength of the test and control groups are shown in Table 1 and Fig. 3. The control group's mean value was 7.20 MPa while the test group's mean value was 7.39 MPa. A comparison of the types of failures between the test and control groups is shown in Table 2 and Fig. 4. Both the test and control groups experienced mixed failure (test group—47.5%, control group—57.5%). Cohesive failure (47.5%) and adhesive failure (32.5%) were noted in the test group. Cohesive failure (22.5% in the control group) and adhesive failure (22.5%) and cohesive failure in GIC (20%) were observed.

Table 1: Mean comparison of bond strength (Mpa) between test group and control group

	Mean	*SD*	*Mean difference*	*t-value*	*p-value*
Test group	7.39	2.30	0.19	0.493	0.625 not significant
Control group	7.20	1.95			

NS, not significant; S, significant at the 0.05 level; statistical analysis, paired *t*-test

Table 2: Frequency of type of failures between the groups

	Test group (N = 40)		*Control group (N = 40)*		*Chi-squared test*	
Type of failure	*Frequency*	*Percent*	*Frequency*	*Percent*	*Chi-squared value*	*p-value*
AF	13	32.5	9	22.5	1.108	0.575 NS
CF	8	20.0	8	20.0		
MF	19	47.5	23	57.5		

AF, adhesive failure; CF, cohesive failure; MF, mixed failure; NS, not significant; S, significant at the 0.05 level; statistical analysis, paired *t*-test

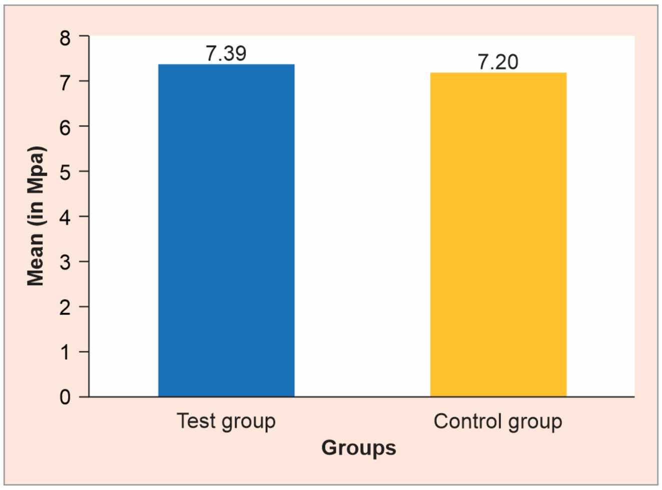

Fig. 3: Mean comparison of bond strength (Mpa) between test group and control group

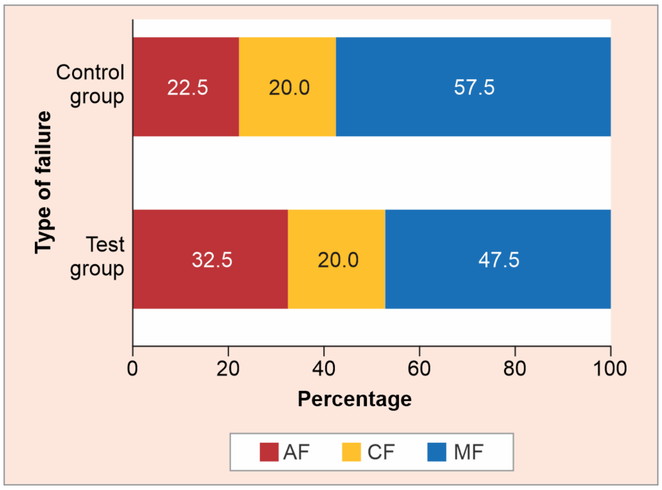

Fig. 4: Comparison of type of failures between test and control groups

Discussion

The traditional approach in managing caries is complete mechanical removal of infected, demineralized tooth structure before placing a restoration in its place which is a challenging task for clinicians not only in the case of uncooperative children but also in special healthcare children. With the current understanding of the caries process, sealing the carious lesion rather than excavating all dentinal caries is given higher priority. As a result, conservative caries excavation methods, like selective caries excavation to soft or hard dentin, have been developed.[8] Silver compounds have a long history of usage in both medicine and dentistry due to their antibacterial properties. Fluoride has been used in a variety of forms to prevent and arrest tooth decay. Yamaga et al. has proposed a mechanism for how fluoride ions and silver ions function on carious teeth. They hypothesized that silver ions mainly affect cariogenic bacteria and fluoride ions primarily affect tooth structure. In an alkaline environment, SDF combines with hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] to produce calcium fluoride (CaF_2) and Ag_3PO_4 as the main reaction products. Fluorapatite [$Ca_{10}(PO_4)_6F_2$], which is less soluble than hydroxyapatite in an acidic environment, is formed from CaF_2. The Ag_3PO_4 produces an impermeable coating over the tooth's surface that serves as a reservoir for phosphate ions to accelerate the transformation of hydroxyapatite to fluorapatite.[9]

The collagen matrix degrades as a result of matrix metalloproteinases (MMPs) and cysteine cathepsins. The MMPs are trapped in the dentinal matrix as latent zymogens (pro-MMPs). MMPs are crucial for the enzymatic degradation of extracellular matrix components. Additionally, cysteine cathepsins have been found in carious dentin. It has been demonstrated that these cathepsins either directly destroy type I collagen in the dentin or activate MMPs. Due to exposure to acidic environments, both of these enzymes may become active during the caries process or acid etching. At the adhesive-dentin interface, these proteases hydrolyze peptide bonds in the collagen molecules. They can reduce the bond strength and are responsible for bond disintegration at the resin-dentin interface.[10]

Therefore, it has been hypothesized that the combined actions of silver and fluorides will simultaneously hinder the progression of caries and prevent the development of new caries.[11]

The toxicity of 38% SDF remains an issue when used on very young children because of the high quantities of fluoride and silver. As a result, each kid receives one drop of 38% SDF (25 L), which contains around 1.12 mg of fluoride and 6.34 mg of silver. The quantity of fluoride and silver acquired following SDF application would be significantly below a lethal level based on the median lethal dosage of silver by oral administration indicated to be 380–520 mg/kg and the probable harmful dose of fluoride at 5 mg/kg, respectively.[12]

Prior to GIC restoration, SDF was used to make sure it wouldn't affect the bond strength at the dentin-GIC contact and not improve the bond strength of GIC. As a consequence, it seems possible to combine the arrest caries technique (ACT) *via* SDF with the ART utilizing a GIC. When assessing the impact of SDF treatment on the strength of the binding between a glass ionomer and dentin, several parameters must be taken into account; when SDF was applied, fluorapatite crystals developed that were more tightly packed and had fewer voids than hydroxyapatite.[13]

Studies have demonstrated that SDF does not reduce the bond strength, despite the fact that it enhances the microhardness of the dentin and may potentially result in a reduction in ion exchange from the acid-base interaction. It has been proposed that the generation of Ag_3PO_4 bonding to the carboxylic acid contained in the GIC may be the cause of the increased bond strength. It is also hypothesized that this increase in bond strength may be brought on by a dentin surface that has hardened, a decreased rate of collagen degradation, or protein. The micromechanical interlocking of the glass ionomer to dentin may be enhanced by the increased microhardness of the dentin. Additionally, the presence of silver and silver oxide on the surface of the dentin following application of SDF may improve the bond since glass ionomer also attaches to metal.[14]

The major goal of the current investigation was to assess the microtensile bond strength between GIC and carious primary dentin and SDF-treated carious primary dentin. SDF has a drawback that prevents patients with esthetic concerns from accepting it broadly. To lessen this adverse effect, certain substitutes have been recommended. One method to eliminate the staining effect is to use a saturated potassium iodide (KI) solution or ammonium hexafluorosilicic acid, which can react with leftover silver ions. Another possibility is to use GICs or composites over the SDF to camouflage up the discoloration or as a direct restoration following SDF treatment.[15]

The test group had a mean value of 7.39 MPa when tested for microtensile bond strength in the universal testing machine, while the control group had a mean value of 7.20 MPa. This result suggests that SDF had no adverse effects on the bond strength between GIC and carious primary dentin, which was inconsistent with studies by Quock et al., Zhao et al., Kim et al., and Ng et al., who found no noticeable difference in the bond strength between the SDF and control groups.[15–18] The current study's findings were in disagreement with those of Knight and McIntyre, Koizumi et al., Lutgen et al., and Kucukyilmaz et al., which might be attributed to the different preparation methods used for the test specimens.[19–22] In a study conducted by Knight and McIntyre, it was shown that the bond strength was not affected adversely when silver fluoride/KI was applied to etched dentin samples as long as the reaction products of SDF/KI on the dentin surface were rinsed away after the application. The bonding strength was profoundly reduced if the SDF/KI precipitates were left on the dentin surface.[10] Kucukyilmaz et al. discovered that in the cold agglutinin disease groups, the dentinal tubule occlusion and intense Ag ion agglomeration caused by SDF administration resulted in the lowest microtensile bond strength values.[22] When sound bovine dentin surfaces treated with SDF were tested for bond strength to two resinous luting agents, Soeno et al. speculated that the reaction products CaF_2, $AgNO_3$, Ag_3PO_4 which were found in SDF reacted with protein and hydroxyapatite effectively limited the monomers infiltration into dentin for the creation of a resin-infiltrated layer in bonding systems and subsequently decreased the bond strength value.[23]

Additionally, these findings were not in agreement with Mohan et al., Soliman et al., who suggested that the higher bond strength brought about by the use of SDF alone may be caused by the Ag_3PO_4 bonding to the carboxylic acid in the glass ionomer.[14,24] A harder dentin surface, less collagen deterioration, or fixing of the dentin proteins are all suggested as possible causes of this improved bond strength. The glass ionomer and dentin's micromechanical interlocking may be improved by increasing the microhardness of the dentin.

When the pretreatment aspect was taken into account, Ng et al., found that placing the GIC just after SDF dramatically reduces the GICs' 24-hour bond strength to demineralized dentin. A statistically insignificant improvement in bond strength was shown when GIC was put in 1 week after allowing SDF to be established. This may be because when GIC is immediately applied, SDFs' delayed response and penetration kinetics are still active.[18] In all groups (test group—47.5%; control group—57.5%), mixed failure was the most frequent type of failure observed throughout the study. Likewise, in the control group, there were 22.5% adhesive failures and 20% cohesive failures in GIC as compared to 32.5% adhesive failures and 47.5% cohesive failures in the test group. The microtensile bond strength did not differ significantly between the test and control groups.

The current investigation shows that SDF, which was employed to hinder the progression of caries, had no negative effects on the bond strength of GIC to carious primary dentin. The efficacy of this therapeutic association seen in this study needs to be tested in practical settings, on large-scale clinical intervention.

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