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EVALUATION OF MICRO-SHEAR BOND STRENGTH OF GLASS IONOMER CEMENT TO SILVER DIAMINE FLUORIDE TREATED ARTIFICIAL DENTINAL CARIES

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ABSTRACT

After selective caries excavation, silver diamine fluoride (SDF) can be used to stop the caries from progressing further. Aim: This in vitro study was directed to Evaluate Micro-shear Bond Strength of Glass Ionomer Cement to Silver Diamine Fluoride Treated Artificial Dentinal Caries. Material and method: In vitro study, carried out in Pedodontics and Oral Health Department, Faculty of Dentistry (Boys, Cairo), Al-Azhar University. A total of 36 teeth were used in this study for shear bond strength test were divided into four equal groups (n= 9). The collected data during the study were tabulated and statistically analyzed. Results: application of SDF resulted in insignificant increase in the micro-shear bond strength of RMGIC and GIC to the carious dentine. The cohesive failure of GIC and RMGIC alone or with SDF was the lower when compared to the adhesive and mixed types of bond failure. While, the adhesive bond failure mode was the higher among the investigated failure modes in the both groups. Conclusion: SDF did not adversely affect the bond strength between the GICs restoration and the carious dentine. SDF insignificantly increase the bond strength between the GICs restoration and the carious dentine. RMGIC has the higher micro-shear bond strength to carious dentine than the conventional GIC.

KEYWORDS: Dental caries, Silver Diamine Fluoride, Shear Bond Strength.

INTRODUCTION

Dental caries is a microbiologic infection that affects the hard enamel and dentin structures.[1] The treatment of this lesion is determined by the invasiveness of the lesion in the enamel and/or dentin, as well as the amount of tissue removed during the operation.[2] The standard treatment for a carious lesion involves total mechanical removal of the diseased, demineralized tooth structure and restoration placement.[3]

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The goal of minimally invasive dentistry is to prevent tooth decay or remove very little tooth structure as appropriate.[(4)] Instead of doing considerable cavity preparation while treating a carious lesion, a minimally invasive technique is indicated to maintain both sound tooth structure and tissues with remineralization potential.[(5)] The goal of treating dentinal caries is to remove the outermost part of infected caries and restore the interior damaged dentin based on this concept.[(6)]

SDF is a colourless alkaline solution containing the diamine-silver ion and the fluoride ion. The diamine-silver ion complex comprises of 2 ammonia molecules linked to a silver ion, increasing the stability and less oxidising than silver ion.[(7)] SDF can be a beneficial technique in the minimal-intervention management of dental caries, preventing and arresting cavities in both primary and permanent teeth.[(8)]

The development of silver phosphate deposit and calcium fluoride, out of which fluoride is accessible for remineralization, is credited with SDF's capacity to stop existing caries.[(9)]The outmost surface layer of the SDF arrested dentine caries lesion has a considerable rise in micro hardness, as well as an enhanced quantity of calcium and phosphorus.[(10)] Furthermore, it has a broad antibacterial range of activity against a variety of cariogenic pathogens.[(11)]

Tooth-colored restorations, such as glass ionomer cement (GIC), can hide the black stain left by SDF-treated caries lesions, enhance aesthetics, and increase parent pleasure with their child's teeth.[(12)] Since the dentine surface of cavities has been handled with SDF prior to the implantation of the restoration, it's crucial to look into its impact on the bond strength of GIC restorations. According to the principle of minimally invasive dentistry, caries-affected dentine should indeed be maintained in clinical treatment. As a result, in clinical settings, caries-affected dentine instead of normal dentine has been used as the bonding substrate.

Caries management

SDF can be utilised in combination with GIC in cavitated lesions to integrate the advantages of caries prevention and repair.[(13)] Selective caries removal is emphasised in modern caries therapy. However, few research have looked at the impact of SDF on carious lesion bond strength.

When other choices are unavailable, topically administered SDF is a cost-effective solution for arresting early child caries (ECC) and root caries lesion in elderly people.[(14,15)]

One of the difficulties to be considered is early childhood caries (ECC), in young children, is difficulties in child's behavioural, which may complicate or impede ECC treatment.However, if left untreated, the condition worsens, causing discomfort, a decrease in quality of life, and, in the worst-case scenario, death. Furthermore, underprivileged groups suffer throughout life with untreated illness due to access restrictions to dental treatment.[(16)]

The fluoride concentration in SDF is 44,800 ppm, the highest of any fluoride agent available in dentistry. SDF's ability to interrupt the carious process while also preventing the production of new lesions sets it apart from other caries-preventive drugs like stannous fluoride and sodium fluoride.[(17)]

SDF combines with hydroxyapatite crystals in the tooth, forming calcium fluoride and silver phosphate, which could cause the stopped lesion to harden.[(18)] It leads in the progressive synthesis of fluoro-hydroxyapatite under acidic circumstances, such as caries attack, which is more stable than hydroxyapatite alone. Because of the presence of fluoride, SDF raises mineral content and hence enhances the microhardness of the stopped carious lesion.[(19)]

Dentine's organic matrix is broken down by microbial collagenases, matrix metalloproteinases, and cysteine cathepsins, which break down type I collagen.[20] In an acidic environment, these enzymes can be triggered. The alkaline characteristic of SDF helps counteract this.[19]

SDF has been shown in several research to have no effect on the binding strength of various restorative materials to dentine. Other research, on the other hand, indicated that SDF has the ability to weaken the dentine connection.[21,22]

Finally, more study into SDF and binding strength is necessary. As a result, the purpose of this study was to see how SDF affected the micro-shear bond strength of carious primary molars in vitro.

Aim of the study

This in vitro study was directed to evaluate micro-shear bond strength of glass ionomer cement to silver diamine fluoride treated artificial dentinal caries.

MATERIALS AND METHODS

In vitro study, carried out in Pedodontics and Oral Health Department, Faculty of Dentistry (Boys, Cairo), Al-Azhar University.

Primary sound molars or carious lesions localized to the outer enamel were chosen, either extracted for orthodontic considerations or due to normal shedding. From the results of a previously published study of Uchil et al,.[23] The sample size was calculated using G-power program with partial η^2 0.07 and effect size 0.27 approximately and the power of the test was settled as 0.8. The sample size was nine in each group, with a total of 36 primary molars.

The teeth were kept in 10% formalin for at least 14 days and no more than a month after collection.[23]

The teeth were checked under a light microscope (Olympus polarized CX31 (America Inc). for fractures and structural problems, and those that had them were eliminated. The roots were removed two millimetres below the cemento-enamel junction. The pulp chambers were cleaned with large round bur in a slow-speed handpiece, and then the pulp content was excavated with large a spoon excavator.

The cleansed pulp chambers were packed and capped with resin composite to enhance the tooth's resistant form. To achieve a uniform at dentin surface perpendicular to the long axis of the teeth, the occlusal enamel was cut using a slow-speed diamond disc under water coolant. On a water-cooled lathe, the dentin surfaces were next abraded and smoothed with silicon carbide paper (600 grit), exposing a flat dentin surface and lowering the dentin thickness by 1 mm. A light microscope was used to check the exposed tooth surfaces to confirm that no enamel remained.

For grouping; teeth were randomly allocated into 4 equal groups, and the carious dentin was treated as follows:

Group I: Conventional GIC restoration alone (Medifil Glass ionomer filling cement. .Promedica Dental Material, Germany).

Group II: Silver diamine fluoride followed by GIC restoration.

Group III: Resin modified GIC restoration alone (Riva Light Cured Resin Reinforced Glass Ionomer, SDI Limited. Australia).

Group IV: Silver diamine fluoride (Advantage Arrest Silver Diamine Fluoride 38%, Elevate Oral Care USA), followed by resin modified GIC restoration.

Only the smooth dentin was exposed since the specimens were coated in nail polish (Figure 1).

Streptococcus mutans (ATCC 25175 Type strain (16S rRNA gene, Serotype c. carious dentin) were obtained from MIRCEN (Microbiological Resources Centre, Cairo, Egypt) was inoculated onto the exposed dentin to induce caries microbiologically. The specimens were autoclaved first, then transferred to a cariogenic solution aseptically.

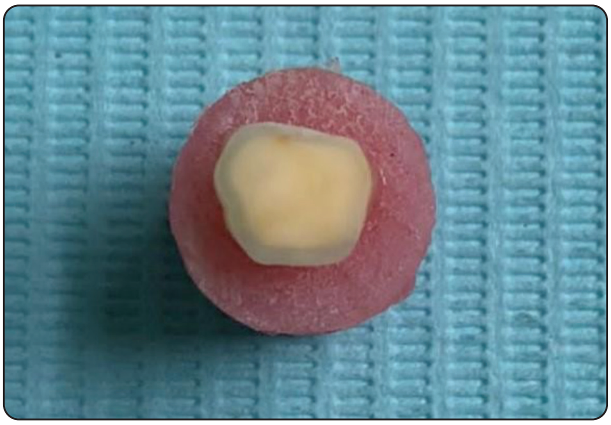

Fig. (1): Tooth sample preparation.

Fig. (2): Restored tooth.

For every 100 ml of distilled water with a pH of roughly 4.0, the cariogenic solution contained 3.7 g of brain–heart infusion (BHI) broth (Becton Dickinson and Company, Sparks, MD 21152, USA),, 2.0 g of sucrose, 1.0 g of glucose, and 0.5 g of yeast extract.

The solution was autoclaved at 121°C for 20 minutes before being inoculated with 2 percent S. mutans. The teeth were submerged in an acidic cariogenic solution and cultured for 6 weeks at 37°C in a CO2 incubator. The tooth specimens were moved to a container containing a fresh cariogenic solution to offer extra fresh substrate to the bacteria. every 48 h. [23]

The organism's viability was maintained by subculture into a new BHI broth every 24 hours. The end point of caries initiation was determined when caries induction was confirmed (viewing the dentin, change in dentin colour to yellowish brown, and softness felt with a blunt probe). Gauze was used to clear the biofilm on the teeth, and the samples were autoclaved.[4]

The dentine surface of each tooth sample along with the allocated groups (group II and group IV) was treated with 38% SDF solution using a micro-brush for three minutes. Then the surface was rinsed with water for 30-second.

A T-band metal matrix was placed to enclose the entire border of the tooth sample.

Then, the carious dentin surfaces were restored with different restorative protocol along with their group according to the manufacturer instructions figure (2).

For SDF/GIC (group II), the SDF was applied after the conditioning of GIC with 10% polyacrylic acid solution. For SDF/RMGIC (group IV), the SDF was applied after acid etching of carious dentine with 37% phosphoric acid. RMGIC was lightly cured with quartz tungsten halogen (QTH) lamb (COXO-DB-682, Deep Blue Technology Co., Limited, China) for 20 seconds according to manufacturer instructions.[23] then the restored specimens were stored in artificial saliva for 7 days at 37°c in incubator [1].

Artificial saliva preparation

In 1000mL distilled water, 0.400g natrium chloride, 0.400g potassium chloride, 0.795g calcium chloride monohydrate, 0.69g sodium dihydrogen phosphate, 0.005g sodium sulphide non-anhydrate, and 1.0g urea were mixed together to create fake saliva. PH was changed to seven. For 24 hours, the containers were incubated and kept at 37°C.[24]

Evaluation of micro-shear bond strength

A water cooled diamond saw was used to

Fig. (3) : Universal testing machine.

Fig. (4) : Stereo microscope.

segment each tooth specimen serially in the occlusogingival direction, resulting in 1–mm thick slabs. The resultant beams had a cross sectional area of 1.0 mm 8.0 mm, with restorative material in the top half and dentin in the lower half, and were referred to as beams. For each tooth specimen, at least two beams were created. Each specimen was placed in a universal testing machine's Figure(3) testing jig and strained in compression at 1 mm/min crosshead speed until bond failure was observed. The maximum stress at failure will be recorded and changed to megapascal (MPa) units.[23]

Evaluation of mode of failure

Stereo microscope (nikon, Tokyo, Japan) Figure (4) was used to determine the failure mode, the dentin side of the fractured specimens was scanned and the most distinctive areas were recorded at 40-times magnification to assess the failure mode.

Four groups of failure modes were identified:

a) Failure of the restorative material to adhere to the dentin surface.

b) Dentin cohesive failure;

c) Restorative material cohesive failure;

d) Mixed failure (a combination of adhesive failure between the dentin and cohesive failure in the restorative material).

Data Management and Analysis

The collected data during the study were tabulated and statistically analyzed using the one-way ANOVA test, using SPSS version 22. The Kolmogorov-Smirnov test was used to explore the normality of the data. Student t-tests between the two groups. One-way analysis of variance (ANOVA) test between groups. Chi-square test to compare the numerical values. The level of significance was at p-value < 0. Comparison among the groups was done using Post-Hock's test.

RESULTS

Micro-shear Bond strength in all tested groups:

An informative statistical analysis showing mean values and standard deviation (SD) of micro-shear bond strength test results measured in Mega Pascal (MPa) for GIC groups and RMGIC groups bonded to carious dentine.

The statistical analysis of micro-shear bond strength of GIC and RMGIC groups revealed that; there was ***statistically significant*** difference in micro- shear bond strength between RMGIC groups and GIC groups as indicated by **One-way ANOVA** test (f=3261.49, p<0.00001).

The results showed that the application of SDF resulted in an insignificant increase in the micro-shear bond strength of RMGIC and GIC to the carious dentine. Table (1)

Among the groups; Tukey's pair-wise post-hoc test showed ***statistically significant*** difference ($P< 0.05$) in-between the RMGIC and GIC tested groups. However, the GIC and SDF/GIC treated groupsgroups showed ***non-statistically significant*** differencesdifferences. Also, the RMGIC and SDF/RMGIC treated group showed ***non-statistically significant*** difference

Mode of failure in all groups:

The informative statistical analysis showing number (n) and percentage (%) of mode of bond failure test results for GIC alone, RMGIC alone, and SDF/GIC, and SDF/RMGIC bonded to carious dentine. Table (2) Figure (5)

The statistical analysis of the mode of bond failure of GIC and RMGIC groups alone or in combination with SDF revealed that; there was **no *statistically significant*** difference in mode of bond failure between the groups as indicated by Chi-square test (Chi=1.5556, p=0.95571).

TABLE (1): Comparison of micro-shear bond strength among all groups:

Variable	Mean ±SD	*f*-ratio	p-value
GIC (Group I)	0.37±5.86^{B}	3261.49	<0.00001*
SDF/GIC (Group II)	0.36±6.23^{B}		
RMGIC (Group III)	0.45±25.05^{A}		
SDF/RMGIC (Group IV)	0.65±25.33^{A}		

; The results statistically at *p*<0.05. ; different capital litters in the same column were indicted statistically significantly. ; ns= non-significant.

TABLE (2): Comparison of failure mode among all tested samples:

Variable	Mode of failure; n (%)			Total(n)	Chi- square	p-value
	Cohesive	Adhesive	Mixed			
GIC (Group I)	2 (11.11%)	10 (55.56%)	6 (33.33%)	18	1.5556	0.95571 ns
SDF/GIC (Group II)	2 (11.11%)	9 (50%)	7 (38.89%)	18		
RMGIC (Group III)	1 (5.56%)	9 (50%)	8 (44.44%)	18		
SDF/RMGIC (Group IV)	1 (5.56%)	8 (44.44%)	9 (50%)	18		

; The results statistically at p<0.05. ; ns= non-significant.

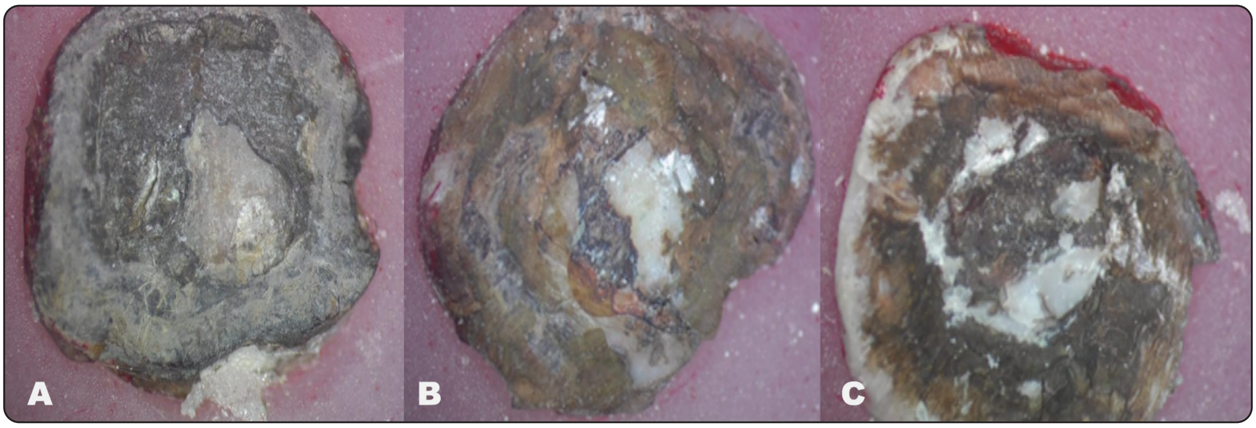

Fig. (3) (A) Stereomicroscope photograph showed adhesive mode of failure.(B) mixed mode of failure. (C) cohesive mode of failure.

DISCUSSION

The improvement of restorative materials and our understanding of the caries process has given us the capacity to perform with a minimally invasive dentistry (MID) concept in mind.[25] It necessitates conducting the procedure with as minimal tissue loss as feasible and without inflicting any damage to the good dental tissues nearby.[26]

It is a matter of controversy about the influence of SDF on bond strength in traumaticatraumatic restorative therapies, in particular (ART). Despite laboratory experiments.[27] SDF treatment is compatible with GIC and RMGIC restorations, however there is inadequate data about the adhesion qualities of GIC and RMGIC restorations when attached to caries-affected dentine surfaces that have previously been treated with SDF.

Therefore, the present in vitro study was conducted to evaluate the effect of SDF ability to arrest the existent caries and to evaluate its effect on the bond strength between the carious dentine and two restorative material (GIC and RMGIC).

There are different commercially available concentrations of SDF used in dentistry 12%, 30% and 38%.[25] The concentration of 38% was chosen for the present study according to Fung et al.[28] who concluded that 38% SDF was statistically significant in caries prevention and arrest in primary teeth in comparison to 12% SDF.

Also, Koizumi et al.[29] found that dentin pretreatment with a combination of SDF-KI adversely affected adhesion of resin-based adhesives and RMGIC to dentin. Therefore, in this study SDF alone was chosen as a tested material under RMGIC and GIC restorative materials.

Furthermore, formalin was utilised as a storage medium for dental specimens in this investigation since it has no effect on the bond strength of materials when held for up to one month.[23]As a result, in clinical settings, caries-affected dentine other than healthy dentine is frequently used as the bonding substrate. Thus, in the present study, the caries affected dentine was selected as test samples.

In this study, caries induction was conducted by bacteria biofilm to simulate the normal caries process that occurs in the oral cavity and to get caries affected dentine that simulates the color and texture of natural carious lesion.[23]

The micro-shear bond test method was employed in this investigation because it is the most generally known and accurate test method for assessing binding strength to dentin. This test method uses numerous specimens from a single tooth; it permits testing of tiny regions, which eliminates the fluctuation in bond strength observed in larger cross-sectional areas; and it more accurately depicts adhesive failure.[30]

In this work, the micro-shear bond strength of GIC and RMGIC was also investigated after SDF application. Because SDF will be applied to carious dentin, it is necessary to investigate its impact on material bond strength following microbiological caries induction.[23]

In the current study, prior to the application of the SDF solution, the carious dentine was condition and/ or acid etched, since application of SDF following acid etching could increase fluoride absorption in the demineralized dentin while having no effect on strontium ion uptake, with is no disruption in bonding and also improves remineralization.[23]

Pretreatment of sound primary dentin with SDF increased the micro shear bond strength across both restorations (GIC and RMGIC) and the carious dentin insignificantly, according to the findings of this investigation. This might be because SDF releases fluoride ions, which deposit in the carious dentine and create fluorohydroxyapatite, and also aids in the precipitation of silver phosphate to restore mineral content, resulting in increased micro hardness of the carious dentin surfaces and hence increased bond strength.[31]

However, this results in disagreement with other investigators who concluded that the prepared dentin surface for the bond test was blackened after applying SDF which may occur by the precipitation of silver granules, resulting in the coagulation of exposed denatured collagen fibrils. This precipitation could result in lower bond strength of restorative material for SDF-modified dentin.[32]

The results of the present study show that SDF has no adverse effect on the bond strength between GIC and primary carious dentin. This finding agrees with results from a previous study revealed that SDF and potassium iodide did not deteriorate the bond strength of auto-cure GIC to non-carious permanent dentin.[33]

Our finding suggest that SDF can be used as a dentin pretreatment prior to GIC's restoration potentially contributing to secondary caries prevention in primary teeth.

The insignificant increase in bond strength between the carious dentine pretreated with SDF and GIC when compared to GIC alone in the present study may be attributed to the fact that GIC adheres chemically to tooth structure. The ionic bond to GIC might be improved by the precipitation of silver grains and silver ions produced by SDF pretreatment.[34]

This result in agreement with the results of Nasr and Saber [35], which showed that the adhesion of glass ionomer cement (GIC) restorations to tooth structure is not jeopardized by SDF pretreatment of primary dentin, on the contrary it may improve it. This is because glass ionomer adherence to teeth is thought to be the result of a chemical engagement with tooth structure via ion exchange. Its micromechanical entry into the tooth structure has been improved.[36] In a prior study, the binding strength of GIC to non-carious primary dentin was greater than in the current study.[37] This is to be anticipated, given that GIC's binding strength to caries-affected primary dentin is lower than that of non-carious dentin.

Also, the results of the present study showed that application of SDF has no adverse effect on the bond strength between RMGIC and primary carious dentin. This might be due to the fact that RMGIC adheres to the dentin by chemical and micromechanical means, similar to resin adhesives.[38] Silver absorption by dentinal tubules following SDF application can obstruct the flow of dentinal fluid, allowing the resin ingredient of the RMGIC to be micromechanically bonded.[4] Despite the fact that acid etching causes the collagen fibres in dentin to collapse, it has no effect on the tensile binding strength of GIC to dentin.[39] When SDF was applied following acid etching, the bond strength rose even more, comparable to the findings of a previous investigation.[27] This is owing to SDF's ability to penetrate the dentinal tubules and collagen fibril network, increasing the mineral concentration of the dentin.[23]

SDF reacts with calcium hydroxyapatite to produce silver phosphate and calcium fluoride (CaF_2).[24] Silver phosphate may combine with RMGIC's carboxylic group, forming a stronger binding with primary dentin.[31]

Furthermore, fixing the organic content causes the organic material inside dentinal tubules to constrict, enhancing interlocking and perhaps contributing to the enhanced bond strength.[23]

Furthermore, light curing the RMGIC for 20 seconds may boost the shear bond strength between both the SDF-pretreated primary dentin and the RMGIC.[17] Demineralized dentin treated with SDF and subsequently light cured exhibited stronger bond strength than demineralized dentin handled with SDF but not light cured or not treated at all, according to research.[23]

Also, when SDF was light cured, the dentin surface darkened more, indicating that more metallic silver precipitated, strengthening the ionic contact between GIC and dentin.[8] This might also explain why RMGIC has a significantly stronger bond strength than GIC.

In the test and control groups, adhesive and mixed types of failure were more common than cohesive types of failure, and the difference between the two was substantial. The observed mode of failure suggests that the retentive strength between SDF pretreatment primary carious dentin and GIC or RMGIC was comparable to that of the control group, indicating that the values obtained in this investigation are typical of adhesive bond strength. The strength of the interfacial connections, as well as variations in elastic moduli and energy loss per unit crack extension, determine the distinction between the two materials.(23) For GIC/dentin bonds, both elastic moduli and energy loss per unit crack length are in the same manner. RMGIC, on the other hand, exhibited stronger bond strengths. This means that the interface bond strength is greater than the binding strength of the dentin and RMGIC.(38) This might explain why RMGIC has a significantly stronger bond strength than GIC.

CONCLUSIONS

Within the limitations of this in vitro study the following conclusions can be drawn:

SDF did not adversely affect the b ond strength between the GICs restoration and the carious dentine. SDF insignificantly increase the bond strength between the GICs restoration and the carious dentine. RMGIC has the higher micro-shear bond strength to carious dentine than the conventional GIC.

Therapeutic studies are required to evaluate if the bond's effectiveness in this investigation is sustained in the clinical situation.

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