EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 69, 761:771, January, 2023
Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 27-09-2022 • Accept Date : 15-11-2022 • Available online: 1-1-2023 • DOI : 10.21608/edj.2022.162574.2261

SILVER DIAMINE FLUORIDE EFFECT ON SHEAR BOND STRENGTH OF RESIN MODIFIED GLASS IONOMER CEMENT TO DEMINERALIZED DENTINE

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ABSTRACT

Objective: to evaluate SDF effect on shear bond strength of light cured RMGIC to sound dentine and demineralized dentine.

Materials and Methods: The 40 samples were divided into two main groups (20 teeth for each) according to SDF treatment, Each main group was subdivided into two subgroups according to artificial demineralization. The occlusal enamel was removed using wheel diamond stone under coolant. Samples were wet ground against 600,800,1200 grit SC paper to obtain smooth occlusal surface then molded into self-cured acrylic resin. Half of the samples were immersed into demineralizing solution to obtain dentine surface demineralization, then divided into 4 groups (n = 10), Group 1: Sound Dentine without SDF, Group 2: Sound Dentine with SDF, Group 3: Demineralized Dentine without SDF, Group 4: Demineralized Dentine with SDF. Macroshear bond strength was measured using Universal testing machine.

Results: Results revealed that Demineralized dentine had a significantly higher macroshear bond strength value than sound dentine. Results of first two groups showed that the highest value was found in Group 2 (SDF), followed by Group 1 (no surface treatment) and there was no significant difference between Group 1 and 2 (p=0.106). Results of second two groups showed that the highest value was found Group 4 (SDF), followed by Group 3 (no surface treatment) and there was no significant difference between Group 3 and 4 (p>0.05).

Conclusion: Treatment of sound and demineralized dentine surfaces by SDF don't affect bonding to light cured resin modified glass ionomer cement.

KEYWORDS: SDF, Demineralized Dentine, Silver Diamine Fluoride, Macroshear Bond Strength, Caries Affected Dentine.

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INTRODUCTION

Dental caries is a localized, destructing dental hard tissues, pathological system with variable factors and proceeding to making of cavities, continues to be a prevalent disease all around the world.[1] The progression of materials of restoration and development in our understanding of the process of caries have created the capability to exercise in consideration of a philosophy of minimally invasive dentistry.[2] It requires treatment of cautious disease with as small tissue loss as possible and without making any harmful defects to the adjoining healthy tooth structures.[3]

In the latest years, silver diamine fluoride (SDF or, Ag[NH3]2F) has received popularity because of its financial advantages and using easily for kids or the elderly in communities or places with challenging get entry to dental treatment. It is commercially reachable within a range of concentrations (10 % to 38 %) in solution form and the 38 % concentration of SDF has been proven in an in-vitro reports to be effective in stopping caries clinically and in inhibiting enzymes of bacteria.[4] SDF is a simple, painless, non-invasive and inexpensive approach, shifting dentistry towards greater regular non-surgical management to arrest dental caries. There are many practicable advantages of silver diamine fluoride (SDF) that ought to include decrease rates of surgical care, tooth loss, and enlarge tooth-restoration cycle.[5] SDF [Ag (NH3)2F] is a colourless alkaline solution containing 25% silver, 5% fluoride, 8% amine and 62% water (AgNH2 F) and is the most concentrated fluoride product (44,800ppm) commercially reachable for caries management[6] and has confirmed to be effective in management of dental caries [7] which includes pediatric, geriatric, specific health care needs, and these with constrained get entry to to oral health care can all advantage from silver diamine fluoride[8,9]. However, the major drawback of using SDF is making carious teeth discolored, which effects in patient dissatisfaction and kids with black anterior teeth can also acquire some social isolation.[10]

Although laboratory research confirmed that utility of SDF is well matched with restorations of glass ionomer cements, there is inadequate proof regarding the adhesive mechanism of resin modified glass ionomer cement (RMGIC) restorations when they are adhered to caries-affected dentine before SDF treatment.[11,12] Therefore, the purpose of this in-vitro study was to investigate SDF impact on shear bond strength of light cured RMGICs to demineralized dentine.

MATERIALS AND METHODS

1. Selection of Teeth

A whole number of 40 natural human molars were accumulated from the department of Oral and Maxillo-facial surgery, faculty of dentistry, ASU, beneath the roles of the Ethical Committee of Faculty of dentistry, ASU. The collected molars should be totally sound and free from de-mineralization. They were positioned in 6% sodium hypochlorite solution for 24 hours to make sure that all soft tissues, staining and plaque were removed.

Teeth had been cleaned from tissue remnants and particles the usage of periodontal curette then polished with slurry of pumice and water. Teeth had been examined by using the blue light of a light curing unit to make sure they were sound without any seen hypoplastic defects, white spots (demineralized enamel), or cracks. They had been saved in refrigerated saline solution for maximum three months as recommended through the ISO norms (ISO. Guidance on testing of adhesion to tooth structure. International Organization for Standardization, 1994).[13]

TABLE (1) Materials, Composition, Manufacturer and Lot Number.

Material (Lot number)	Composition	Manufacturer
Solution of Demineralization	2.2 mM CaCl, 2.2 mM NaH2PO4, 0.05 mM Acetic Acid pH 4.4	Manufactured in pharmaceutical laboratory, Faculty of Pharmacy Ain shams University
Cavity conditioner	Polyacrylic acid (20%), water, aluminum chloride hydrate.	(GC Corporation, Tokyo, Japan)
Silver Diamine Fluoride (SDF)	(AgNH2F) solution contains 25% silver 62% water, 5% fluoride, 8% amine PH = 10	(Advantage Arrest™ , Elevate Oral Care, West Palm Beach, Fl, USA).
Light cured Resin modified glass ionomer cement	Powder: 100% fluoro-alumino-silicate Liquid: 35% HEMA, 25% distilled water, 24% polyacrylic acid, 6% tartaric acid and 0.10% camphorquinone.[15]	(Fuji II LC, GC Corporation, Tokyo, Japan).

2. Study Design

2.a. Grouping of Teeth

A whole number of 40 extracted molars were used in this study. The specimens were divided into 4 groups (n=10) in accordance to two levels of the study: Level 1: substrate, 2 groups (Sound dentine and Demineralized dentine), level 2: Surface treatment of dentine, 2 groups (No Surface treatment and silver diamine fluoride (SDF) application).

TABLE (2) Variables of the study.

Substrate (A)	**(a1)**	Sound dentine
	(a2)	Demineralized dentine
Surface treatment of dentin (B)	**(b0)**	No Surface treatment
	(b1)	Silver diamine fluoride (SDF)

TABLE (3) Interaction between variables.

		a	
B		**a1**	**a2**
	b0	a1b0 **(group 1)**	a2b0**(group 3)**
	b1	a1b1**(group 2)**	a2b1**(group 4)**
n = 10			

2.b. Specimen Preparation

Occlusal enamel was ground flat using high speed wheel diamond bur under running water, then wet-polished sequentially with 600, 800, and 1200 grit silicon carbide (Sic) paper for fifty repetitions in a figure eight pattern to expose a flat dentin surface. Using digital ultrasonic cleaner (CODYSON Ultrasonic cleaner CD-4860, Shenzhen Codyson co., Ltd., China) (5 minutes/40Oc) to remove any debris.[16]

Crowns of the collected teeth had been separated from the roots at cementoenamel junction. Using customized made cylindrical molds (20mm diameter and 22 mm high), separating medium for internal surface and then, were filled with chemically polymerizing acrylic resin until it became flushed with the higher rim of the mold. Each crown used to be embedded vertically in the acrylic resin making the occlusal surface facing upwards and flushed with the higher rim of the mold then left to eventually set.[17]

A layer of nail varnish (Revlon, New York City, NY, USA) was utilized on the non-coronal dentine surfaces of all the samples to shield from demineralization.[18] Then unvarnished occlusal surface would be ready for intervention.

2.c. Creation of Artificial Partial Demineralization:

Creation of Artificial Partial Demineralization: Half of the specimens (n=20) were immersed in an acidic buffer solution of ph 4.4 (2.2 mM CaCl, 2.2mM NaH2PO4, 0.05mM Acetic Acid)[18], each in a separate container at room temperature to create artificial partial demineralization of dentin for 72 hours to produce lesion depth range between 482µm±57µm.

The demineralization depth was measured at Oral Pathology Department, faculty of dentistry, ASU with polarized light microscope with magnification power X10 (oil immersion) using a digital camera (EOS 650D, canon, Japan) which was fixed on a light microscope (BX60, Olympus, Japan). Demineralization depth was around 482± 57 um[19].

2.d. Surface treatments

All specimens were conditioned the dentin surfaces with cavity conditioner (GC, Tokyo, Japan) using a micro brush for 10 seconds, then were rinsed by distilled water for 20 seconds, and dried by cotton pellets.[20]

They were divided into 2 subgroups (n = 10) in accordance to the treatment of surfaces, for first subgroup (b0), the control group, no surface treatment, the demineralized and sound dentine surfaces were conditioned and RMGIC was bonded.[21].

For second subgroup (b1), the demineralized and sound surfaces were treated with a 38% SDF solution (Advantage Arrest™ , Elevate Oral Care, West Palm Beach, Fl, USA) according to the instructions of manufacturer, 1–2 drops of solution were placed into a mixing well and applied directly to the tooth surface with a micro brush for 10 seconds. SDF was allowed to absorb for 1 min, then excess SDF was removed with a cotton[22] and specimens were rinsed with water for 30 seconds and air-dried for 5 seconds prior to bonding[23,21].

2.e. Resin modified glass ionomer cement disc preparation

A plastic cylindrical shaped mold using pediatric catheter tube (3-mm height and 3-mm diameter) was placed on the dentine surfaces. GICs capsules were mixed using a rotational/centrifugal capsule mixing unit (Roto Mix, 3M ESPE, St Paul, MN, USA) for 10 seconds, and then the mixture was injected in the plastic mold to form a cylindrical button and light cured for 20 seconds to ensure a perfect setting by using a light emitting diode (LED) polymerizing unit (3M ESPE Elipar™ DeepCure-L curing light device) at a light intensity of 1200mW/cm2.[24]

After bonding, the plastic mold surrounding the glass ionomer cylindrical buttons were removed using blade No. 15 (Sterilance Medical Suzhou Inc.). The RMGIC specimens were coated with a protective varnish (Equia coat, GC, Tokyo, Japan). Samples were stored in artificial saliva 24 hours in an incubator at 37ºC after removal from the mold to allow complete setting of GICs.[17]

3. Macro-shear bond strength Testing

The SBS test was performed with a universal testing machine that had a flat edge loading head. The acrylic block with the specimen was attached to the lower fixed head of the universal testing machine (Instron, model 3345, England). A shear force was applied perpendicularly to the GIC cylindrical button placed as close as possible to the GIC/dentine interface to the loading head. The loading head moved at crosshead speed of 1.0mm/min up to specimen failure. The force required for failure (Newton) was divided by the surface area (mm2) to calculate the shear bond strength in mega-Pascals (MPa) by machine software (BlueHill 3 Instron England)[24].

4. Statistical Analysis

Numerical statistics had been explored for normality through checking the data distribution the usage of Shapiro-Wilk test. Data confirmed parametric distribution so; they had been represented via mean and standard deviation (SD) values. Two-way ANOVA followed via Tukey's post hoc test was once used to study the impact of different tested variables and their interaction. Comparison of main and simple effects had been carried out using pooled error term of the ANOVA model with Bonferroni correction. The significance level used to be set at p ≤0.05 within all tests. Statistical analysis was carried out with R statistical analysis software version 4.1.2 for Windows.

RESULTS

1. Effect of different variables and their interaction

Effect of different variables and their interaction on macro-shear bond strength (MPa) were presented in table (4)

Type of dentine and surface treatment used both had a significant effect on macro-shear bond strength (p<0.001), while the effect of their interaction was not statistically significant (p=0.399).

TABLE (4) Effect of different variables and their interactions on macro-shear bond strength (MPa)

Source	Sum of Squares	df	Mean Square	f-value	p-value
Dentine	137.5	1	137.5	27.86	**<0.001***
Surface treatment	96.12	2	48.06	9.74	**<0.001***
Dentine* Treatment	9.23	2	4.61	0.94	**0.399ns**

df =degree of freedom*; significant (p ≤ 0.05) ns; non-significant (p>0.05).

A. Effect of dentine

Mean and standard deviation (SD) values of macro-shear bond strength (MPa) for different dentine types were presented in table (5) and figure (1)

Demineralized dentin (7.74±2.98) had a significantly higher value than sound dentin (4.71±2.03) (p<0.001).

TABLE (5) Mean ± standard deviation (SD) of macro-shear bond strength (MPa) for different dentine types

Macro-shear bond strength (MPa) (mean±SD)		P-value
Sound dentine	**Demineralized dentine**	
4.71±2.03	7.74±2.98	**<0.001***

; significant (p ≤ 0.05) ns; non-significant (p>0.05)

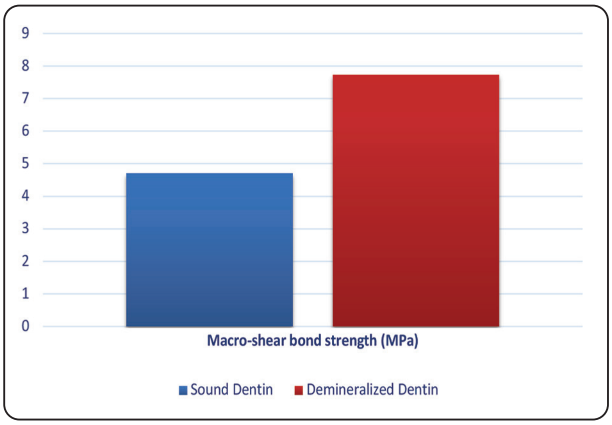

Fig. (1) Bar chart showing average macro-shear bond strength (MPa) for different dentine types.

B. Effect of surface treatment

Mean and standard deviation (SD) values of macro-shear bond strength (MPa) for different surface treatments were presented in table (6) and figure (2)

There was no significant difference between different treatments (p=0.106). The highest value was found in SDF (5.26±2.42), followed by no surface treatment (5.11±2.53).

TABLE (6) Mean ± standard deviation (SD) of macro-shear bond strength (MPa) for different surface treatments

Macro-shear bond strength (MPa) (mean±SD)		P-value
No surface treatment	SDF	
5.11±2.53[B]	5.26±2.42[B]	**p=0.106**

Means with different superscript letters are statistically significantly different *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

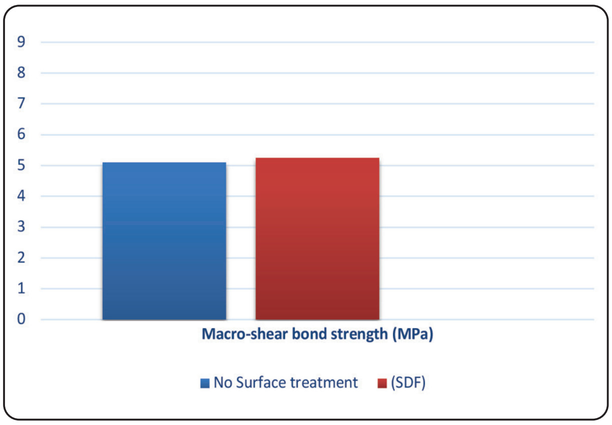

Fig. (2) Bar chart showing average macro-shear bond strength (MPa) for different surface treatments

TABLE (7) Mean ± standard deviation (SD) of macro-shear bond strength (MPa) for different dentine types and surface treatments

Surface treatment	Macro-shear bond strength (MPa) (mean±SD)		p-value
	Sound dentine	Demineralized dentine	
No surface treatment	3.97±2.09	6.39±2.45	**0.021***
SDF	4.27±1.55	6.47±2.81	**0.032***

Means with different superscript letters are statistically significantly different within the same horizontal row *; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)

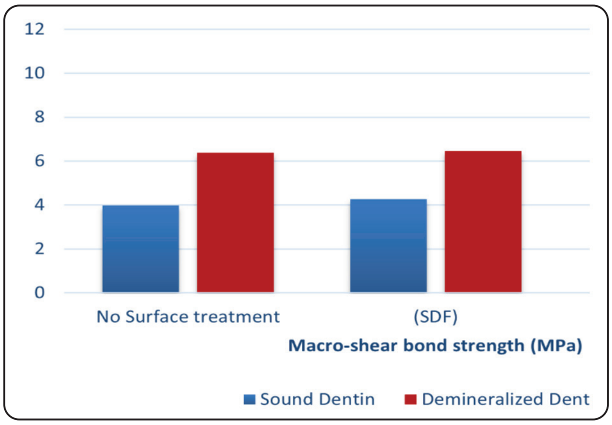

Fig. (3) Bar chart showing average macro-shear bond strength (MPa) for different dentine types and surface treatments (A)

2. Interactions

A. Effect of dentine with each surface treatment

Mean and standard deviation (SD) values of macro-shear bond strength (MPa) for different dentine types and surface treatments were presented in table (7) and figures (3).

- ***No surface treatment***

Demineralized dentine (6.39±2.45) had a significantly higher value than sound dentine (3.97±2.09) (p=0.021).

- ***SDF***

Demineralized dentine (6.47±2.81) had a significantly higher value than sound dentine (4.27±1.55) (p=0.032).

B. Effect of surface treatment within each dentine type

Mean and standard deviation (SD) values of macro-shear bond strength (MPa) for different dentine types and surface treatments were presented in table (8) and figures (4).

- ***Sound dentine***

There was no significant difference between different groups (p=0.106). The highest value was found in SDF (4.27±1.55), followed by no surface treatment (3.97±2.09).

- ***Demineralized dentine***

There was no significant difference between different groups (p>0.05). The highest value was found in SDF (6.47±2.81), followed by no surface treatment (6.39±2.45).

TABLE (8) Mean ± standard deviation (SD) of macro-shear bond strength (MPa) for different dentine types and surface treatments

Surface treatment	Macro-shear bond strength (MPa) (mean±SD)		p-value
	No surface treatment	SDF	
Sound dentine	3.97±2.09^{A}	4.27±1.55^{A}	**0.106ns**
Demineralized dentine	6.39±2.45^{B}	6.47±2.81^{B}	**>0.05ns**

Means with different superscript letters are statistically significantly different within the same horizontal row *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

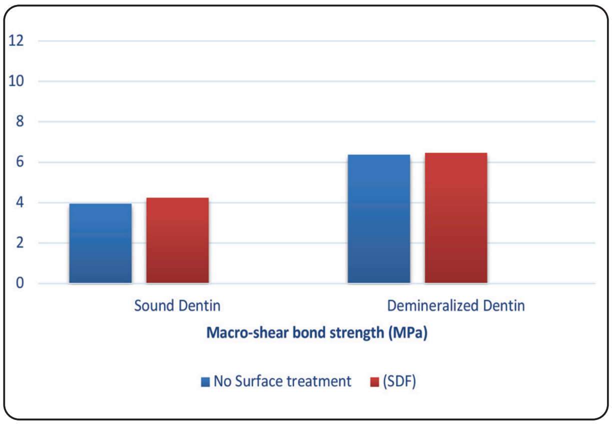

Fig. (4) Bar chart showing average macro-shear bond strength (MPa) for different dentine types and surface treatments (B)

DISCUSSION

Silver diamine fluoride has been identified as a bactericidal chemical that can minimize growing of bacteria causing caries and its adherence.[10] Moreover, it can be used to give up the recurrent caries surrounding GIC restorations.[25] Thus, silver diamine fluoride can be a promising biological way in the exercise of minimally invasive dentistry in opposition to traditional restorative methods. The use of silver diamine fluoride, however, has been commonly restricted to deciduous teeth due to the fact of the discoloration impact related with its application. SDF can be used as a liner as a dentine base beneath the restoration does not include viable bacteria.[11] This study was conducted to examine if pretreating sound and demineralized dentin with silver diamine fluoride (SDF) adversely affects the bond strength of light cured RMGIC to dentine or not.

A conditioner (20% polyacrylic acid) was used before the application of glass ionomer in the current study, the pervious studies has found that the addition of conditioner, removes the smear layer and has minimal etchant effect.[26] The usual step of conditioning dentine surfaces before bonding is the application of a polyacrylic acid solution.[27] Tay et al, 2001, have proven there isn't considerable difference in bond strengths between dentine that has been etched for maximum fifteen seconds or conditioned.[28]

In this study, silver diamine fluoride (SDF) products that are simply commercially accessible had been chosen to make the current work extra applicable for dentists. Although 30% and 12% concentrations of SDF are reachable in the commercial market and the most produced SDF products are at a concentration of 38%.[29] 12% SDF is no longer as effective as 38% SDF is in stopping caries amongst kids.[30] SDF in the form of a 38% solution proven an inhibitory impact on the activities of each MMPs and cathepsins. The use of 38% silver diamine fluoride (SDF) decreased demineralization and protected collagen from destruction in demineralized dentine.[31,32]

Type of glass ionomer cement was used in current study, was light cured RMGIC as they are considered as one of the excellent choices for restorative materials which are a fluoride-releasing, which have been regarded to be most efficient to compomers and giomers from the aspects of non-stop fluoride launch and recharge.[34] Hence, treatment of dentine surfaces with SDF before GIC restoration has been proposed via some researchers to improve antibacterial and remineralizing capability of GICs.[25,11] These "hybrid" materials have been improved to mix the anti-carious doable of glass ionomer cements with the mechanical properties of a resin composite. Indeed, it has been discovered that the RMGIC no longer solely release fluoride but they additionally have flexural strength greatest to those of traditional glass ionomer cements, as well as decrease solubility.[35]

The test of macro shear bond strength was used in this study. To obtain testing procedures more simple, shear bond strength testing is considered as the most used method for evaluation of bond strength, and the measured SBS results with various conditions are showed in the literature.[36]

The results of the current study revealed that Demineralized dentine (7.74±2.98) MPa had a significantly higher macro shear bond strength value than sound dentine (4.71±2.03) MPa. table (5) and figure (1). This result was supported by S. Holmstrom et al, (1988)[37], who confirmed that glass ionomer cement bonds to dentine due to a mechanical and chemical bonding that demineralization of dentin exposes microporous collagen which improves micromechanical interlocking and consequently makes infiltrations via hybridization. In addition, the chemical bonding between polyacrylic acid (from GIC) and calcium ions (from GIC or hydroxyapatite) formed generally the ionomer, calcium polycarboxylate, that is capable to create a relatively steady and chemical chelation.[37] Furthermore, hydrogen bonds between a number of free radicals in collagen fibers and carboxyl radicals in the glass ionomer cement would make a contribution to the bond strength.[37,38]

Regarding the impact of each treatment of surface on macro SBS of Glass ionomer cements to sound dentine, our results revealed that there wasn't significant difference between different groups (p=0.106) in table (8) and figures (4) with the highest value in group 2 (a1b1) (sound dentine treated with SDF) (4.27±1.55), followed by group 1 (a1b0) (sound dentine without surface treatment) (3.97±2.09). This was in agreement with A.S. Wang et al, 2016,[4] who mentioned that in both the fractured surface of GIC adhesive layer and the dentine surface there were an observed silver elements in accordance to EDX analysis and SEM images. These silver- or fluoride-containing elements have been observed to make the demineralized dentine harder[39], which efficiently improves the interfacial hardness and roughness at the GIC-dentine interface. Therefore, the resin or cement infiltration would possibly no longer be essential in SDF utility on sound dentine. Also, this may be due to the methodology used, in which after the decays have been treated with 38% SDF solution for the instructed period of time (for one minute), the SDF was washed for 30 seconds with distilled water to clean it off the dentin surface.

Regarding the effect of each treatment of surface on macro SBS of glass ionomer cement to demineralized dentine, our result showed that there wasn't significant difference between group 4 (a2b1) (demineralized dentine treated with SDF) (6.47±2.81) MPa and group 3 (a2b0) (demineralized dentine without surface treatment)6.39±2.45) MPa in table (8) and figures (4). Our results of this study verified that SDF pretreatment didn't adversely have an effect on bonding of the restoration to dentine, various factors ought to be considered:

SDF causes fluorapatite crystals formation in the dentine which are increased nearly condensed with little voids in contrast to hydroxyapatite, also improves the dentine microhardness.[48] While this is accompanied via a viable discount in change of ions from the acid base reaction, have to theoretically reduce the bond strength of GIC, studies have confirmed that SDF doesn't reduce the bond strength.[41] It has been postulated that improved bond strength produced after the use of SDF solely have to be due to silver phosphate bonding formation to the carboxylic acid in the glass ionomer.[23,49] Also it can also be due to increase hardness of dentine surface, collagen degradation decreased, or dentine proteins fixation.[23]

Elevation of the dentine hardness can also improve the interlocking micromechanically of GIC to dentine. Additionally, after utility of SDF, each silver and silver oxide are presenting on the dentine surface. This may additionally enhance the bond strength as the glass ionomer adheres to metal as well.[4] Enhancement chemical bonding of GIC should additionally be attributed to be dentine surface harder as an end result of SDF.[50] Formation of hydroxylapatite and fluoroapatite on uncovered organic matrix can additionally make contributions to elevated bond strength.[51]

Decreasing the loss of calcium and phosphorous from the carious decayes had been confirmed due to the insoluble precipitate of silver phosphate, calcium fluoride, and silver protein formed after the utility of SDF. Improvement of bonding can be an end result of this as well.[52] Decreased degradation of collagen and enhancement of remineralization with the aid of the anti-matrix metalloprotease action of SDF ought to additionally have increased the bond strength of GIC to the collagen fibrils.[52,50] Fixation of the organic matrix via SDF, leading to improve interlocking to the dentinal tubules and leading to improve bond strength.[12]

CONCLUSION

Under limitation of this study, the following conclusions could be suggested:

Treatment of sound and demineralized dentine surfaces by SDF don't affect bonding to light cured resin modified glass ionomer cement.

Conflict of interest

The authors declare that they have no financial interest in the materials used in this study. This study was a part of khaled A. Abd Elsattar's Master thesis in the partial fulfillment of the requirements of the Master Degree in Operative Dentistry, Faculty of Dentistry, ASU.

REFERENCES

1. Kassebaum NJ, Bernabé E, Dahiya M, Bhandari B, Murray CJL, Marcenes W. Global burden of untreated caries: a systematic review and metaregression. J Dent Res. 2015;94(5):650-658. doi:10.1177/0022034515573272
2. Quock RL, Barros JA, Yang SW, Patel SA. Effect of silver diamine fluoride on microtensile bond strength to dentin. Oper Dent. 2012;37(6):610-616. doi:10.2341/11-344-L
3. Ericson D, Kidd E, McComb D, Mjör I, Noack MJ. Minimally Invasive Dentistry--concepts and techniques in cariology. Oral Health Prev Dent. 2003;1(1):59-72.
4. Shuhua A, Botelho MG, Tsoi JKH, Matinlinna JP. International Journal of Adhesion & Adhesives Effects of silver diammine fl uoride on microtensile bond strength of GIC to dentine. 2016;70:196-203.
5. Wright JT, White A. Silver Diamine Fluoride: Changing the Caries Management Paradigm and Potential Societal Impact. N C Med J. 2017;78(6):394-397. doi:10.18043/ncm.78.6.394
6. Ekambaram M, Yiu CKY. International Journal of Adhesion & Adhesives Bonding to hypomineralized enamel – A systematic review. Int J Adhes Adhes. Published online 2016:1-6. doi:10.1016/j.ijadhadh.2016.03.016
7. Challenges R, Them O. Restorative Challenges and How to Overcome Them. :71-91.
8. Savas S, Kucukyılmaz E, Celik EU, Ates M. Effects of different antibacterial agents on enamel in a biofilm caries model. J Oral Sci. 2015;57(4):367-372. doi:10.2334/josnusd.57.367
9. Ccahuana-Vásquez RA, Cury JA. S. mutans biofilm model to evaluate antimicrobial substances and enamel demineralization. Braz Oral Res. 2010;24(2):135-141. doi:10.1590/s1806-83242010000200002
10. Zhao IS, Gao SS, Hiraishi N, et al. Mechanisms of silver diamine fluoride on arresting caries: a literature review. Int Dent J. 2018;68(2):67-76. doi:10.1111/idj.12320

11. Knight GM, McIntyre JM, Mulyani. The effect of silver fluoride and potassium iodide on the bond strength of auto cure glass ionomer cement to dentine. Aust Dent J. 2006;51(1):42-45. doi:10.1111/j.1834-7819.2006.tb00399.x

12. Yamaga M, Koide T, Hieda T. Adhesiveness of glass ionomer cement containing tannin-fluoride preparation (HY agent) to dentin--an evaluation of adding various ratios of HY agent and combination with application diammine silver fluoride. Dent Mater J. 1993;12(1):36-44. doi:10.4012/dmj.12.36

13. Shebl EA, Etman WM, Genaid TM, Shalaby ME. Durability of bond strength of glass-ionomers to enamel. Tanta Dent J. 2015;12(1):16-27. doi:10.1016/j.tdj.2014.08.001

14. Hamama HH, Yiu CK, Burrow MF. Effect of silver diamine fl uoride and potassium iodide on residual bacteria in dentinal tubules. Published online 2015:80-87. doi:10.1111/adj.12276

15. El Wakeel AM, Elkassas DW, Yousry MM. Bonding of contemporary glass ionomer cements to different tooth substrates; microshear bond strength and scanning electron microscope study. Eur J Dent. 2015;9(2):176-182. doi:10.4103/1305-7456.156799

16. Comar LP, Souza BM, Gracindo LF, Buzalaf MAR, Magalhães AC. Impact of experimental nano-HAP pastes on bovine enamel and dentin submitted to a pH cycling model. Braz Dent J. 2013;24(3):273-278. doi:10.1590/0103-6440201302175

17. Mohammed NY, Sharaf AA, Talaat DM, Hanafi SA. Evaluation of Shear Bond Strength of Nanoparticles Glass Carbomer and High Viscosity Glass Ionomer in Primary Teeth Dentin (in Vitro Study). Alexandria Dent J. 2018;43(1):17-21. doi:10.21608/adjalexu.2018.57590

18. Itthagarun A, Verma S, Lalloo R, King NM, Wefel JS, Nair RG. Effects of fluoridated milk on artificial enamel carious lesions: a pH cycling study. J Dent. 2011;39(12):817-824. doi:10.1016/j.jdent.2011.08.016

19. JUCSF protocol for caries arrest using silver diamine fluoride: rationale, indications, and consent. Br Dent J. 2017;222(7):516. doi:10.1038/sj.bdj.2017.311

20. Knight GM, McIntyre JM, Mulyani. The effect of silver fluoride and potassium iodide on the bond strength of auto cure glass ionomer cement to dentine. Aust Dent J. 2006;51(1):42-45. doi:10.1111/j.1834-7819.2006.tb00399.x

21. Zhao IS, Chu S, Yu OY, Mei ML, Chu CH, Lo ECM. Effect of silver diamine fluoride and potassium iodide on shear bond strength of glass ionomer cements to caries-affected dentine. Int Dent J. 2019;69(5):341-347. doi:10.1111/idj.12478

22. Mohan M, Chidsey C, Rosivack RG. Comparison of Microtensile Bond Strength of Glass Ionomer to Carious Primary Dentin After Treatment with SDF and SDF / KI. Published online 2020:203-210.

23. Gupta J, Thomas MS, Radhakrishna M, Srikant N, Ginjupalli K. Effect of silver diamine fluoride-potassium iodide and 2% chlorhexidine gluconate cavity cleansers on the bond strength and microleakage of resin-modified glass ionomer cement. J Conserv Dent. 2019;22(2):201-206. doi:10.4103/JCD.JCD_485_18

24. Zhao IS, Chu S, Yu OY, Mei ML, Chu CH, Lo ECM. Effect of silver diamine fluoride and potassium iodide on shear bond strength of glass ionomer cements to caries-affected dentine. Int Dent J. 2019;69(5):341-347. doi:10.1111/idj.12478

25. Zhao IS, Mei ML, Burrow MF, Lo ECM, Chu CH. Prevention of secondary caries using silver diamine fluoride treatment and casein phosphopeptide-amorphous calcium phosphate modified glass-ionomer cement. J Dent. 2017;57:38-44. doi:10.1016/j.jdent.2016.12.001

26. Landuyt KL Van, Munck J De, Coutinho E, Peumans M, Lambrechts P, Meerbeek B Van. Bonding to Dentin: Smear Layer and the Process of Hybridization. In: ; 2005.

27. Mount GJ. An atlas of glass-ionomer cements : a clinician's guide. Published online 2003. http://site.ebrary.com/id/5005359

28. Tay FR, Smales RJ, Ngo H, Wei SH, Pashley DH. Effect of different conditioning protocols on adhesion of a GIC to dentin. J Adhes Dent. 2001;3(2):153-167.

29. Mei ML, Lo ECM, Chu CH. Arresting Dentine Caries with Silver Diamine Fluoride : What ' s Behind It ? Published online 2018. doi:10.1177/0022034518774783

30. Chu CH. Randomized Clinical Trial of 12 % and 38 % Silver Diamine Fluoride Treatment. Published online 2018. doi:10.1177/0022034517728496

31. Mei ML, Li QL, Chu CH, Yiu CKY, Lo ECM. The inhibitory effects of silver diamine fluoride at different concentrations on matrix metalloproteinases. Dent Mater. 2012;28(8):903-908. doi:10.1016/j.dental.2012.04.011

32. Mei ML, Ito L, Cao Y, Li QL, Chu CH, Lo ECM. The inhibitory effects of silver diamine fluorides on cysteine cathepsins. J Dent. 2014;42(3):329-335. doi:10.1016/j.jdent.2013.11.018

33. Koizumi H, Hamama HH, Burrow MF. Effect of a silver diamine fluoride and potassium iodide-based desensitizing and cavity cleaning agent on bond strength to dentine. Int J Adhes Adhes. 2016;68:54-61. doi:https://doi.org/10.1016/j.ijadhadh.2016.02.008

34. Zhao IS, Mei ML, Zhou ZL, Burrow MF, Lo ECM, Chu CH. Shear bond strength and remineralisation effect of a casein phosphopeptide-amorphous calcium phosphate-modified glass ionomer cement on artificial "caries-affected" dentine. Int J Mol Sci. 2017;18(8):1-10. doi:10.3390/ijms18081723

35. McCabe JF. Resin-modified glass-ionomers. Biomaterials. 1998;19(6):521-527. doi:10.1016/s0142-9612(98)00132-x

36. Odthon P, Khongkhunthian P, Sirikulrat K, Boonruanga C, Sirikulrat N. In vitro shear bond strength test and failure mechanism of zinc phosphate dental cement. Int J Adhes Adhes. 2015;59:98-104. doi.org/10.1016/j.ijadhadh.2015.01.010

37. Holmstrom SE, Gammon RL. Glass ionomers. J Vet Dent. 1988;5(4):14.

38. Lohbauer U. Dental Glass Ionomer Cements as Permanent Filling Materials? —Properties, Limitations and Future Trends. Published online 2010:76-96. doi:10.3390/ma3010076

39. Mei ML, Ito L, Chu CH, Lo ECM, Zhang CF. Prevention of dentine caries using silver diamine fluoride application followed by Er : YAG laser irradiation : an in vitro study. Published online 2014:1785-1791. doi:10.1007/s10103-013-1329-y

40. Quock RL, Barros JA, Yang SW, Patel SA. Effect of silver diamine fluoride on microtensile bond strength to dentin. Oper Dent. 2012;37(6):610-616. doi:10.2341/11-344-L

41. Puwanawiroj A, Trairatvorakul C, Dasanayake AP, Auychai P. Microtensile Bond Strength Between Glass Ionomer Cement and Silver Diamine Fluoride-Treated Carious Primary Dentin. Pediatr Dent. 2018;40(4):291-295.

42. Jiang M, Mei ML, Wong MCM, Chu CH, Lo ECM. Effect of silver diamine fluoride solution application on the bond strength of dentine to adhesives and to g1. Jiang M, Mei ML, Wong MCM, Chu CH, Lo ECM. Effect of silver diamine fluoride solution application on the bond strength of dentine to adhesives a. BMC Oral Health. 2020;20(1):1-10.

43. Fröhlich TT, Rocha R de O, Botton G. Does previous application of silver diammine fluoride influence the bond strength of glass ionomer cement and adhesive systems to dentin? Systematic review and meta-analysis. Int J Paediatr Dent. 2020;30(1):85-95. doi:10.1111/ipd.12571

44. Nguyen V, Neill C, Dds JF, Primus C. Potassium Iodide. The Solution to Silver Diamine Fluoride Discoloration ? 2017;5(1):1-6. doi:10.19080/ADOH.2017.05.5555655

45. Craig GG, Knight GM, McIntyre JM. Clinical evaluation of diamine silver fluoride/potassium iodide as a dentine desensitizing agent. A pilot study. Aust Dent J. 2012;57(3):308-311. doi:10.1111/j.1834-7819.2012.01700.x

46. Tyler MW, Fitzgerald M, Dennison JB, Heys DR. The effect of pulpal fluid flow on tensile bond strength of a glass-ionomer cement: an in vivo and in vitro comparison. Oper Dent. 1994;19(3):116-120.

47. Knight GM, McIntyre JM, Craig GG, Mulyani. Ion uptake into demineralized dentine from glass ionomer cement following pretreatment with silver fluoride and potassium iodide. Aust Dent J. 2006;51(3):237-241. doi:10.1111/j.1834-7819.2006.tb00435.x

48. Gupta A, Sinha N, Logani A, Shah N. An ex vivo study to evaluate the remineralizing and antimicrobial efficacy of silver diamine fluoride and glass ionomer cement type VII for their proposed use as indirect pulp capping materials - Part I. J Conserv Dent. 2011;14(2):113-116. doi:10.4103/0972-0707.82603

49. Knight GM, McIntyre JM, Craig GG, Mulyani, Zilm PS, Gully NJ. Differences between normal and demineralized dentine pretreated with silver fluoride and potassium iodide after an in vitro challenge by Streptococcus mutans. Aust Dent J. 2007;52(1):16-21. doi:10.1111/j.1834-7819.2007.tb00460.x

50. Zhao IS, Mei ML, Burrow MF, Lo ECM, Chu CH. Effect of Silver Diamine Fluoride and Potassium Iodide Treatment on Secondary Caries Prevention and Tooth Discolouration in Cervical Glass Ionomer Cement Restoration. Int J Mol Sci. 2017;18(2). doi:10.3390/ijms18020340

51. Mei ML, Ito L, Cao Y, Li QL, Lo ECM, Chu CH. Inhibitory effect of silver diamine fluoride on dentine demineralisation and collagen degradation. J Dent. 2013;41(9):809-817. doi:10.1016/j.jdent.2013.06.009

52. Uzel I, Ulukent O, Cogulu D. The effect of silver diamine fluoride on microleakage of resin composite. J Int Dent Med Res. 2013;6:105-108.