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EFFECT OF SILVER DIAMINE FLUORIDE AND POTASSIUM IODIDE ON MICRO-TENSILE AND SHEAR BOND STRENGTH OF GLASS IONOMER RESTORATION TO DENTIN OF PRIMARY MOLAR (IN VITRO STUDY)

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ABSTRACT

Objectives: This in vitro study was performed to assess the effect of the silver diamine fluoride (SDF) solution in combination with the potassium iodide (KI) solution on the microtensile bond strength (μTBS) and shear bond strength (SBS) of glass ionomer cement (GIC) restoration bonded to the carious dentin of primary molars.

Materials and Methods: 60 primary molars were collected and stored in saline. For the μTBS; 20 teeth were separated into two equal halves across caries and allocated randomly to intervention and control groups (n=20). For the SBS, 40 teeth were categorized into two groups, the intervention group (n=20) and the control group (n=20). The intervention teeth specimens were primed with 38% SDF followed by KI, and the control teeth specimens were primed with deionized water. The specimens were kept in saline for 14 days at room temperature before being restored with Fuji IX GP Extra. The specimens were prepared for μTBS and SBS testing after 24 hours in saline and the failure modes were analyzed. To compare the results of bond strengths the paired t-test was used.

Results: The micro-tensile and shear bond strength results showed a statistically non-significant difference between the intervention and control groups (P>0.05). The mode of failure was the adhesive failure only in all groups.

Conclusion: Pre-treatment of primary carious dentin with 38 percent SDF+KI (Riva Star, SDI, Australia) didn't influence the micro-tensile or shear bond strength of glass ionomer restoration.

KEYWORDS: Bond Strength, Carious Dentin, Glass Ionomer Restoration, Primary Molar, Potassium Iodide, Silver Diamine Fluoride.

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INTRODUCTION

Tooth caries is the most common disease affecting childhood. [1] Restorations are usually required for cavitated lesions to provide an effortlessly cleanable surface that decreases the chance of initiation of secondary caries.[2] In pediatric dentistry, the overall treatment of caries has aimed at removing infected tooth structures and filling them with restorative materials such as amalgam, composite, or GIC. [3,4] Packable GIC due to its superior biocompatibility, chemical adhesion, anti-cariogenic property, and lower moisture sensitivity has been suggested to be used as restorations in deep caries management. [5] GIC is also the material of choice in pediatric patients with active caries and high caries risk. [3]

SDF is a clear solution that associates the silver (Ag) antibacterial effects and the fluoride (F) remineralizing effects. [6] According to the "ADA" American Dental Association, SDF is a favorable material for the prevention and/or management of caries disease, as well as the treatment of dentin sensitive surfaces in specific dental situations such as holding care, special needs dentistry, and the precooperative child.[6,7] SDF has been approved by the Food and Drug Administration (FDA) in the United States as a Class-II dental product for the treatment of the hypersensitivity of the tooth.[6, 8]

Additionally, the use of SDF simplifies therapeutic procedures caries elimination is not required prior to the use of the SDF solution. [9] In vitro studies demonstrated that SDF reduces dentin demineralization, enhances tooth re-mineralization, increases the pH of biofilm, and hardens tooth structure. [2, 5, 6] However, food accumulation, difficulty maintaining proper oral hygiene, and black staining were also adverse effects of SDF treatment in class-II cavities. [8, 10]

As a result, two alternative approaches to solving the problem have been suggested. One of them is the application of KI solution prior to SDF treatment, which reacts with free Ag ions to form a mix of creamy white silver iodide (Ag-I). [11] However, Koizumi et al.,[12] 2016 found that dentin pre-treatment with the "SDF+KI" combination reduced the adhesion of resin-based adhesives and resin-modified GIC to dentin.

The addition of direct esthetic restorations such as GIC restorations after the application of SDF to cover the black staining caused by the SDF and to improve aesthetics and chewing ability is the other alternative approach. [11] Combining these two options, silver-modified A-traumatic restorative treatment (SMART) was shown to be advantageous in preventing dentin caries in children's primary teeth. [13, 14]

According to Zhao et al., [2] and Ng et al.,[15] SDF treatment of artificial carious dentin in permanent teeth didn't affect the bond strength markedly of GIC restoration to demineralized dentin. Selective removal of caries is stated in the modern management of dental caries. [2,15] Despite this, insufficient studies have looked into the effect of SDF on the bond strength of carious lesions. Hence, this in vitro study aimed to examine the effect of the "SDF+KI" solutions on the microtensile and SBS of the GIC to the carious dentin of primary molars.

MATERIALS AND METHODS

Sample collection

A total of 60 first and second primary molars with proximal caries were gathered from the Department of Pediatric Dentistry and Dental Public Health, Faculty of Dentistry, Cairo University by the end of every day. Teeth with radio-graphically dentin proximal caries that extend more than half the dentinoenamel junction (DEJ) and the pulp cavity distance and with at least two surfaces of tooth structure remaining were encompassed in the present study (**Figure 1**). The teeth with previous restorations, sealant, hypo-plastic pits, or with attrition of more than half of the occlusal-gingival height were excluded. [5]

Fig. (1): Application of SDF followed by KI till forming a creamy mix.

Sample size calculation

For calculation of sample size, a power analysis was considered to have adequate power to employ a 2-sided statistical test of the null hypothesis that the bond strength of GIC restoration to dentin of primary molars does not affect by SDF. By implementing an alpha (α) level of 0.05 (5%), a Beta (β) level of 0.2 (20%) i.e. power=80%, and an effect size (dz) (0.454) - calculated based on the results of Nasr and Saber [5], the anticipated sample size (n) was a total of (60) samples (20 per group). Sample size calculation was achieved using G*Power version 3.1.9.4.

Sample grouping

The selected primary molars were grouped into; 20 teeth for the micro-tensile bond strength that were segmented into two halves across the carious disease and teeth samples were randomly assigned to intervention group "group I" (n=20) and control group "group II" (n=20). The other 40 teeth for the SBS were randomly assigned to intervention group "group III" (n=20) and control group "group IV" (n=20). To generate the sequence for the teeth sample randomization, (Random.org software) was used.

Sample preparation

The selected teeth were stored in saline in a separated container and numbered from 1 to 60.

I. The preparation for Micro-tensile bond strength

After randomization and group allocation, the 20 teeth that were utilized for the μTBS test were sectioned through the center of the carious lesion using the water-cooled cutting machine (Isomet 4000 saw, Buehler, USA) forming two equal halves. Following sectioning, the resulting specimens were again randomly assigned to the experimental group (n=20) and control group (n=20). [5]

A. Intervention group (Group I)

The 38% "SDF" solution was applied for 1 minute preceded by "KI" for 1 minute using two different micro-brushes till forming a creamy mix (**Figure 1**), preceded by a 30-second rinse with distilled water. [18]

B. Control group (Group II)

The deionized water was applied for 1 minute. All specimens in both groups were kept in saline for 14 days at room temperature.

After storage, the carious proximal surface of each specimen was polished manually with silicon carbide paper under running water for 60 seconds to create a uniform surface. [5,17] Then an application of approximately four mm high GIC block (Fuji IX GP Fast Capsule, GC, Japan) on the dentin surface after being mixed via Amalgamator (Impla, China). After the glass ionomer hardened (five minutes), the specimens were kept in saline for the next 24 hours. [5,17]

Micro-tensile bond strength test

After being fixed in self-cured acrylic blocks each specimen in each group was sectioned using a slow-speed water-cooled cutting machine to obtain slices approximately 0.7 mm in thickness. [5,17] Each specimen was placed in the testing for Universal Testing Machine (INSTRON universal testing machine, model 3345 England) and stressed in tension at a crosshead speed of one mm per minute until bond failure. Then recorded the maximum stress at failure was recorded and converted to mega-Pascals (MPa) units (**Figure 2**).

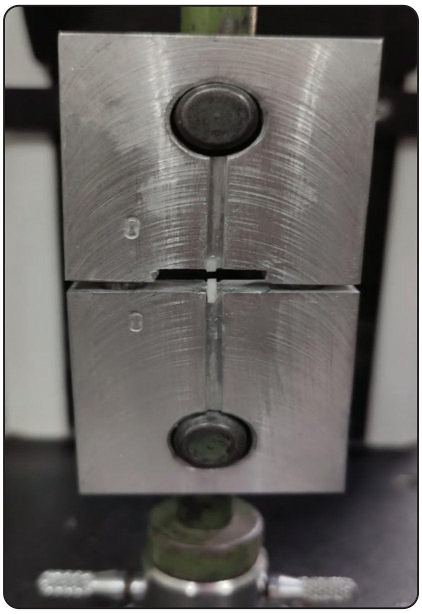

Fig. (2) Tensile bond strength, each slices of approximately 0.7 mm thick is stressed in tension at a crosshead speed of one mm per minute until bond failure using universal testing machine.

II. The preparation for shear bond strength:

The roots of 40 extracted primary molars for groups III (n=20) and IV (n=20) were cut off 2-mm below the cementum-enamel junction (CEJ). Then, the teeth specimens were mounted in acrylic resin moulds with their carious surfaces exposed along their axis in perpendicular directions to the moulds. To obtain a flat dentin surface, the carious surface of the crowns was gently polished using the water cooled cutting machine. [19]

A) Intervention Group (Group III)

The teeth specimens in this group were treated with 38% “SDF” solution on the carious dentin surface for 1 minute preceded by application of “KI” for 1 using two different micro-brushes minute till forming the creamy mix, followed by a 30-second rinse with distilled water.

B) Control Group (Group IV)

Teeth were treated with deionized water for 1 minute. All specimens were stored in saline for 14 days at room temperature.

After storage, A polyvinyl mould with an internal diameter of (3 mm and a height of 4 mm) was placed at right angles on the polished surface of the carious dentin and restored with GIC (Fuji IX GP Fast Capsule, GC, Japan) in increments to create a standardized bonding area of approximately 4-mm high (**Figure 3**). The GIC was applied on the carious dentin surface after being mixed via Amalgamator (Impala, China). After the glass ionomer was left to harden for five minutes, the specimens were kept in saline for 24 hours. [2, 5, 19]

Fig. (3): Application of GIC into the plastic cylindrical shaped (Polyvinyl) with an internal diameter of 3 mm and a height of 4 mm after application of SDF/KI.

Shear bond strength test:

A shear force applied perpendicularly to the GIC button at a distance of 1-mm from the carious dentin surface to the loading head using the Universal Testing Machine until bond failure. [2,19] The load required to de-bond GICs is measured in Newtons. The bond strength was measured in MPa (**Figure 4**).

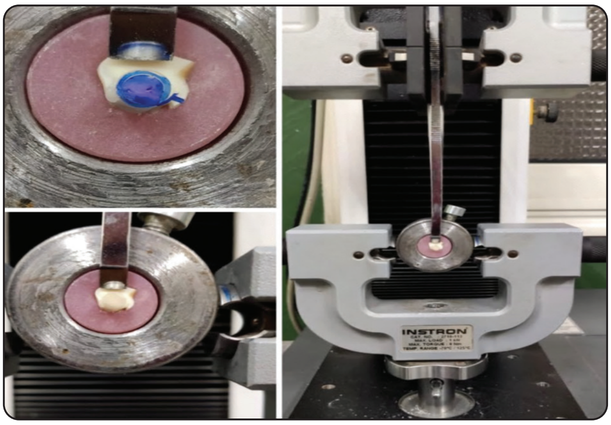

Fig. (4): A shear force was applied perpendicularly to the GIC cylindrical button at a distance of 1 mm from the dentine surface to the loading head using universal testing machine.

Mode of failure

A magnifying microscope was used to examine the de-bonded samples (MA 100 NIKON stereomicroscope Japan, 50 X magnifications). Failure modes were classified into three types: Type-1 is adhesive failure between dentine and GICs with exposed carious dentine surfaces; Type-2 is cohesive failure in GICs or carious dentine; and Type-3 is partially adhesive and partially cohesive failure (mixed failure). [2]

Statistical analysis

Numerical data were explored for normality by checking the data distribution, calculating the mean and median values, and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values and was compared using an independent t-test. Spearman's rank-order correlation coefficient was used to study the correlation between variables. The significance level was set at $p \leq 0.05$ within all tests. Statistical analysis was performed with IBM® (IBM Corporation, NY, USA) SPSS® (SPSS, Inc., an IBM Company) Statistics Version 26 for Windows.

RESULTS

I. Micro-tensile and shear bond strengths

The results of micro-tensile bond strength revealed that however the test group had a higher mean value (3.29±1.15) than the control group (2.77±1.16) yet the difference was not significant (P=0.163). However, the shear bond strength results exhibited that the control group had a higher mean value (4.08±1.40) than the test group (3.84±0.99) but yet the difference was not significant (p=0.530) (**Table 1**).

II. Mode of failure

The mode of failure for shear and micro-tensile bond strengths were presented as frequencies (n) and percentages (%). The results showed that all samples (intervention and control) that tested for micro-tensile and shear bond strength only failed adhesively without any cohesive or mixed mode of failure (**Figure 5, 6**).

TABLE (1): Mean ± standard deviation (SD) of micro-tensile and shear bond strengths (MPa) for different groups

Variable	Group I (test)	Group II (control)	P-value
Micro-tensile bond strength	3.29±1.15	2.77±1.16	0.163 ns
Shear bond strength	3.84±0.99	4.08±1.40	0.530 ns

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

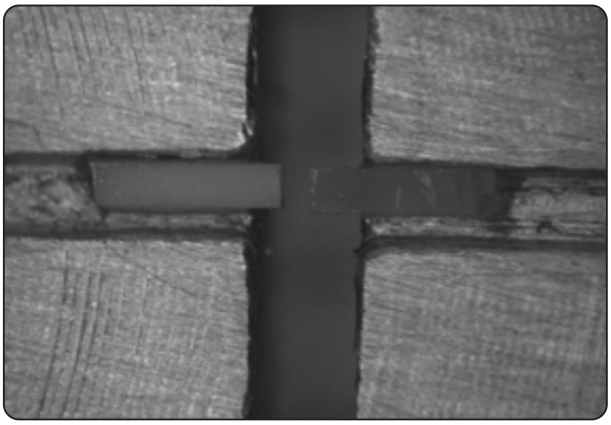

Fig. (5): Adhesive mode of failure for the micro-tensile bond strength inspected under the stereomicroscope.

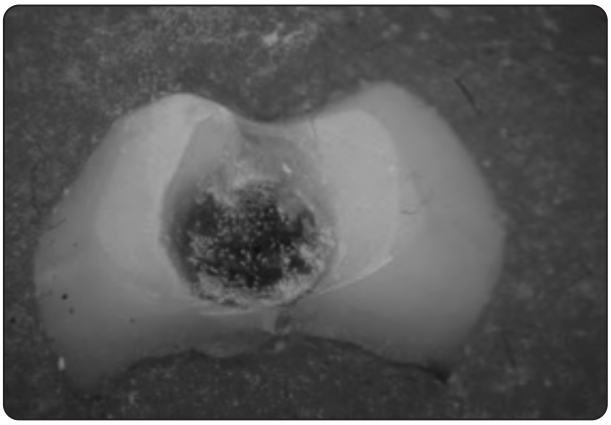

Fig. (6): Adhesive mode of failure for the shear bond strength inspected under the stereomicroscope.

DISCUSSION

Minimally invasive caries treatment is becoming more popular in pediatric dentistry. Sealants, composite restorations, and resin infiltration are some of the techniques used to achieve this. On the other hand, it is more difficult to apply in infants and toddlers. Drilling and filling the cavities is the conventional method of treating carious lesions, which involves mechanically removing the soft and infected dentine before filling the cavity with a suitable restorative material. [20] Despite this, there is evidence that suggests that soft carious lesions may not require removal. A clinical trial found no difference in the amount of arrested tooth surfaces between children who had caries excavation prior to SDF application and those who did not. [21]

SDF enhances re-mineralization, increases dentin hardness and significantly improves in terms of bactericidal activity. The unattractive permanent black staining of teeth caused by silver phosphate and silver sulphide precipitates is the main disadvantage of SDF application. Thus an Australian group suggested using a saturated “KI” solution to cover the black staining. [16] “SDF+KI” treatment has also been shown to improve resistance to a cariogenic challenge. [22] SDF Riva Star is the only commercially readily available product of “SDF + KI”. As a result, it was chosen on our study.

AAPD 2018 chairside guide for SDF application recommends a one-minute dwell time after SDF application. [18] Here in our study we followed the AAPD’s chairside guide for SDF application with dwell time 1 minute preceded by KI for one minute till forming a creamy mix.

The SMART method, which manages to combine the use of “SDF” to arrest caries and a “GIC” for aesthetics, is a relatively new method that combines both tooth structure preservation and an aesthetic restoration [23]. These have the advantages of low cost and the ability to be used outside of the traditional clinical setting by dental personnel, which could lead to an increase in dental service coverage. While this technique has the advantages of minimal tooth preparations and the caries-preventing properties of both “SDF” and a “GIC”, Little studies have been conducted on the combined impact of these materials. [23,24]

SDF can cause a fluoride hyper-saturation environment in dentin, resulting in the formation of fluor-apatite crystals, which are larger than hydroxyapatite crystals and have a more closely packed structure with fewer voids and higher micro-hardness than hydroxyapatite crystals [25] From this morphological perspective, we would expect lower bond strength in the “SDF+KI” treated group because fluoride hyper-saturation and an acidresistant surface might decrease ion exchange from an acid base reaction. The bond strength of the carious dentin specimen treated with "SDF+KI" in our study, however, was not statistically different from the control group. When polished with silicon carbide paper manually under running water, it's possible that SDF/KI modified dentin zone was partially removed at the superficial level.

In this study, the bond strength of the carious dentin specimen treated with SDF/KI was not statistically different from the control group for both micro-tensile and shear bond strength. The average value for micro-tensile bond strength did improve from 2.77 to 3.29 Mpa when SDF was added, thus supporting a restorative procedure of SDF treated caries with a GIC in a clinical setting. This is also in line with the findings of Nasr and Saber who discovered that "SDF+KI" when added prior to the glass ionomer restorations, had no adverse effect on the micro-tensile bond strength at the adhesive interface with Paired t-test showing that test samples (8.31±2.49) had a non-significant higher micro-tensile bond strength than control samples (7.94±1.25) (P=0.479). [5]

From the results of this study, on comparing the shear bond strength of GIC on carious dentin (4.08+1.40) to "SDF+KI" followed by GIC on carious dentin (3.84+0.99) the mean difference was not statistically significant (P=0.530). So the addition of "SDF+KI" solution onto the carious dentin surface does not affect the shear bond strength of GIC to carious dentine of primary molars. This is in line with the findings of Zhao and his teammates [2] who showed that the addition of SDF product before the glass ionomer cement restorations, did not affect the shear bond strength at the adhesive interface.

The mode of failure observed by the stereomicroscope in this study was 100 percent adhesive only; there was no cohesive or mixed failure. These findings support Chung and colleagues' findings that conventional glass failures were adhesive along with the dentin interface, indicating a weak bond between material and dentin. [30]

Clinical application of SDF before GIC bonding to demineralized dentin may be advantageous. Addition of GIC after the application of SDF product has been shown to improve marginal caries resistance as well as restore function and reduce food impaction in cavitated lesions. [22]

CONCLUSION

Pre-treatment of carious primary dentin with 38 percent "SDF+KI" (Riva Star, SDI, Australia) had no adverse effect on the micro-tensile or shear bond strength of glass ionomer restoration. This study supports the addition of GIC to caries lesions after treatment with 38% "SDF+KI"product.

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