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Original Research Article

Comparative Evaluation of Microtensile Bond Strength of Different Restorative Materials on Silver Diamine Fluoride Treated Carious Primary Teeth- an in Vitro Study

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Abstract

Aim: To compare the micro tensile bond strength of three restorative materials after SDF treatment to primary carious teeth and evaluate the mode of restoration failure.

Methods and Material: this is a Cross-sectional study. 60 extracted carious primary molars were sectioned in two halves through the carious lesions and randomly allocated to three different groups. All groups were treated with SDF and stored in artificial saliva. The samples were restored with conventional glass ionomer cement, light cure glass ionomer cement, and composite. After 24 hours in artificial saliva, the specimens were prepared for micro tensile bond strength testing and stressed with tension at 1mm/min until failure.

Mean bond strengths were compared using the One-way ANOVA test with post hoc Tukey HSD **test** and failure mode was recorded.

Results: The mean micro tensile bond strength was highest in the light-cure glass ionomer cement followed by conventional glass ionomer cement and composite. The most common failure mode was the adhesive failure in all groups.

Conclusions: Resin-modified glass-ionomer cement is better material for SDF-treated carious primary teeth.

Keywords: SDF, silver, diamine, fluoride, carious, primary, teeth, micro, tensile, bond, strength.

Introduction

The most prevalent disease to which man is liable is Dental Caries. Early childhood caries (ECC), also known as nursing bottle caries and baby bottle tooth decay, remains a noteworthy public health problem. [1]

Silver diamine fluoride (38% w/v Ag $(NH_3)_2F$), a colorless topical agent, comprising of 24.4-28.8% (w/v) silver and 5.0-5.9% fluoride, at pH 10.4 is marketed as Advantage Arrest™ by Elevate Oral Care.

SDF is used to arrest caries and treat dentin hypersensitivity. Topical application for treatment of exposed sensitive dentin surfaces results in squamous layer development on the exposed dentin, partially plugging the dentinal tubules. This protective layer has been known to be formed by high concentration aqueous silver. [2]

Micro-tensile-Bond-strength (µTBS) test method is one of the most commonly used methodology to assess the strength of the resin-dentin interface complex mechanically, because it has several advantages over traditional Tensile and shear bond test methodologies. µTBS test is more versatile because a single tooth can provide for multiple specimens.

µTBStest produces more adhesive failure than cohesive failure, thus allowing testing of bond to irregular surfaces and very small areas. Therefore, purpose of this study is to compare the micro-tensile-bond-strength of Glass-ionomer cement (GIC), resin-modified Glass-ionomer cement (RM-GIC), and resin-based composite to SDF-treated carious dentin of primary molar and also the mode of failure at interface.

Material and methods

The present cross-sectional study was conducted in the department of pediatric and preventive dentistry, RDCH, Jaipur with due permission from the ethics committee of the faculty of dentistry from the institution (RDCH/Ethical/2020/055/8). After approval of the plan by research review board till the desired sample size is completed (2020 to 2021).

Sample size

Sample size is calculated at 80% study power and alpha error of 0.05 assuming standard deviation of 5.1Mpa. For minimum detectable mean difference of 5Mpa in micro-tensile-bond-strength between the groups, 19 cases in each of three groups is required as sample size which is enhanced and rounded off to 20 in each of three groups considering attrition.

Extracted carious human primary molars, stored in a solution of 0.9% sodium chloride and 0.2% sodium-azide at room temperature for a maximum of two months were used. Only primary molars with dentinal caries that radiographically extended more than half the distance between the dentino-enamel junction and pulp chamber with at least two surfaces of intact tooth structure remaining were selected. Sectioning of tooth was done. Specimens were randomly allocated to either test groups. Sections of the tooth were divided in the 3 groups A, B and C.

In the tests group, the carious dentin surfaces were treated with 38% SDF solution using a micro-brush for three minutes, followed by a 30-second rinse with water. All specimens were stored in artificial saliva. After storage, the carious proximal surface of each specimen was reduced occluso-gingivally with a diamond bur in a high-speed handpiece and polished with a silicon carbide paper to create a flat surface. The sectioned specimens were kept wet during the shaping and testing procedures. The SDF-treated samples were reduced, leaving a blackened dentin layer remaining. The roots were removed from the remaining crown with a high-speed diamond bur under water-cooling. In different groups GIC, Resin-modified GIC and composite restorations were built upon the dentin surface.

After the restoration hardening, the specimens were stored in artificial saliva at 37ºCelsius for 24 hours. Each specimen was placed in the testing jig of a universal testing machine and stressed in tension at a crosshead speed of 1mm/minute until bond failure. The maximum stress at failure was recorded and converted to megapascal units (MPa).

The failure mode was assessed with a stereo microscope under 40x magnification, and the modes were classified into four groups:(1) Adhesive failure between the restorative material and the dentin surface; (2) Cohesive failure in dentin; (3) Cohesive failure in the restorative materials; and (4) Mixed failure, which was a combination of adhesive failure between the adhesive and dentin and cohesive failure in the restorative materials.

Results

The present in vitro study was designed to evaluate the micro-tensile-bond-strength of three restorative systems (GIC, RM-GIC, COMPOSITE) to SDF-treated carious primary teeth.

Comparison of restorative systems:

Table 1: An intergroup comparison of Mean Micro tensile bond strength (MPa)and standard deviation values of adhesive systems.

Adhesive Systems		Micro tensile bond strength (Mpa)
GIC (Group 1)	MEAN	7.142
	SD	±1.33
Light cure GIC (Group 2)	MEAN	9.688
	SD	± 1.45
Composite (Group 3)	MEAN	5.7055
	SD	±1.28

Samples treated with resin-modified GIC gave the highest mean micro-tensile bond-strength value i.e., 9.688 (±1.45) MPa followed by GIC: 7.142 (±1.33) MPa followed by composite: 5.7055 (±1.28) MPa. p-value was highly significant ($p<0.0001$) in comparison to groups which showed significant difference. (Table-1)

Table 2: Mode of fractures of tested samples were as follows:

FAILURE TYPE	ADHESIVE SYSTEMS		
	GIC (Group 1)	**RESIN MODIFIED GIC (Group 2)**	**COMPOSITE (Group 3)**
Adhesive	**19**	**14**	**20**
Cohesive (Dentine)	**---**	**----**	**----**
Cohesive (Restorative system)	**---**		**----**
Mixed	**1**	**6**	**----**

Under 40x stereomicroscope the tested samples were observed to check the mode of fracture. In the present study there was no cohesive mode of fracture. In RM-GIC group, adhesive and mixed mode of fracture was observed. While in GIC and composite the mode of fracture of tested samples was adhesive due to observed low micro-tensile bond-strength.(Table-2)

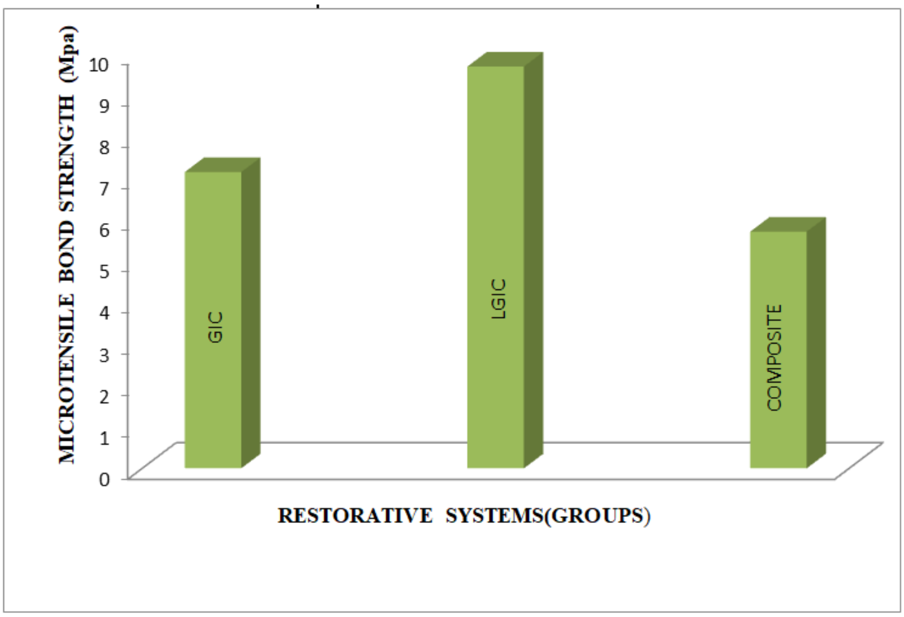

Figure 1: Demonstrates the intergroup comparison of micro tensile shear bond strength (MPa) restorative systems to SDF treated primary carious teeth

Discussion

Out of 291 most common health problems evaluated in The Global Burden of Disease 2010 Study, untreated dental caries of primary teeth was the tenth. SDF stems from the conjunction of silver nitrate and fluoride. It decreases the growth of caries-causing bacteria, hampers degradation of collagen in dentin, prevents demineralization and encourages remineralization of both enamel and dentin [3].

Pediatric Dentistry is moving towards minimally invasive caries treatment. In August 2014, the Food and Drug Administration (FDA) of United States of America permitted the first SDF product for market, which was available by April 2015 [4].SDF is commonly used at 38% (12% is also available). However, clinical studies found that 12% was not as effective as 38% in arresting dental caries among children [5]. We used 38% SDF in our study. In an 18-months study, SDF was found to be more effective in arresting dentin caries in the deciduous dentition of preschool children at 38% concentration than at 12% concentration and when applied biannually rather than annually [6].

Another dental restorative material which has become important for use in primary dentition is Glass-ionomer cements. The advantages of glass-ionomer cements are fluoride-ion release and uptake, biocompatibility and chemical bonding to both enamel and dentin an important development in Glass-ionomer technology that has influenced dentistry for children is development of the Resin-modified-Glass-ionomer Cements. The resin-modified-Glass-ionomer cements consist primarily of Glass-ionomer and a minor amount of resin. These cements harden initially by free-radical photopolymerization of the resin component in the formulation. Subsequently, a chemical resin polymerization reaction and the Glass-ionomer setting reactionprogress. Addition of the resin component not only decreases initial hardening time and handling difficulties, but also increases wear resistance and physical strengths of the cement substantially [7].RM-GIC comes in market to overcome low early strength and moisture sensitivity of conventional GIC. It is a hybrid cement that sets partly by acid base reaction and partly by polymerization reaction (Mc lean).

In this study, we assessed the micro-tensile-bond-strength of conventional Glass-ionomer cement, Resin-modified-Glass-ionomer cement and Composite to SDF-treated primary carious dentin.

Several studies have studied the bond-strength of restorative materials to SDF-treated sound dentin and the bond-strength of GIC to SDF-treated carious dentin. Comparing the bond-strengths between these various restorative materials gives the clinician evidence-based guidance on how to restore an area that may involve carious dentin previously treated with SDF. Two decades ago, shear and tensile bond-strength tests were performed exclusively in specimens with a relatively large bonded surface, usually 3-6 mm in diameter (approximately 7-28 mm^2). However, the validity of these test results was questioned due to the heterogeneity of the stress distribution at bonded interface. It is suggested that a very small surface has a better stress distribution so that more adhesive failures can be generated. Thus, specimen with small bonding region (i.e., below 2mm^2) is adopted in the micro-tensile-bond-strength and micro-shear-bond-strength tests which have gained increasing popularity in the recent 20 years. Compared to the traditional tensile bond-strength test with a relatively large, bonded surface, the micro-tensile-bond-strength test has several advantages, such as proportionally more adhesive failures generated, possibility of measuring a relatively high bond-strength value and more specimens can be harvested from one tooth. In addition, the micro-tensile-bond-strength test is found to have a larger discriminative power than the SBS test [8].

This study found that RM-GIC demonstrated the highest micro-tensile-bond-strength values (9.688± 1.45), followed by GIC (7.142 ± 1.33) and composite (5.7055 ± 1.28). In SDF-treated carious primary molars, RM-GIC demonstrated higher bond-strength values compared to composite at a significant level ($P<0.05$), but not very higher and not very statistically significant micro-tensilebond-strengths compared to GIC.

Thus, resin-modified-Glass-ionomer cement had higher micro-tensilebond-strength than conventional Glass-ionomer cement. This was in accordance with the study done by Lucia et al (2002) [9] which revealed that resin-modified-Glass-ionomer cement has higher diametral and tensile bond-strengths than Glass-ionomer cement. Similar findings were achieved by Vishnu Rekha et al (2012) [7] that RM-GIC has the high tensile bond-strength than the conventional Glass-ionomer cement in carious primary teeth. Hanan Alzraikat et al (2016) [10] also had achieved similar result that the diametral tensile strength of conventional GIC was lower than that of RM-GIC. In the same way K Choi et al (2006) [11] found that RM-GIC had high micro-tensile bond-strength to both sound and carious dentin than Conventional GIC. The choice of restorative material can be either of the two and cannot be judged based only on the tensile bond-strength. Multiple studies have found the trend of relatively higher bond-strength values of RM-GIC and GIC to SDF-treated carious dentin compared to composite.

The higher bond-strength values of RM-GIC compared to GIC and composite to SDF-treated primary carious dentin is in contrast to their respective bond-strengths to sound dentin, where composite exhibits the highest bond-strength, followed by RM-GIC, and GIC with the lowest bond-strength. Some recent studies have shown that SDF treatment of dentin reduces the micro-tensile-bond-strength to composite but not Glass-ionomer. The bonding mechanism of GIC relies mainly on chemical bonds between free negatively-charged hydrophilic carboxyl groups in GIC to the positively charged calcium of hydroxyapatite in dentin. In contrast, the bonding mechanism of resin-based composite relies on micromechanical retention, forming hybrid layers within dentin collagens and resin tags within dentinal tubules. The bonding of RM-GIC is a hybrid of the two, setting with both chemical and micromechanical polymerization reactions varying with time of Resin-modified activation. These differences in bonding mechanisms may explain the varying bond-strength values in this study.

Application of SDF to dentin results in remineralization and incorporation of various ions, especially in previously demineralized, carious dentin. **Willers hausen et al** (2015) [12] found that SDF formed a film on the dentin surface and deposits were detected in some dentinal tubules. **Rossi et al** (2017) [13] took Scanning Electron-Microscope cross-section images of dentin tubules of sound dentin vs SDF-treated carious dentin of primary teeth and showed that SDF-treated lesions displayed more hyper mineralized inter-tubular dentin and partially blocked dentin tubules with silver precipitate. Composite relying on micromechanical bonding within dentinal tubules and collagen matrix, these restorative materials may exhibit decreased bond-strengths to SDF-treated carious dentin as the dentinal tubules and collagen network become partially blocked or plugged. Thus, the open dentinal tubules and collagen matrix upon which micromechanical bonding with resin tags and hybrid layers relies is impossible if a blockage is present. This can account for the lower bond-strength values of composite seen in this study. Conversely, GIC relies on chemical bonding and not micromechanical bonding.

Furthermore, increased incorporation of positively-charged silver ions and silver deposits into SDF-treated carious dentin can lead to improved chemical bonding to the negatively-charged carboxyl groups of GIC, which may explain the higher micro-tensilebond-strength values of GIC.

Puwanawiroj a et al (2018) [14] concluded that SDF does not adversely affect the bond-strength between GIC and carious primary dentin. **Uchilsr et al** (2020) [15] conducted a study and evaluated the application of SDF with and without acid etching and KI does not affect the bond-strength of RM-GIC to carious dentin of primary teeth.

While this study helps to evaluate bonding to SDF-treated dentin, the adhesion to carious dentin is less successful than adhesion to healthy dentin, which is well established. Also, the lumens of dentinal tubules in the CAD (caries affected dentin) are filled with carious crystals; thus, resin infiltration into the tubules is restricted. The porosity of inter-tubular dentin increases in the CAD as a result of demineralization during the caries process. This might permit the deeper etching of the inter-tubular dentin and more collagen exposure. The bond-strength to the CAD might decrease because of irregular and incomplete hybridization of the etched dentin layer. The lower mechanical properties of the CAD due to demineralization can be accounted for the lower bond-strength [16].This is another reason for lower micro-tensile-bond-strength for composite on SDF-treated tooth in present study.

Some studies contradict this finding, which can be explained by use of different adhesive systems. SDF application on the non-carious dentin did not affect the bond-strength, but significantly increased the bond-strength of caries affected dentin.

RM-GIC cements adhere to dentin via two mechanisms. Application of a polyalkenoic acid conditioner leads to occurrence of micromechanical interlocking. This is owing to the increase in surface area when micro-porosities are created. Furthermore, true chemical bonding transpires when the carboxyl groups of the polyalkenoic acid bond to the calcium in the hydroxyapatite. When evaluating the effects of SDF application on the bond-strength of a RM-GIC to dentin, several factors must be considered [17].

SDF leads to the formation of fluorapatite crystals in the dentin which are more closely packed with scarcer voids compared to hydroxyapatite. Microhardness of the dentin is also increased by SDF. This, combined with a possible reduction in ion exchange from the acid base reaction, could theoretically lower the bond-strength of the Glass-ionomer. However, studies have shown that SDF does not lower the bond-strength. It has been hypothesized that increased bond-strength produced after the use of SDF alone could be due to the development of silver phosphate bonding to the carboxylic acid in the resin-modified-Glass-ionomer.

It is also proposed that this increase could be due to a hardened dentin surface, reduced collagen degradation or fixation of the dentin proteins. The micromechanical interlocking of the resin-modified-Glass-ionomer to dentin may be enhanced by increasing the microhardness of the dentin. Moreover, after application of SDF both silver and silver oxide present on the surface of the dentin.[18]

Regarding modes of failure, all specimens in GIC and composite groups displayed adhesive failures, while the RM-GIC group was split between adhesive (63%) and mixed (37%). No specimens in this study exhibited only a cohesive mode of failure. The absolute adhesive failure mode of the restorative materials that rely more on micromechanical bonding (GIC and composite) suggests that the adhesive interface may be impaired by the film and blocked tubules induced by SDF on carious dentin. The higher proportion of mixed failures in RM-GIC may be due to stronger chemical bonds to the ions incorporated into SDF-treated carious dentin.

Conclusion

Since the beginning of time, the materials used in the human body, particularly those used in the oral cavity, should be stable, as well as passive, with no interactions with their surrounding environment. Such characteristics are generally seen in amalgam, composite resins and cements. It is possible that the first sparks to produce active materials, with definite interactions with the human body, originated from the fact that materials capable of releasing fluoride can exert useful effects. In the recent decade, the concept of producing "smart" materials in dentistry has gathered pace. Davidson was the first to note the smart behavior of glass ionomer (GI) cement. Glass-ionomer cements (GICs) are extensively used in various branches of dentistry. Compared to other restorative materials, one of the main advantages of GI is that they can be placed in cavities without any need for bonding agents; they also have good biocompatibility. Although GI are frequently used cements in dentistry, they too have shortcomings. The most imperative drawback of conventional GI is lack of appropriate strength and toughness. In order to enhance the mechanical properties of conventional glass ionomer, resin-modified glass ionomers (RMGIs) containing hydrophilic monomers and polymers like HEMA, have been introduced.

Nevertheless, the results of this study confirmed that SDF has the potential to be included in dental armamentarium addressing caries burden in developing countries. Even in developed nations most parents still take their children to the dentist for curative and not for preventive treatment. Orientation to prevention is not considered and preventive dentistry is yet to reach the common population in India. Preventive programs based on the use of fluoride and especially SDF should be expanded to regions/communities at risk, which lack access to those strategies, maximizing cost efficiency. However, further clinical studies should be emphasized on to establish the clinical outcomes of tensile bond strengths of restorative materials while using silver diamine fluoride.

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