Microshear Bond Strength of Resin Composite to Pretreated Dentin with Silver Diamine Fluoride/Potassium Iodide: An In Vitro Study

Ola M. Sakr

1. Department of Conservative Dentistry, College of Dentistry, Qassim University, Kingdom of Saudi Arabia.
2. Department of Operative Dentistry, College of Dentistry, Misr University for Science and Technology, Egypt.

Abstract

The aim of this in vitro study was to evaluate the microshear bond strength of total etch adhesives to pretreated dentin with silver diamine fluoride (SDF) or silver diamine fluoride/potassium iodide (SDF/KI) and to evaluate the mode of bond failure under scanning electron microscope (SEM).

Forty five dentin specimens were prepared from extracted human permanent premolars and divided into three groups (n = 15) based on the dentin surface treatment as follows: Control group (A) : total etch bonding system ; group (B) SDF pretreatment of etched dentin followed by bonding system and group (C) SDF/KI pretreatment of etched dentin followed by bonding system .

Resin composite cylinder was built on the dentin slabs to a height of 4 mm and dentin-composite cross section is approximately 0.8 mm. The prepared specimens were subjected to microshear bond strength analysis, and evaluation of the mode of failure of fractured surface was observed under SEM.

Statistical Analysis: One-way ANOVA followed by Tukey’s post hoc multiple comparison tests. Group C was found to have the highest mean value of microshear bond strength followed by a mean value of group A then group, B mean value. The difference between all group was non-significant as shown by the non-significant one-way ANOVA Tukey and post-hoc (P>0.05). The predominant mode of failure was adhesive followed by cohesive in resin and mixed.

Dentin Pretreatment with SDF or SDF/KI then dentin surface washing showed non-significant effect on the microshear bond strength of resin composite to dentin.

Keywords: Microshear bond strength, resin composite, silver diamine fluoride, potassium iodide, scanning electron microscope.

Introduction

The main goal of adhesive dentistry is to enhance an effective adhesion to dental tissues. Adhesion to dental hard tissues through micromechanical resin / tissue infiltration and hybrid layer formation. Stable hybrid layer depends on the degree of resin extension into demineralized dentin and the integrity of dentin matrix and resin components. Many studies have recorded dentin hybrid layer nanoporosities and have related these nanoporosities to incomplete or short resin infiltration into the demineralized dentin with subsequent matrix metalloproteinases (MMP) activation and dentin matrix degradation. The penetration of any substance into these nanoporosities is known as nanoleakage. The movement of water and enzymes like MMPs through nanoporosities can cause collagen fibrils degradation , exposing infiltrated adhesives, resulting in a reduction of bond strength by time.

In addition after proper cavity preparation and removal of caries the presence of potent microorganisms remaining resulting in secondary caries.

Different studies have shown that bacteria left in the prepared cavities will remain viable for a long period of time. Thus, tooth disinfection is considered as an essential step before restoration. Various strategies have been tried to

*Corresponding author:
Ola M. Sakr
1. Department of Conservative Dentistry, College of Dentistry, Qassim University, Kingdom of Saudi Arabia.
2. Department of Operative Dentistry, College of Dentistry, Misr University for Science and Technology, Egypt.
E-mail: olassakr2004@yahoo.com
eliminate or minimize nanoleakage at the resin-dentin interface at the same time act as antimicrobial agent. SDF is a colorless alkaline solution with active ingredients diamine-silver and fluoride ions has a valuable effect in dentin caries arrest. SDF can preserve the collagen fibers in dentin from degradation and inhibit further dentin demineralization, increasing dentin microhardness with an increase in calcium level and phosphorus in the surface dentin layer and inhibit the cariogenic bacteria active growth. FDA approved SDF 38% for the treatment of dentinal hypersensitivity in adults. In addition, SDF can chemically react with calcium and phosphate ions to form fluorohydroxyapatite with reduction of re-solubility, which is considered one of the key factors in caries lesion arrest.

The major drawback of SDF treatment, staining of dental tissues and restorative materials caused by the residual silver ions. It was noticed that application of potassium iodide (KI) can reduce staining caused by residual silver ions due to formation a washable creamy yellowish product silver iodide.

Potassium iodide (KI) is commonly used as an additive to nutrition. Supersaturated KI solutions were evaluated as a second step following treatment with SDF. SDF’s effectiveness in arresting caries was not impaired by KI use, or minimally impaired by it. But other studies showed that KI decreased the effects of SDF on anti-caries by reducing the number of silver ions. Caries arrest is dependent on the number of SDF applications to the affected lesion; re-application of SDF may be useful after one year. Systematic reviews stress that the best results for inhibiting caries are to reapply SDF every 6 months to an affected area for a period of 2 to 3 years.

The bonding strength of dentin to glass ionomer (GI) was not affected by SDF / KI treatment if the precipitates were properly rinsed off before GI was applied. When the precipitate is not washed away, the bonding strength has been reduced substantially. The pretreatment of dentin with SDF and KI minimized nanoleakage at the resin-dentin interface, assessed with a transmission microscope without reducing the bond strength of auto cure glass ionomer cement to dentin.

The aim of this in vitro study was to evaluate the microshear bond strength of total etch adhesives to SDF or SDF / KI pretreated dentin and to evaluate the mode of bond failure under scanning electron microscope (SEM).

Materials and methods

Selection of the Specimens
Forty-five permanent premolar teeth were collected free from caries, fluorosis, restorations or fractures, which were extracted for orthodontics.

The teeth were scaled and placed in distilled water. Using a diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) under water cooling at a low level, roots were cut and discarded 2 mm apical to the cementoenamel junction.

All specimen was embedded in self-curing acrylic resin (Meliodont, Heraeus Kulzer, Dormagen, Germany) in Teflon molds which exposed the occlusal surfaces of the specimen. Enamel was then removed using a 600-grit silicon carbide paper under running water to prepare a flat dentin surfaces 1 mm deep to dentinoenamel junction controlled by 2 grooves prepared with small abrasive round bur. Specimens were tested under a 40× stereomicroscope (Leica, MZ 12, Leica AG, CH-9435 Heerbrugg, Switzerland) to remove any defected, hypoplastic or cracked specimen.

Specimens Preparation and Grouping:

Forty-five dentin specimens were prepared and randomly divided into three groups (n = 15) according to dentin pretreatment. Group A (Control group) Specimens were used for direct application of adhesive and resin composite to dentin as follows: first, Dentin surface acid etching using 35% phosphoric acid gel (Scotchbond etchant gel) for 10 seconds without agitation and water rinsing for 10 seconds. The excess water was dried gently using a small cotton pellet, a hollow cylinder 4 mm in height was cut from a micro-bore tygon tube (Norton Performance Plastic; OH, USA) with an inner diameter of 0.8 mm and centered on the etched surface. Second, adhesive (Adper Single Bond 2 ) was applied to the etched surface of the dentin in accordance with the manufacturer's instructions and light cured for 10 s Third step , Resin composite(Filtek Z350XT, 3 M ESPE, St Paul, MN, USA )cylinder was placed incrementally on the dentin slabs at a height of 4 mm, and the dentin-composite cross section is
approximately 0.8 mm and cured using halogen curing light (3 M ESPE, St Paul, USA) with a light output of 600 mW / cm². The specimens were maintained in distilled water for 24 h at 37 °C. For group (B) specimens were tested for etched Dentin pretreatment using The SDF (38% Silver Diamine Fluoride) was applied to the dentin surface and left in place for three minutes water washing was done using distilled water and the excess water was blot dried using cotton pellet. then adhesive application and resin composite building.

For group (C) specimens were tested for etched Dentin pretreatment using the SDF /KI (38% Silver Diamine Fluoride was applied to the dentin surface and left in place for three minutes followed by application of KI solution, potassium iodide 5%, until a creamy yellowish precipitate formed, water washing was done using distilled water and the excess water was blot dried using cotton pellet. then adhesive application and resin composite building. Data for test materials are listed in Table 1.

### Table 1. Tested materials data.

<table>
<thead>
<tr>
<th>material</th>
<th>composition</th>
<th>Lot number</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotchbond etchant gel</td>
<td>35 % phosphoric acid</td>
<td>N 110288</td>
<td>3M ESPE</td>
</tr>
<tr>
<td>Adper Single bond 2</td>
<td>(10% colloidal nanofiller) BisGMA, HEMA, dimethacrylates, ethanediol, water, photosensitive system and a methacrylate-functional copolymer of polyacrylate and polyethylene glycol</td>
<td>N235024</td>
<td>3M ESPE</td>
</tr>
<tr>
<td>Fibre Z250 XT</td>
<td>(20 µm silica filler 4-11 nm zirconia filler) 72.5% by wt filler bis-GMA, UDMA, TEGDMA, PEGDMA and bis-GMA resins</td>
<td>N339145</td>
<td>3M ESPE</td>
</tr>
<tr>
<td>F-Array</td>
<td>38% Silver Diamine Fluoride</td>
<td>B327</td>
<td>Tesqueim</td>
</tr>
<tr>
<td>J. Crow's Lugol's sol.</td>
<td>Distilled water 85% potassium iodide 5%</td>
<td>18Q1207</td>
<td>J. Crow Company</td>
</tr>
</tbody>
</table>

### Table 2. Comparison, between all groups, of microshear bond strength test results (Mean±SD).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean±SD</th>
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<tr>
<td>Experimental groups</td>
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<tr>
<td>Group A</td>
<td>13.951±2.11</td>
</tr>
<tr>
<td>Group B</td>
<td>13.944±1.39</td>
</tr>
<tr>
<td>Group C</td>
<td>14.002±1.27</td>
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</table>

### Statistical analysis:
Analysis of the data was carried out in several steps. Descriptive statistics initially for the results of each group. One-way ANOVA accompanied by pair-wise post-hoc tests by Tukey were carried out to detect difference between groups. In all tests, P values below 0.05 are considered statistically significant.

### Results

It was found that group C showed the highest mean value of microshear bond strength (14.002±1.27MPa) followed by group A mean value (13.951±2.11MPa), then group B mean value (13.944±1.39MPa) The difference between all groups was non-significant as indicted by one-way ANOVA Tukey and non-significant post-hoc values (P>0.05).

### Scanning Electron microscope images and Fracture pattern.
Fracture pattern was evaluated visually and by SEM imaging (Figures 1,2,3).

**Figure 1.** Scanning electron microscopic image of representative group A fracture surfaces. Fracture was observed at the adhesive dentin conjunction, most of the dentin surface exposed.
Figure 2. Scanning electron microscopic image of representative group B. Fracture was observed cohesive within resin, most of dentin surface covered by adhesive.

Figure 3. Scanning electron microscopic image of representative group C. Fracture was observed cohesive within resin, most of dentin surface covered by adhesive.

Most fracture was adhesive, cohesive within resin or mixed fractures (Table 3).

<table>
<thead>
<tr>
<th>Table 3. Modes of fracture patterns.</th>
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<tr>
<td>Group</td>
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<tr>
<td>---------</td>
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<tr>
<td>Group A</td>
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<tr>
<td>Group B</td>
</tr>
<tr>
<td>Group C</td>
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In group (A), Control group specimens: Fracture was observed at the adhesive dentin conjunction, where breakage occurred in microtags and left most of the dentin surface exposed (Figure 1).

In groups (B and C) SDF and SDF/KI groups specimens: Fracture was observed cohesive within resin, where breakage occurred within adhesive and left most of the dentin surface covered by adhesive (Figure 2 and 3).

Discussion

SDF has been well documented as clinically effective treatment in caries arrest\(^{19}\). Many studies reported the in vivo success of SDF, in arresting and preventing dental caries\(^{20-22}\). In addition to its apparent initial bonding compatibility with resin composites in vitro, SDF may actually play a major role in operative dentistry.

The main disadvantage of using SDF is black staining of the tooth structure. Many studies documented that by application of KI following SDF application eliminate dark staining. As KI reacts with free silver ions forming a creamy yellowish precipitate of silver iodide, which eliminates the black staining caused by SDF application\(^{18,23}\).

Our finding showed that there was no significant difference in microshear bond strengths between the control group A (acid etched and rinsed dentin before bonding of resin composite), experimental group B (pretreatment of etched dentin with only 38 percent SDF before bonding of resin composite) and experimental group C (pretreatment of acid etched and rinsed dentin with combination of SDF/KI before bonding of resin composite).

SDF/KI precipitate formed on the dentin surface has reduced significantly the bond strength of auto cure glass ionomer cement to dentin\(^{18}\). There was a controversy results regarding the bond strength of SDF dentin pretreatment to adhesives\(^{25,26}\).

Jiang et al mentioned that No solid conclusion can be drawn on the effect of SDF application on the bond strength of dentin to adhesives due to Lack of a standard way to prepare specimen, including the SDF application protocol, is a probable reason to explain the inconsistency\(^{27}\).
From the results of this study, it was observed that pretreatment with SDF alone or SDF/KI did not adversely affect the bond strength of total etch bonding system to dentin. These findings may be explained that SDF or the reaction products of SDF/KI were thoroughly washed with water and dentin gentle drying before dentin bonding application. Moreover, SDF or SDF/KI application were done after acid etching of the dentin surface with 35% phosphoric acid. These findings were in acceptance with Knight et al and Quock et al\textsuperscript{18,28} who mentioned that either leaving SDF or the SDF/KI precipitate on the surface significantly reduced the bond strength to dentin. Moreover, Knight et al\textsuperscript{29} used an electron probe microanalysis and found that, following application of SDF/KI, increased levels of silver and fluoride were present on demineralize dentin samples compared to nondemineralized samples. The failure mode reflects not only the reliability of stress distribution during testing, but also the weakest area of the complex dentin-adhesive interface\textsuperscript{30}. In all groups of this study, the predominant mode of failure was adhesive followed by cohesive in resin then mixed.

According to the ultrastructure of the resin-dentin interface, specimens classified as adhesive failure which failed at the joint or adhesive layer. Cohesive failure in resin composite or dentin which the fracture was located cohesively in the resin composite or dentin. Any combinations of these two substrates were classified as mixed group.

Cohesive failure is explained by the brittleness of the materials involved and the mechanism of the test as an example of strong bonding. In our analysis, the failure was not further classified as cohesive in the resin composite or in the dentin.

Specimens with adhesive, cohesive, and mixed failures were included in analyses made.

As the properties of substrate have a remarkable effect on the bond strength results, so we can’t exclude cohesive failure specimens. Allaker R et al confirmed that testing bond strength and the analysis of failure mode didn’t depend on only substrate property but also on specimen preparation, design and flaws within materials, properties of materials subjected to bond strength testing, and the method of testing\textsuperscript{31}.

While Scherrer et al\textsuperscript{32} recommended exclusion of cohesive failure specimens from the statistical analyses, since the cohesive failure did not reflect the true interfacial bond strength but rather the mechanical properties of the substrates themselves.

Our results showed that more failure emerged in the control group A at the adhesive-dentin conjunction, leaving most dentin surfaces exposed, fracture occurred more frequently within the adhesive layer in the SDF and SDF / KI groups, leaving the dentin covered with some adhesive material.

This suggests that the bonding is stronger between the adhesives and dentin pretreated with SDF and SDF/KI groups rather than between adhesives and dentin with total etch bonding.

In clinical practice, SDF is usually applied to the dentin surface without rinsing with water\textsuperscript{18,24}. In the present study, SDF or the reaction products of SDF/KI were thoroughly washed with water and dentin gentle drying before dentin bonding application. Moreover, SDF or SDF/KI application were done after acid etching of the dentin surface with 35% phosphoric acid. These findings were in acceptance with incorporating SDF as clinical step of operative care for selective indications seems promising.

Conclusions

Within the limitations of this in vitro study, it can be concluded that pretreatment of dentin with either SDF or SDF/KI showed non-significant effect on the microshear bond strength of resin composite to dentin.

List of Abbreviation

SDF: silver diamine fluoride
KI: potassium iodide
SEM: scanning electron microscope

Acknowledgements

The author gratefully acknowledges Qassim University, represented by the Deanship of Scientific Research, on the material support for this research under the number (dent2018-1-14-S-3557) during the academic year 1437 AH /2016 AD"
Declarations of Interest

The authors report no conflict of interest.

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