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Effect of Silver Diamine Fluoride on Micro-Tensile Bond Strength of Composite to Dentin on Primary and Permanent Teeth

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ABSTRACT

Aim: The aim of the current study was to investigate the effect of silver diamine fluoride on micro-tensile bond strength of composite to dentin and on the bonding mechanism of dentin surface on primary and permanent teeth. Material and methods: This study included two groups: group 1 included twenty-four primary molars and group 2 included twenty-four premolars. Each group was further subdivided equally into sub-group A and sub-group B. Each group’s sub-group A had a self-etch bonding system treatment, and 4-mm thick composite buildups were applied in 1 mm increments. Each group’s sub-groups B were treated with 38% SDF, followed by the same self-etch bonding method as sub-group A, and composite was added. After being maintained in distilled water for 24 hours at 37°C, the restored specimens were cut into serial slabs about 1.0 mm thick using a slow-speed water-cooled diamond saw. Each slab was separated into composite/tooth structure beams with cross sections measuring 1.0*1.0 mm., which were then fastened to the test block of a micro-tensile testing apparatus to measure the maximum tensile force that could be applied before failure. A slab from each sub-group was examined using a scanning electron microscope, and microphotographs were recorded. Results: The study’s findings revealed a non-significant decrease in micro-tensile bond strength in the SDF-treated subgroups and significant decrease in primary molar micro-tensile bond strength when compared to premolars. In samples treated with SDF, microphotographs revealed a notable decrease in the quantity and depth of resin tags on the dentin surface. Conclusions: 1) The micro-tensile binding strength of the composite to the dentin is unaffected by SDF. 2) Premolars have a stronger micro-tensile binding strength between composite and dentin than primary molars. 3) SDF inhibits the development of resin tags.

1. INTRODUCTION

The four main etiological causes for dental caries are bacteria, fermentable carbohydrates, susceptible hosts, and time. Additionally, a person’s caries prevalence is influenced by a number of social and dietary factors, such as age, gender, nutritional status, and socioeconomic position. (1)

Early childhood caries (ECC) is not thought to be a life-threatening condition, but if left untreated, it can progress and cause severe pain, dental abscesses, severe local and systemic infections, and damage and early loss of primary teeth, which will eventually affect the permanent dentition. (2)

The World Health Organization’s Millennium Goals for 21st-century healthcare appear to be met by the caries-preventive agent silver diamine fluoride (SDF), which is effective, efficient, fair, and safe. (1) (4)

2. MATERIALS AND METHODS:

The Dental Research Ethical Committee of Faculty of Oral and Dental Medicine, Future University in Egypt (FUE.REC (4)4-2019, Meeting 4/4/2019) ethically approved the study. (Appendix 1).

2.1 Sample size:

Based on previous studies (5) (6) the proposed sample size was 48 teeth divided into two groups: 24 primary molars and 24 premolars.

2.2 Eligibility criteria:

According to the following criteria for eligibility, teeth were chosen:

Inclusion criteria:

Twenty-four primary molars and twenty-four premolars were collected from the output clinic of the department of Pediatric Dentistry and Dental Public Health, Faculty of Oral and Dental Medicine, Future University in Egypt.
The extracted teeth were conformed to the following criteria:

Materials and Methods

a) Molars were only extracted upon a clear clinical indication such as over-retained primary molars, molars near exfoliation, showing an erupting successor tooth or for orthodontic reasons.

b) Molars were free of any form of carious lesion, hypo-calciification or restoration.

c) Premolars were only extracted upon a clear clinical indication such as ankylosed premolars or for orthodontic reasons.

2.3 Teeth grouping:

After evaluation of these criteria, the samples were split into two groups of twenty-four teeth each at random. Each group was split up into two separate groups, each with twelve teeth.

2.4 Preparation of the extracted teeth:

Forty-eight non-carious, extracted primary molars and premolars were collected according to human subjects’ regulations and stored in 0.9% sodium chloride. To create acrylic resin blocks, a cylinder-shaped Teflon mould (15 mm in diameter and 40 mm in height) was combined with a metal ring that had two opposing screws on top (Figure 1). In order to keep the tooth centred and aligned to the mould’s long axis while the acrylic resin was setting, screws were used (Figure 2). After being set in acrylic resin blocks, teeth were attached to an automated diamond saw. (Isomet 4000, Buehler Ltd., Lake Bluff, IL, USA) (Figure 3), this is a low Speed cutting machine that was employed for all sectioning procedures during this investigation and is made to cut a variety of materials with little deformation. Under extensive water cooling, occlusal surfaces were flattened to reveal flat mid-coronal dentin (Figure 4). (Cool 2 water-soluble anticorrosive cooling lubricant, Buehler Ltd., Lake Bluff, IL, USA), with a concentration of 1:30, lubricant: water. 

Group 1: Primary molars:

Sub-group A1: Exposed flat dentin surface of twelve primary molars were treated with universal bonding system (figure 5) as instructed by the manufacturer.

Sub-group B1: Twelve primary molars’ exposed flat dentin surfaces were treated with a 38% SDF solution for three minutes (figure 6), then rinsed with distilled water for 30 seconds. (Young et al., 2021 and Frohlich et al., 2020) After that, the dentin surface received the same universal bonding treatment as sub-group A.

Group 2: Premolars:

Sub-group A2: Exposed flat dentin surface of twelve premolars were treated with universal bonding system according to manufacturers’ instructions.

Sub-group B2: Twelve premolars had their exposed flat dentin surfaces treated for three minutes with a 38% SDF solution, and then they were rinsed with distilled water for 30 seconds. (9,10) The same universal bonding method that was applied to the dentin surfaces in sub-group A was then utilized. CeramX® restorative composite buildups measuring 4 mm thick were applied in 1 mm increments after the required adhesives had been applied in accordance with the manufacturer’s recommendations. (figure 7). A LED
curing light was used to complete the curing process. After being kept in distilled water for 24 hours at 37°C, the restored specimens were sectioned occluso-gingivally into serial slabs about 1.0 mm thick \((11,12)\). Each slab was divided into composite/tooth structure beams with a cross section of around \(1.0 \times 1.0\) mm using the same slow-speed water-cooled diamond saw. \((13,14)\)

The cylindrical metal ring with the dimensions of 16 mm in diameter, 3 mm in height, and 2 mm in thickness that was used to create the L-shaped attachment (Figure 8) was soldered at the base to a metal rod (Figure 9), which was used to attach the component to the diamond saw apparatus. To enable precise positioning and rotation of acrylic blocks inside the gripping attachment, two axial grooves that are perpendicular to one another were constructed on the upper surface of a metal ring. The final part was two 5-cm long screws lined up to hold acrylic blocks in place while sectioning with the least amount of movement.

Then, while being properly cooled, the restored teeth were serially sectioned using a 0.3-mm thick diamond coated disc (Buehler, IL, USA) at 2050 rpm and an 8.8 mm/min feeding rate. (Figure 10). Serial sections were made in the bucco-lingual direction, rotated 90 degrees anticlockwise, and then cut in the mesio-distal direction (Figure 11). To obtain beams, At the level of the cemento-enamel connection, a final horizontal cutting was made\((15,16)\).

The resulting beams had lengths of \(5.5 \pm 0.1\) mm and a thickness of \(0.9 \pm 0.1\) mm. All beams’ length and thickness were measured using a computerised calliper (Mitutoyo, Tokyo, Japan) (Figure 12). Each beam was stored in distilled water at room temperature in a plastic cone with a secure closure and was identified by the subgroup and tooth from which it came.

2.5 Beam preparation:

To create composite-dentin beams of 1 mm x 1 mm in area, repaired teeth were longitudinally sectioned. An especially made gripping device was utilised to firmly hold acrylic blocks with installed teeth in place, parallel to the direction of sectioning, maintaining the perpendicular relationship between the cutting disc and the occlusal surface. Each beam was made of composite and dentin with adhesive at the interface.

Figure (5) — Universal adhesive

Figure (6) — Silver diamine fluoride

Figure (7) — Ceram.x composite

Figure (8) — L-Shaped gripping attachment (Front view) with perpendicular axial grooves (arrows)

Figure (9) — L-Shaped gripping attachment (Rear view) - Perpendicular metal rod (arrow)

Figure (10) — Operating parameter of the diamond saw machine. (Isomet 4000)
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2.6 Micro-tensile bond strength measurement:

36 beams, three from each tooth, were tested for each subgroup that was tested. Beams were mounted using Geraldeli’s jig onto the universal testing equipment (Instron, MA, USA). Each beam was positioned appropriately in the jig’s centre groove and then secured by the ends of each beam with cyanoacrylate-based glue (Zapit, DVA Inc., USA). Zapit Accelerator enhanced the glue’s hardening process. (17)

The jig was then attached to the universal testing apparatus (Instron, MA, USA), which has a load cell with a 500 N capacity (Figures 13–15). At a crosshead speed of 0.5 mm/min, tensile force was applied until the specimen’s bonding failed. In MegaPascal, bond strength was calculated. (Bluehill Lite software, Instron, MA, USA) (Figure 16).

2.7 Preparation of teeth for micro-photography:

For scanning electron microscopy (SEM) analysis, additional representative samples (n=4) from each subgroup were restored using the same techniques that were previously described. The same technique used to create beams was utilised to section the samples into 2-mm-thick slices, the slices were fixed with double sided sticky strip on aluminum stubs (Figure 17) and gold coating for 60 s at 45 mA in a vacuum metalizing chamber (QUORUM Q 150T ES, England) (Figures 18 and 19) were applied before observation by SEM (TESCAN-VEGA3, CZECH REPUBLIC) operated under 20 kV in different magnifications. (Figure 20) (18)
2.8 Statistical Analysis:

The data that was supplied to the computer was examined using IBM SPSS software, version 20.0. (Armonk, NY: IBM Corp.) Quantitative data were described in terms of percentage and number. The Kolmogorov-Smirnov test was used to determine whether the distribution was normal. Quantitative data were described using the range (minimum and maximum), mean, standard deviation, and median. The significance of the findings was established at the 5% level.

1. Mann Whitney test

In order to compare two study groups for quantitative variables having asymmetric distributions.

2. Kruskal Wallis test

Comparing between more than two investigated groups when a quantitative variable has an irregular distribution and employing the Post Hoc (Dunn’s multiple comparisons test) for pairwise comparisons.

4. Two-sample t-test

The two-sample t-test, sometimes referred to as the independent samples t-test, was employed to determine whether the unknown population means of two groups are equal.

3. RESULTS

3.1 Micro-tensile bond strength measurements:

A) Microtensile bond strength measurements of primary teeth:

The mean value of bond strength of sub-group A1 was 22.95(±0.82) MPa and for sub-group B1 22.76(±0.66) MPa and P value was 0.5366 which made SDF’s impact on the microtensile binding strength of the composite to the primary molar’s dentin not statistically significant. (Table 1) (Figure 21)

B) Microtensile bond strength measurements of premolars:

The mean value of bond strength of sub-group A2 was 31.47(±1.4) MPa and for sub-group B2 31.17(±1.26) MPa and P value was 0.5853 Thus rendered the impact of SDF on Micro-tensile bonding capacity of composite to premolar dentin not statistically significant. (Table 2) (Figure 22)
C) Comparison of microtensile bond strength measurement between sub-groups A in each group:

The mean value of bond strength of sub-group A1 was 22.95(±0.82) MPa and for sub-group A2 was 31.47(±1.4) MPa and P value was <0.0001 resulting in a statistically significant difference in primary and permanent teeth’s microtensile bond strength without SDF pretreatment. (Table 3) (Figure 23)

Table (3) Comparison between sub-groups A in each group:

<table>
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<th>n, beams</th>
<th>Sub-group A</th>
<th>P value</th>
<th>Statistically significant</th>
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<tr>
<td></td>
<td></td>
<td>(mean ± SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum load</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A1</td>
<td>36</td>
<td>22.95±0.82</td>
<td>&lt;0.0001</td>
<td>Sig.</td>
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<tr>
<td>Group A2</td>
<td>36</td>
<td>31.47±1.4</td>
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</tr>
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</table>

Statistical test used: Tow sample T Test

p-value≤0.05 considered statistically significant (95% confidence interval).

Figure (23) — Comparison between sub-groups A in each group

D) Comparison of microtensile bond strength measurements between sub-groups B in each group:

The mean value of bond strength of sub-group B1 was 22.76(±0.66) MPa and for sub-group B2 was 31.17(±1.26) MPa and P value was <0.0001 which made the difference of micro-tensile bond strength between primary and permanent teeth after SDF treatment statistically significant. (Table 4) (Figure 24)

Table (4) Comparison between sub-groups B in each group:

<table>
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<th>Sub-group B</th>
<th>P value</th>
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<td>Group B1</td>
<td>36</td>
<td>22.76±0.66</td>
<td>&lt;0.0001</td>
<td>Sig.</td>
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<tr>
<td>Group B2</td>
<td>36</td>
<td>31.17±1.26</td>
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</tr>
</tbody>
</table>

Statistical test used: Tow sample T Test

p-value≤0.05 considered statistically significant (95% confidence interval).

3.2 Micro-morphological analysis:

The micro-photographs of both primary and permanent dentin surface without SDF application revealed a clearly defined resin-dentin inter-diffusion zone and a large number of tags of resin in the dentinal tubules interlacing to create resin bundles in the primary molar sample, for SDF treated group, While the resin tags were generated, they were not as regular in shape and consistency as the untreated specimen, which were longer, more regular, and diffused more in the dentinal tubules than those formed in the SDF group. (Figure 25)

Figure (25) — SEM images of the dentine and restorative materials interface; without SDF treatment (first column) and with SDF treatment (second column)
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4. DISCUSSION

In this study, the investigators measured the micro-tensile bond strength of composite to dentine of primary and permanent teeth with and without SDF pretreatment. The results showed that both primary teeth and permanent teeth in the SDF groups had a non-significant drop in micro-tensile bond strength. Figures 1-2. This study’s findings supported those of other research by Quock et al. (2012) and Wu et al. (2016), which discovered that pretreating dentin with 38% SDF had no effect on the micro-tensile strength of composite. (19,20)

The current study’s findings were in agreement with those of Wang et al. (2016) and Puwanawiroj et al. (2018), who measured the micro-tensile bond strength of glass ionomer cement to dentin before and after SDF application. Their findings indicated that SDF had no impact on the bond strength between glass ionomer cement and primary dentin. (31)(32)

On the other hand, in a 2016 study, Koizumi et al. discovered that pretreating the surface of dentin with potassium iodide and silver diamine fluoride (SDF/KI) significantly decreased the binding strength. The inclusion of potassium iodide in their experiment, which was applied immediately after SDF and before bonding to reduce the dark staining brought on by SDF, may have contributed to these differences in their results. (21)

The current study showed a significant difference in composite bond strength to dentin between primary and permanent teeth with and without SDF application (Tables 3-4) which agreed with a study by Burrow et al., who evaluated the micro-tensile bond strengths of different dentin bonding agent to primary and permanent dentin and discovered that permanent dentin had greater overall bond strengths than primary dentin. (22)

This goes in parallel to the results of a systematic review made by Pires et al who collected data from 37 articles. The meta-analysis showed that primary and permanent teeth did not bond to dentin similarly, with permanent dentin having a higher bond strength than primary dentin. This may be because primary and permanent dentin differ in composition and micro-morphology, which may affect how well adhesives work. (23)

The decreased concentration of calcium and phosphorus in the peritubular and intertubular dentin of primary teeth may be the reason for the poorer binding strength to primary dentin, according to Courson et al. (26). In 2013 a study performed by Lenzi et al. found that in primary teeth, the tubular density is higher and the intertubular dentin area was smaller than permanent teeth, which might put the bonding performance in risk. (27)

According to other studies, primary teeth’s lower mineral content may make them more vulnerable to the effects of acidic conditioners, which led to the development of a thick hybrid layer and weaker bond strengths. (22,29,30)

In this study, the results of micro-morphological examination of primary and permanent teeth’s dentin surfaces with and without the administration of SDF revealed that SDF had negative effect on resin tags formation for both primary and permanent dentin samples. This result agreed with the result obtained from another study conducted by Koizumi et al., who concluded that samples treated with SDF showed much fewer tags formation than non-treated samples. This demonstrated that the tubules were blocked, preventing the entrance of resin. (31)

The negative effect of SDF on resin tags penetration was supported with other studies which stated that SDF had an important role in minimizing dentin hypersensitivity and managing the symptoms of MIH affected teeth by silver ions’ capacity to occlude dentinal tubules by protein precipitation as well as the stimulation of the synthesis of calcium fluoride and silver iodide, both of which can do so and reduce the patency of the tubules. (32)(33)(34)

Although the result of the current study showed a negative impact of SDF on the resin penetration into dentinal tubules and negatively affect resin tags formation, the binding strength of composite to dentin was not affected by this finding as the role of resin tags in bonding was claimed to be very limited and not effective. Some self-etch adhesives do not produce resin tags and have high bond strength, and some etch and rinse adhesives produce long and many resin tags but at the same time have low bond values which agreed with Kwong et al. who found that higher bond strength was achieved by using self-etch adhesive systems rather than etch and rinse systems as a result of the ability of self-etch adhesives to produce chemical bonding with tooth structure which is more important and effective than micro-mechanical bonding achieved by resin tags formation. (35)

In the current study, the investigator used universal adhesives, which contain functional monomers with a specific phosphate or carboxylate group that form an ionic bond with calcium found in the hydroxypatite of the tooth surface and so influence the bonding strength. (36) This reaction led to formation of non-soluble calcium salts which help in promoting strong adhesion to tooth surface. (37) This finding agrees with previous reports that support the fact that the role of chemical bonding is much more important than micro-mechanical bonding. (38)

One strength of this study was testing the impact of SDF on the micro-tensile bond strength of composite to dentin of primary and permanent teeth, evaluating its impact on the resin-dentin interface by microphotographs, and comparing the micro-tensile bond strength of composite to dentin between primary and permanent teeth before and after SDF treatment. Moreover, all clinical procedures done in the present study were performed by the same operator to exclude inter-operator bias. Besides, all study participants (except the main investigator), technicians and the statistician were made blind to the type of treatment used to reduce possibility of detection and performance bias.

5. CONCLUSIONS:

The following conclusions could be taken from the current study’s findings:

1. The micro-tensile binding strength of composite to dentin is unaffected by SDF.
2. Premolars have a stronger micro-tensile binding strength to the dentin than primary molars.
3. Resin tag formation is adversely affected by SDF.
4. Role of chemical bonding is much more important than micro-mechanical bonding.

6. RECOMMENDATIONS

1. SDF is highly recommended to be used as caries arresting material and restoring the tooth with an adhesive restoration after SDF application is a successful alternative treatment to traditional surgical approach.
2. Further studies are required to examine the impact of SDF/KI on micro-tensile bond strength of composite to dentin.
3. Further clinical investigations are required to assess the effect of etch and rinse system on resin tags penetration into dentinal tubules after SDF treatment.

7. REFERENCES


