Influence of Dentinal Erosion on Shear Bond Strength of Composite Restorations with Different Bonding Systems

Dental Erozyonun Farklı Bağlayıcı Ajan Kullanılarak Yapılan Kompozit Restorasyonların Kesme Bağlanma Kuvvetine Etkisi

Aim: The aim of the study is to examine the effect of dentinal erosion on shear bond strength of composite restorations.

Materials and Methods: A half of 80 dentin pairs were subjected to erosion and toothbrush abrasion (eroded samples) whereas the other half was subjected to toothbrush abrasion (non-eroded samples) during six days. The restorations were bonded with (1) OptiBond FL, (2) Excite, (3) One Coat SE Bond and (4) G-Bond. The samples were stored at 37°C for 24 h and thermally cycled 1000 times. The shear bond strength was measured and fractured areas were analyzed by SEM.

Results: Without pre-test failures (PTF), the mean bond strength for the eroded samples was 18.20±10.31 MPa and for the non-eroded samples 21.12±11.14 MPa. In the eroded samples, groups 1, 3 showed higher shear bond strengths than groups 2, 4, but without statistically significant differences (p>0.05). In the non-eroded samples, group 1 showed higher bond strength than groups 3, 4 (p<0.05). A comparison between the eroded and non-eroded groups showed statistically significant increase of bond strength in the non-eroded samples of groups 1 and 2, but a decrease in the non-eroded samples of group 3.

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INTRODUCTION

Dental erosion can be defined as a progressive mineral loss resulting from nonbacterial chemical process when the surrounding phase is unsaturated with respect to tooth mineral\(^1\). The initial enamel erosion lesion can be overlooked by the dental practitioners since it appears as a smooth glazed surface of the tooth. With the progression of the lesion, a concavity in enamel followed by loss of the morphology may be encountered\(^2\). Fluoride containing products were shown to promote remineralization of enamel erosion\(^3\). Therefore, enamel erosion lesions may need restorative therapy due to esthetic disturbances. However, in case of a dentinal erosion, sealing of the dentin becomes mandatory to avoid hypersensitivity and future complications including pulpal inflammation, necrosis and periapical inflammation\(^4\)\(^,\)\(^5\).

For restoration of the dentinal erosion lesions, composite resins have been considered as the material of choice since it is possible to restore erosion lesions with a conservative manner\(^6\). Until recent years, bonding systems that require a separate etching step have been commonly used with composite resins. The self-etching primer and adhesive systems have been introduced with the aim of simplifying the bonding procedure and to reduce technique sensitivity suggested to be related to the total etch systems\(^7\). In the literature, although it was shown in situ that applying dentin bonding agents on dentin prevents erosive attacks, the effect of dentinal erosion on bond strengths still remains to be researched\(^4\)\(^,\)\(^5\). The aim of this study was therefore to investigate the effect of erosively altered dentin on the shear bond strength of composite restorations with different types of bonding systems to dentin. The null hypothesis was that there are no differences between the shear bond strength of erosively altered and non-altered dentin.

MATERIALS AND METHODS

The tissue remnants of 40 extracted impacted human molars were removed and they were kept in 0.2% thymol solution at 4\(^\circ\)C for two months. Before use, the teeth were rinsed under running tap water for 15 s.

Preparation of the samples

The buccal tooth surfaces were ground under constant tap water cooling with a 1000-grit silicon carbide paper on a rotating polishing machine (Struers LaboPol 21, Copenhagen, Denmark) to obtain flat dentin surfaces at the mid-coronal

\(p<0.05\). Among failure types, no statistically significant differences were found between the eroded and non-eroded groups \((p>0.05)\).

**Conclusion:** The data suggested that erosion and toothbrush abrasion can alter dentinal surface and influence bond strength.

**KEYWORDS**

Dental erosion, dental abrasion, bond strength, composite resin, dental adhesive

**ANAHTAR KELİMELER**

Dental erozyon, dental abrazyon, bağlanma kuvveti, kompozit rezin, dental adeziv

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**Conclusion:** The data suggested that erosion and toothbrush abrasion can alter dentinal surface and influence bond strength.

3'ün erozyonsuz örneklerinin bağlanma kuvvetinde ise azalma tespit edilmiştir \((p<0.05)\). Kırılma tipleri açısından erozyonlu ve erozyonsuz gruplar arasında istatistiksel olarak anlamlı farklılık bulunmamıştır \((p>0.05)\).

**Sonuç:** Erozyon ve diş fırçası abrazyonun dentin yüzeyini ve dentine olan bağlanma kuvvetini etkilediği sonucuna varılmıştır.
portion. The roots of the teeth were embedded in a self curing resin (Paladur, Heraeus Kulzer GmbH, Wehrheim, Germany) by using plastic molds. After setting of the resin, the teeth were cut bucco-lingually with a double-faced diamond saw (Isomet, Buehler Ltd, IL, USA). The roots were cut away to obtain two identical crown pairs from each tooth. It was planned to subject one pair to erosion and toothbrush abrasion (eroded sample) whereas the other pair to toothbrush abrasion without erosion (non-eroded sample).

Each tooth pair was embedded in resin in two planar parallel molds as follows:

Firstly, a thin mold (200 µm thick) was put onto an adhesive tape. The dentin surface of the tooth pair was placed on the adhesive tape so that it was positioned in the center of the thin mold. Then, the thick mold (3 mm thick) was put on the thin mold. A self curing resin (Paladur, Heraeus Kulzer GmbH, Wehrheim, Germany) was poured into the molds. After setting of the resin, the adhesive tape and the thin mold were removed from the glass. The dentin surface was ground down on the thick mold with a 1000-grit silicone carbide paper under constant water-cooling until the marks of the removed thin mold on the acrylic resin was eliminated. This procedure allowed obtaining a standardized surface substance loss of 200 µm on each sample. After polishing, all samples were rinsed and sonicated in demineralized water for 2 min. The enamel parts of each sample were covered with melted utility wax and then with one coat of nail varnish (Lady Manhatten Cosmetics, Germany). An overview of the preparation of the samples is given on Figure 1.

**Erosion procedure**

The eroded samples were submitted to a computer-assisted, automatic erosion-inducing system. Erosion and remineralization cycles were created by a pH cycling process. Each cycle was composed of four steps (Figure 2):

1. The teeth were placed in a container and 400 ml of a 2 l demineralization solution was pumped from the reservoir. The demineralization solution contained 1% citric acid with a pH of 3.5 and had a temperature of 37°C. The teeth were exposed to demineralization solution for 5 min.

2. After 5 min, the demineralization solution was pumped back from the container to the reservoir and the teeth were washed with 300 ml deionized water for two times.

3. From the reservoir containing remineralizing solution, 400 ml of the solution was pumped into the container. The remineralization solution contained 0.002 g ascorbic acid, 0.58 g NaCl, 0.17 g CaCl₂, 0.16 g NH₄Cl, 1.27 g KCl, 0.16 g NaSCN, 0.33 g KH₂PO₄, 0.34 g Na₂HPO₄ dissolved in 1 liter of demineralized
water. By adding HCl, the pH of the solution was set to 6.4 and had a temperature of 37°C. The teeth were exposed to remineralization solution for 3.5 h.

4. Then the demineralization solution was pumped back from the container into the reservoir and the teeth were washed with 300 ml deionized water for two times.

Each day composed of six demineralization and six remineralization cycles and the experimental procedure was continued for six days. The non-eroded samples were kept in 150 ml remineralization solution at 37°C. The pH of the solutions was checked periodically. The solutions of eroded samples were renewed twice whereas those of the non-eroded samples were changed each day. In each day, at the end of 1st and 3rd erosion cycles of eroded samples, all samples were subjected to tooth brushing (Figure 2). After the eroded samples were washed with 300 ml demineralized water for 60 s by the machine, they were taken out of their container. The non-eroded samples were also washed with the same amount and for the same time in a container. To create toothbrush abrasion, the eroded and non-eroded samples were brushed with a toothbrush (Elmex Medium, Gaba, Switzerland) and a slurry of toothpaste. The slurry was prepared with a fluoridated toothpaste containing 1.450 ppm F in the form of NaF (Signal Mentadent, Sensitive Extra, Lever Fabergé, Thayngen, Switzerland) and remineralization solution in the proportion of 25% (1:3 (w/w), respectively). Fresh slurry was prepared for each brushing time. 0.2 ml toothpaste slurry was applied on each sample by an injector. Then, the dentin surfaces on the samples were brushed with circular rounding movements. In each second, two brushing circles were applied and each tooth was brushed for 15 s. After brushing, the samples were washed with demineralized water for 10 s. While the 2nd washing procedure of the eroded samples was performed in the container by the machine, the 2nd washing of the non-eroded samples was done in a container with the same amount of demineralized water (300 ml) and remained in the container for the same time (60 s) as the experimental samples.

Preparation of the restorations

During the episodes of the study, each sample was kept in individual containers at 40°C under a 100% humidity environment, which was established by a cotton roll wetted with 0.1% chlorhexidine-digluconate solution (Hibitane, Inselspital Apotheke, Bern, Switzerland). A piece of polytetrafluoroethylene (PTFE) tape with a circular hole matching with the same diameter of the further applied mold was positioned on the dentinal surface. The bonding application of the four different adhesive systems was made following the manufacturers instructions (Table I). In all groups Tetric Evo Ceram (Lot No. H16448) Ivoclar Vivadent AG, Schaan, Liechtenstein) was used as the composite resin. It was placed into cylindrical-shaped plastic
molds with an internal diameter of 2.35 mm and a height of 3 mm (Ultradent Products Inc, South Jordan, USA). The composite was light cured for 40 s with a high power LED light curing unit (Bluephase, Ivoclar Vivadent AG, Schaan, Liechtenstein). After completion of the restorations, the samples were stored in a dark humidity chamber at 37°C for 24 h. Then they were subjected to thermal cycling in tap water 1000 times between 5°C and 55°C with a dwell time of 30 s in each bath and a transfer time of 3 s (Figure 1). After thermocycling, the nail varnish and the wax on the samples were removed with a hand instrument.

<table>
<thead>
<tr>
<th>Group</th>
<th>Adhesive system</th>
<th>Ingredients</th>
<th>Lot No</th>
<th>Application protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Optibond FL</td>
<td>Etchant: 37% phosphoric acid&lt;br&gt;Primer: HEMA (2-hydroxymethylmethacrylate)GP DM (glycerol phosphate dimethacrylate), PAMM (phtalic acid monoethyl metacrylate) ethanol, water&lt;br&gt;Adhesive: Bis-GMA, HEMA, GDMA, Ba-Al-borosilicate, silicate glass filler, Na₂SiF₆</td>
<td>Primer 448041</td>
<td>Etch dentin for 15s, rinse 15 s and gently air dry. Apply primer by light scrubbing motions for 15 s. Gently air dry for 5 s.</td>
</tr>
<tr>
<td></td>
<td>Three-step etch-and-rinse adhesive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Kerr Corp., CA 92867, USA)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Excite</td>
<td>Etchant: 37% phosphoric acid&lt;br&gt;HEMA, dimethacrylates, phosphonic acid acrylate, highly dispersed silicon dioxide, initiators, stabilizers, alcohol</td>
<td>H15301</td>
<td>Etch dentin for 15 s, rinse 15 s and gently air dry. Gently agitate the agent to dentin for 10 s. Gently air dry for 3 s. Light cure for 20 s.</td>
</tr>
<tr>
<td></td>
<td>Two-step etch-and-rinse adhesive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Ivoclar Vivadent AG, Schaan, Liechtenstein)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>One Coat SE Bond</td>
<td>Primer: Water, HEMA, dimethacrylates, polyalkenoate methacrylized acrylamidosulfonic acid, Bond: HEMA, dimethacrylates, UDMA (urethane di-methacrylate: 1,6-dimethacryl-ethyloxy-carbonylamino-2,4,4-trimethylhexane), initiators</td>
<td>Primer 0098662</td>
<td>Apply Primer 1 to dentin, rub in for 20 s. Gently air dry for 2 s.</td>
</tr>
<tr>
<td></td>
<td>Self-etch adhesive</td>
<td></td>
<td>Bond 0100888</td>
<td>Apply Bond 2 to dentin, rub in for 20 s. Gently air dry for 2 s. Light cure for 10 s.</td>
</tr>
<tr>
<td></td>
<td>(Coltène / Whaledent, Altstätten, Switzerland)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>G-Bond</td>
<td>4-MET (4-methacryloyloxethyl trimellitic acid), phosphate acid, monomer, UDMA, silica acetone, water, photoinitiator</td>
<td>0606211</td>
<td>Apply to dentin surface, leave undisturbed for 10 s. Strongly air dry for 5 s under maximum air pressure. Light cure for 10 s.</td>
</tr>
<tr>
<td></td>
<td>One-step self-etch adhesive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(GC Corp., Tokyo, Japan)</td>
<td></td>
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</tbody>
</table>
Shear bond strength testing

The shear bond strengths were measured with a universal testing machine (Zwick/Roell, Seidel Servo Drives Dusseldorf, Germany). Each sample was positioned on a holding device attached to the testing machine. An apparatus containing a notched blade on the forcing side was inserted to the machine. A crosshead speed of 1mm/min was applied until fracture occurred, parallel to the dentin surface. Shear bond strength was recorded in MPa.

Fracture analysis

After the samples were sputter coated with gold-palladium, fracture analysis was performed using a scanning electron microscope (SEM) (Noran Instruments, Z- MAX 30 Series, Middleton, USA). Failures were classified as adhesive, cohesive in composite, cohesive in adhesive and cohesive in dentin (Figure 3a, 3b, 4a)\(^{10,11}\). 10 samples were reevaluated one week later to determine the inter-examiner reliability.

STATISTICAL ANALYSIS

The statistical analysis (SPSS Version 11, SPSS Inc., Chicago; IL,USA) regarding bond strength values was performed with and without pre-test failures (PTF). The level of significance was set as \(p=0.05\). Two-way ANOVA was used to analyze the interaction between the erosion process and four different bonding systems. Since the interaction was found to be statistically significant, One-way ANOVA was used to analyze the differences among the eroded and non-eroded groups. Duncan’s multiple comparisons test was used to make comparisons among the

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**FIGURE 3**

(a) Adhesive failure of a non-eroded sample in Group 1. (b) Adhesive failure observed in an eroded sample of Group 1. The picture shows that the interface separated with almost intact resin tags

**FIGURE 4**

(a) Cohesive failure in adhesive with blister-like structures in a non-eroded sample in Group 4. (b) Blister-like formations in an eroded sample of Group 2
eroded and non-eroded subgroups. Paired sample t-test was used to compare the eroded and non-eroded subgroups of all groups. With respect to the failure types, marginal homogeneity test was used to determine the differences between the eroded and non-eroded groups. Due to the small number of samples, extension of Fisher’s Exact test was used to analyze the differences in failure modes among eroded and non-eroded groups. The inter-examiner reliability was evaluated by using the Kappa test.

RESULTS

Shear bond strength testing

The mean bond strength values were shown in Table II. With PTF, the mean bond strength value for the eroded groups was found to be 15.47 ± 11.54 MPa. For the non-eroded groups it was found to be 18.48± 12.58 MPa. Without PTF, the mean bond strength value for the eroded groups was found to be 18.20 ± 10.31 MPa. For the non-eroded groups it was found to be 21.12 ± 11.14 MPa. With or without PTF, no statistically significant differences were found among the eroded groups (p>0.05). However, statistically significant differences were found among the non-eroded groups (p<0.05). Without PTF, there were no statistically significant differences between Groups 1 and 2, 2 and 4, 3 and 4 (p>0.05). With PTF, no statistically significant differences were found among Groups 2, 3 and 4 (p>0.05).

In comparison of the eroded and non-eroded subgroups, the eroded samples exhibited higher bond strength than the non-eroded samples in Group 3. Without PTF, the non-eroded samples exhibited higher bond strength than the eroded samples in Groups 1 and 2 (p<0.05).

<table>
<thead>
<tr>
<th>Group</th>
<th>Eroded ± SD (n=10)</th>
<th>Non-eroded ± SD (n=10)</th>
<th>p</th>
<th>Eroded ± SD (n)</th>
<th>Non-eroded ± SD (n)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.66 ± 12.08</td>
<td>28.63 ± 12.20</td>
<td>0.119</td>
<td>20.74 ± 10.76 (n=9)</td>
<td>31.81 ± 7.33 (n=9)a</td>
<td>0.008**</td>
</tr>
<tr>
<td>2</td>
<td>9.50 ± 11.22</td>
<td>17.41 ± 13.62a</td>
<td>0.072</td>
<td>13.58 ± 11.14 (n=7)</td>
<td>24.87 ± 7.87 (n=7)a,b</td>
<td>0.047**</td>
</tr>
<tr>
<td>3</td>
<td>20.37 ± 12.04</td>
<td>11.00± 9.19a</td>
<td>0.024**</td>
<td>22.64 ± 10.26 (n=9)</td>
<td>12.23 ± 8.85 (n=9)c</td>
<td>0.027**</td>
</tr>
<tr>
<td>4</td>
<td>13.33 ± 8.84</td>
<td>16.86 ± 9.26a</td>
<td>0.284</td>
<td>14.81 ± 7.95 (n=9)</td>
<td>16.86 ± 9.26 (n=10)b,c</td>
<td>0.505</td>
</tr>
<tr>
<td>Total</td>
<td>15.47 ± 11.54</td>
<td>18.48± 12.58</td>
<td></td>
<td>18.20 ± 10.31 (n=34)</td>
<td>21.12 ± 11.14 (n=35)</td>
<td></td>
</tr>
</tbody>
</table>

* The distribution of PTF: Three eroded samples (Groups 1, 2) and two non-eroded samples (Groups 1, 3) broken after thermal cycling. One eroded sample (Group 2) broken while inserting to the testing machine. Two eroded samples (Groups 3, 4) and two non-eroded samples (Group 2) were broken after sample preparation. One non-eroded sample (Group 2) broken after 24 h of storage.

** p values with superscript indicate statistically significant differences between eroded and non-eroded groups of the same line. The same superscript letters indicate statistically insignificant differences between groups of the same column.
Fracture Analysis

The distribution of the failure types of eroded and non-eroded groups were shown in Table III. With respect to the failure types, no statistically significant difference was found between all eroded and non-eroded groups (p = 0.881). In addition, there were no statistically significant differences between the eroded and non-eroded subgroups of all groups. Similarly, no statistically significant differences were found among the eroded and non-eroded groups (p > 0.05).

The inter examiner reliability was calculated as 0.836 with the Kappa test.

DISCUSSION

In the present study, a split design was used to find out the effect of erosion and/or tooth brushing on the dentin bond strength of different bonding systems. Six erosion cycles were distributed to a whole day since erosive attacks may also occur at night because of gastroesophageal reflux. The procedure continued for six days since erosion was detected to occur in the pre-test samples of the study. In the pre-test of the study, it was observed that with the used method and time a regular erosion pattern was achieved on the samples. Brushing the tooth samples was also carried out in both eroded and non-eroded samples because in the recent years attention has been directed towards the combined effects of erosion and tooth brushing on the dentinal wear.

The obtained results showed that each bonding system acted differently against erosion. This may be related to the great variation in the dentin structure and different mineral content of each tooth which may cause each tooth to respond to the erosion process differently. The high standard deviations in each group also showed that each tooth was influenced from erosion and/or tooth brushing separately. Another reason could be related to the variability in the action mode of the bonding agents. In general, the self-etch adhesive groups (Group 3 and 4) exhibited better or very close results in the eroded samples whereas the etch-and-rinse adhesives (Group 1 and 2) acted better

<table>
<thead>
<tr>
<th>Group</th>
<th>Adhesive</th>
<th>Adhesive + cohesive in adhesive</th>
<th>Adhesive + cohesive in adhesive + cohesive in composite</th>
<th>Cohesive in adhesive</th>
<th>Adhesive + cohesive in composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Eroded</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 Non-eroded</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2 Eroded</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2 Non-eroded</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>3 Eroded</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 Non-eroded</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 Eroded</td>
<td>6</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4 Non-eroded</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>27</td>
<td>18</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
in the non-eroded samples. These results may be related to the altered mineral content of the eroded dentin, which may promote the mild etching effect of the self-etch adhesive agents. In addition, in the etch-and-rinse adhesives erosion and subsequently applied phosphoric acid may result in overetching of the dentin, which may lead to excessive mineral loss and insufficient replacement of the adhesive resin and affect the bonding ability. The adhesive failure observed with almost intact resin tags in some eroded samples of etch-and-rinse adhesives (Fig. 3b) may be attributed to the insufficiency of the bonding agent to completely penetrate the demineralized areas created by erosion and subsequently applied phosphoric acid etching.

The finding that demonstrated the effect of erosion on the bond strength was the statistical insignificance among the eroded groups. In contrast, higher bond strengths were obtained in etch-and-rinse adhesives than self-etch ones among the non-eroded groups, which is in conformity with other studies. It would be reasonable to attribute the statistical insignificance in the eroded groups to the changed mineral content of the dentin due to acidic challenges. However, the insignificance between the eroded and non-eroded samples regarding the failure modes may be related to the small sample number due to PTF. Another reason could be related to the classification type since all failure combinations were used instead of classifying them only as a mixed failure.

The term PTF is generally used in the microtensile testing studies. In the present study, however, the results were evaluated both with and without PTF since it could influence the results of the study. Of the 11 failed samples, five were broken after thermal cycling. No study has been found regarding the effect of thermal cycling on erosion. As three of the samples belong to the eroded groups and two of them to the non-eroded groups, the effect of thermal cycling seemed not to be dependent on erosion. The effect of thermal cycling on the failure of the samples may be due to the hydrolysis effect of water at the interface of the bonding resin and the hybrid layer. As there had no failed sample belonged to the 2-Hydroxy-ethyl-methacrylate (HEMA)-free bonding system (Group 4), it would be reasonable to consider the effect of HEMA as it reacts with the collagen fibrils in dentin by forming fragile hydrogen bonds that may be influenced from thermal actions. Other reasons for PTF could be the insufficient replacement of the adhesive due to the altered surface conditions caused by erosion and/ or tooth brushing or technical problems.

In the present study, the dentin surface was strongly air-dried in Group 3 since in recent publications it was reported that in the HEMA containing self-etch adhesives HEMA can retain water. As the one-step self-etch adhesive used in the study was the HEMA-free one, the manufacturer’s instruction was used. Therefore, a dry bonding technique was used by drying the dentinal surface for 5 s. Strong air drying after the application of G-Bond is recommended by the manufacturer and blister-like formations were reported to occur less in number and size when strong blowing was applied. These structures were reported to occur in acetone based, HEMA containing etch-and-rinse adhesive systems with visibly moist and overwet conditions. In the present study, they were commonly observed in Group 4 (Figure 4a), but also detected in few samples of Group 1 and 2 (Figure 4b). The reason for these structures in the etch-and-rinse adhesive groups may be attributed to the solvents ethanol and/or water, which might act as inhibitors of the polymerization of the resin components in adhesive when the air drying of the solvent is inadequate. Although G-Bond is a HEMA-free adhesive, it contains water and high acetone content (40%) that is required to maintain components in the adhesive. Since the vapor pressure of acetone is lower than that of water, it evaporates very quickly while water remains in the adhesive. In addition, the high acetone content contributes to blister formations by facilitating water movement from the dentin...
with or without the initial moisture of the dentin surface\textsuperscript{26-28}.

The shear bond strength testing used in the present study is considered to be representative of the clinical situation\textsuperscript{29}. However, larger adhesive interface compared to the microtensile testing samples may result in more defects which would decrease bond strength and increase coefficient of variation\textsuperscript{29,30}. Therefore, the effect of erosion on bond strength may also be tested by using different bond strength methodologies.

**CONCLUSIONS**

The following conclusions can be drawn within the limits of the present study:

1. In the non-eroded dentin, the etch-and-rinse adhesives exhibited bond strength values exceeding 17 MPa required to prevent debonding and resist polymerization shrinkage \textsuperscript{31}.

2. In the eroded dentin, no superiority was found among materials that can be attributed to the changed mineral content of the dentin due to acidic challenges. Therefore, the null hypothesis was rejected.

**ACKNOWLEDGEMENTS**

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**REFERENCES**

20. Helvatjoglu-Antoniades M, Koliniotou-Kubia E, Dionyssopoulos P. The effect of thermal cycling on the


