Investigation of Micro-leakage of Self-cured and Light-cured composite restorations using a universal bonding system

Original Article

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Abstract

Introduction:
One-bottle light-cured adhesives systems have variable pH. In addition to ease of use, universal adhesives can be used in various restorations and different substrates. Due to the lack of studies, the purpose of this study was to compare the enamel and dentin micro-leakage of self-cure and light cure composite restorations using a universal bonding system.

Materials and methods:
The CL V cavities prepared on 60 bovine incisors (dimensions of 5 mm mesio-distal, 2 mm occluso-gingival and 1.5 mm in depth). Occlusal and gingival margins were 1mm above and below the CEJ. All Bond Universal bonding agent was applied to the cavities according to the manufacturer’s instructions by selective etch method. The teeth randomly divided into group 1 which were restored with Master-Dent self-cure composite and group 2 restored with light cure AEL-ITE All-Purpose composite. After thermocycling, the micro-leakage rates evaluated in two occlusal and gingival margins by stereomicroscope.

Results:
The rate of micro-leakage at both gingival (dentin) (p ≤ 0.035) and occlusal (enamel) (p ≤ 0.015) margins in the self-cure composites were significantly higher than the light cure composites. In each group, gingival micro-leakage was also recorded higher than the occlusal (however, this difference was not statistically significant in the self-cure composite group) (P = 0.474).

Conclusion:
According to the results, the All Bond Universal adhesive agent is not compatible with self-cure composite and can result in increased micro-leakage.

Key words:
•Dental Leakage •Self-Curing of Dental Resins •Light-Curing of Dental Adhesives
Increasing patient demand for more esthetic restorations has led the research toward tooth-colored restorations. In this regard, the resin-based composites are the most widely used ones (1). Due to their specific characteristics such as color, texture, luminosity, translucency, fluorescence properties, lack of mercury, thermal insulation and bonding to teeth feature with adhesives; the composites have numerous uses and applications in direct restorations (2, 3, 4). Dental adhesives have also undergone changes alongside composites and dramatic progress has been achieved in this regard (5). Adhesive systems should create a two-way bond between restorative materials on one hand and the dental tissue, on the other hand (6).

The main topic of this research focused on Universal Adhesives. These adhesives, which are often single-step (1-step), have simplified the bonding process. They can also be used for bonding with various types of materials, including a variety of indirect or direct restorations (self-cure / light-cure / dual-cure restorative materials).

These adhesives include a combination of hydrophilic monomers known as HEMA and hydrophobic monomers known as decandiol dimethacrylate / D3MA and BIS-GMA. These compounds allow the bonding between the wet surfaces of the tooth and the hydrophobic resin monomers of restorative materials (7, 8).

Universal adhesives can be used with three approaches:

1. *Self-etching*

Due to the presence of acidic phosphorylated monomers (MDP) and with no need for separate etching by phosphoric acid.

2. *Enamel Selective Etch*

Separate use of phosphoric acid on enamel and making stronger bond to it.

3. *Total Etch*

The use of phosphoric acid on enamel and dentin for 15 seconds with the presence of acidic monomers found in the adhesives. (9)

Bisco Company is one of the companies that manufacture this kind of adhesives, which has produced an adhesive known as All-Bond Universal. This adhesive is a light- cure bonding agent containing etchant, primer and bonding agents in one bottle. All-Bond Universal is an ethanol/water base adhesive for dentin and cut / uncut enamel.

The manufacturer claimed that it is designed and capable of bonding to self- cure and light- cure composites. This adhesive can also be used with or without phosphoric acid (as an extra etching agent) (8).

The self-cure composites are still used in some cases of cavities where the access of light is limited such as the crowns substructure, bonded posts, cementation of inlays and onlays, and composite and ceramic crowns (9). There is a lack of compatibility between adhesives containing acidic resin monomers and self-cure composites, which leads to reduced shear bond strength between adhesive and composite and increased micro-leakage. The triple amines found in self-cure composites are deactivated with the low concentration of acidic resin monomer of the adhesive.

By increasing the acidic monomers in the adhesive, its tendency for acid-base reaction with the amine component increases. This clinically implies incomplete polymerization between these two substances and reduced bond strength.

To resolve this problem, many manufacturers have produced universal bonding agent with activators. Activator is a separate bottle containing substances such as sodium toluene sulfonate and ethanol, which resolves the bonding problem with the self-cure composites (10, 11). An important point, which requires further investigation, is the Bisco Company claim that proper bonding with self-cure composites does not need an activator. The reason for such a claim has mentioned being the mild pH of this adhesive (PH> 3) (11).

Despite the great importance of micro-leakage, which, if any, will lead to the creation of a gap between the restorative material and the tooth, causing secondary caries, bacterial penetration and stimulation of pulp, no research has been conducted so far to compare the micro-leakage between this adhesive and self/ light cure composites even by the manufacturing
company. Considering that the majority of papers have focused on examining the bond strength and micro-leakage between the adhesive and the dental tissue, we decided to evaluate the micro-leakage between the All-Bond Universal adhesive and the self-cure composite compared to the light-cure composite (9).

**Materials and Methods**

For this study, 60 healthy extracted bovine incisors without any decay and cracks were selected. After cleaning and removal of the tissue debris by scaler and disinfection (in 0.5% chloramine solution for 1 week), the teeth were kept in distilled water at room temperature.

The CL V cavities at labial surface were prepared by high-speed handpiece with #008 fissure diamond burr (Tizkavan, Iran) under a continuous air and water spray by a single operator (after preparing every 5 teeth, the bur was replaced). Cavities dimension were 5 mm mesio-distally, 2 mm occluso-gingivally, and 1.5 mm in depth, with the occlusal and gingival margins placed respectively 1 mm above and below the CEJ. The teeth were then randomly divided into two groups based on the type of composite used (The adhesive was the same in both groups).

In group 1, self-cure composite (Master-Dent) + All-Bond Universal and in group 2 AELITE Composite (Micro-Hybrid and light – cure, Bisco Company) + All-Bond Universal were used (Table 1).

### Table 1. Composition and manufacturers of study materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>Commercial name</th>
<th>Compositions</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical - Cure Composite</td>
<td>MASTER DENT</td>
<td>-Bis-GMA</td>
<td>MASTER DENT, USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-TEGDMA</td>
<td></td>
</tr>
<tr>
<td>Universal Microhybrid light-cure Composite</td>
<td>AELTE All-Purpose body</td>
<td>-Ethoxylated Bisphenol A</td>
<td>Bisco, Schaumburg, IL, USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Dimethacrylated</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Triethylen glycol Dimethacrylate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Glass filler</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Amorphous silica</td>
<td></td>
</tr>
<tr>
<td>Bisco universal adhesive</td>
<td>All- Bond Universal</td>
<td>10MDP,HE-MA,Bis-GMA,ethanol,-photo initiator, water</td>
<td>Bisco, Schaumburg, IL, USA</td>
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</tbody>
</table>
In this study, 60 bovine incisor teeth were divided into two groups of 30 and evaluated for micro-leakage in light-cure and self-cure composite restorations. Therefore, we had two main groups:

**Group 1**: Samples restored with self-cure composite + All-Bond Universal

**Group 2**: Samples restored with light-cure composite + All-Bond Universal

Since the specimens were sectioned into two mesio-distal halves, each group had 60 specimens.

U and Mann-Whitney tests were used for statistical analysis.

Table 2 shows the distribution of micro-leakage in the gingival margin of groups 1 and 2. According to Table 2, 65% of samples had no micro-leakage in group 1 (score 0), while in group 2, 76.7% showed no micro-leakage (Figure 1). Performing the statistical test of $\alpha_2$ (chi-square) confirmed that the difference is significant. Thus, the micro-leakage was significantly lower in the gingival margin of the light-cure composite group ($p \leq 0.035$).

**Table 2. Distribution of micro-leakage in the gingival margin of groups 1 and 2**

| Group | Group 1 | | | Group 2 | | | Total | |
| --- | --- | --- | --- | --- | --- | --- | --- | |
| Score | Number | Percentage | Number | Percentage | Number | Percentage | Number | Percentage |
| --- | --- | --- | --- | --- | --- | --- | --- | |
| 0 | 39 | 65% | 46 | 76.7% | 85 | 70.8% | |
| 1 | 21 | 35% | 11 | 18.3% | 32 | 26.7% | |
| 3 | 0 | 0% | 3 | 5% | 3 | 2.5% | |
| --- | 60 | 100% | 60 | 100% | 120 | 100% | |

**Figure 1. Stereomicroscope images of dye penetration at occlusal and gingival margins (A) score 0, (B) score 1**
Table 3 shows the distribution of micro-leakage in the occlusal margin of two groups. According to Table 4, 80% of the samples had no micro-leakage (score 0) in group 1, while 98.3% of group 2, had score 0. The difference was statistically significant. In other words, the micro-leakage of the occlusal margin in group 2 was also significantly lower than group 1 ($p \leq 0.015$). Table 4 shows the distribution of micro-leakage in the occlusal and gingival margins of group 1. According to table 4, no significant difference was found on micro-leakage rate between the occlusal and gingival margins in group 1 ($P = 0.474$).

<table>
<thead>
<tr>
<th>Score</th>
<th>Group 1</th>
<th></th>
<th></th>
<th>Group 2</th>
<th></th>
<th></th>
<th>Total</th>
<th></th>
<th></th>
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</thead>
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<tr>
<td></td>
<td>Number</td>
<td>Percentage</td>
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<td>Percentage</td>
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<td></td>
</tr>
<tr>
<td>0</td>
<td>48</td>
<td>80%</td>
<td>59</td>
<td>98.3%</td>
<td>107</td>
<td>89.2%</td>
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<td></td>
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<tr>
<td>1</td>
<td>10</td>
<td>16.7%</td>
<td>1</td>
<td>1.7%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1.7%</td>
<td>0</td>
<td>0%</td>
<td>1</td>
<td>8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1.7%</td>
<td>0</td>
<td>0%</td>
<td>1</td>
<td>8%</td>
<td></td>
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<tr>
<td></td>
<td>60</td>
<td>100%</td>
<td>60</td>
<td>100%</td>
<td>120</td>
<td>100%</td>
<td></td>
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</tr>
</tbody>
</table>

Table 4. Distribution of micro-leakage in the occlusal and gingival margins of group 1

<table>
<thead>
<tr>
<th>Score</th>
<th>Gigival margin</th>
<th>Occlusal margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>65%</td>
<td>80%</td>
</tr>
<tr>
<td>1</td>
<td>35%</td>
<td>16.7%</td>
</tr>
<tr>
<td>2</td>
<td>0%</td>
<td>1.7%</td>
</tr>
<tr>
<td>3</td>
<td>0%</td>
<td>1.7%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Based on available information, the gingival margin has a higher micro-leakage rate than the occlusal margin.

Table 5 shows the distribution of micro-leakage in the occlusal and gingival margins of group 2. In group 2 or light-cure composite group, statistical analysis showed a significant difference between the micro-leakage rate of the occlusal and gingival margins ($P \leq 0.0001$).

<table>
<thead>
<tr>
<th>Score</th>
<th>Gigival margin</th>
<th>Occlusal margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>76.7%</td>
<td>98.3%</td>
</tr>
<tr>
<td>1</td>
<td>18.3%</td>
<td>1.7%</td>
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<tr>
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<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>3</td>
<td>5%</td>
<td>0%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5. Distribution of micro-leakage in the occlusal and gingival margins of group 2
Even though light-cure composites are nowadays one of the materials of choice for most restorations, their polymerization shrinkage is still a major problem. This shrinkage and the resulting stress can lead to the creation of a gap between the restorative material and the tooth, which is responsible for post-treatment sensitivity, recurrent caries and ultimately, failure of the restoration. Various methods have been proposed to reduce the polymerization shrinkage, like using a liner with a low elasticity coefficient, decreasing the polymerization rate using less light intensity at the beginning of polymerization, use of composite by an incremental approach, etc. (12).

The micro-leakage test seems to be the most effective method for evaluating the quality of restorative material’s sealing. The micro-leakage appears to be more critical when considering the pulp stimulation is done by bacterial toxin rather than the toxicity of restorative materials. This marginal micro-leakage is especially challenging in the cervical Cl V lesions. Due to the heterogeneity of the dentin, the dentinal margin’s seal at the Cl V restorations is much more complicated than the enamel margin.

This sealing is the most important factor in determining the resistance to recurrent caries, post-repair sensitivity, marginal color change and pulpal damage. New adhesive systems are trying to simplify the clinical steps. Obviously, the bonding system with simpler clinical steps but a micro-leakage equivalent to the old systems would be the best choice for a dentist. Although no bonding system can prevent the micro-leakage completely, especially micro-leakage in the dentin margins (13).

The latest generation of adhesives recently introduced to the market is the single-bottle Universal Adhesives. These Adhesives have many advantages over previous generations, like being used by two self-etch and total-etch methods and with different substrates (14, 15, 16).

In this study, the micro-leakage rate of the AELITE light-cure composite (Bisco, micro-hybrid composite) and a self-cure composite restoration (Master-Dent) with a type of Universal adhesive, known as All-Bond Universal, were examined at two enamel and dentin margins.

To examine the micro-leakage rate, the Cl V cavities were prepared as a box to increase the C-Factor resulting from the polymerization shrinkage similar to the oral cavity. Also, all samples were thermo-cycled to get closer to clinical conditions. Due to the difference in the coefficient of thermal expansion of the tooth and the restorative material, the bonding area develops fatigue, which leads to the creation of gap and micro-leakage (17).

On the other hand, the compatibility between adhesive and composite is one of the most important clinical properties in selecting the materials (18).

As we know, there is an incompatibility between adhesives containing acidic resin monomers and the self-cure composites. With increased acidity of the adhesive, its affinity to acid-base reaction with the amine component of the self-cure and dual-cure composites would increase. This results in incomplete polymerization of these composites at the interface with the adhesive (10). One advantage of Universal adhesives is the use of them by two self-etching and total-etching methods. As a result of our researches and reviews, we decided to use selective enamel etch approach (19, 20).

In this study, we assumed that the micro-leakage of self-cure composite restorations by using a universal bonding system has no difference with the light-cure composite restorations (H0). According to the results of this study, the null hypothesis was rejected at both gingival and occlusal margins, and the micro-leakage rate in the self-cure composite group was recorded higher than the light-cure composite.

Also, in group 1 (self-cure composite) and group 2 (light-cure composite), the micro-leakage rate at the gingival margin was recorded higher than the occlusal margin. However, this finding was not statistically significant in group 1. The cause of increased micro-leakage at dentin surfaces (gingival margin) in both groups was due to the heterozygous nature of dentin tissue. Besides, dentin contains significant amounts of water, collagen type I and a network...
of tubules. These tubules have more branches in the CEJ area and the root surface than the crown surface. Acid etching of these surfaces with phosphoric acid or acidic monomers found in the self-etch adhesives leads to a change in the morphology and chemical composition of these dentinal tubules, resulting in the hybrid layer changes. Consequently, the micro-leakage rate increases and a more unstable bond to dentin is formed (13, 21).

A study conducted by Mahmoud Bahari et al. showed that the use of the Universal adhesive (Bisco Universal adhesive / the same adhesive used in our article) by self-etch and total-etch on the surface of enamel or dentin have different rates of micro-leakage rate. At the enamel margins, the amount of micro-leakage by the total-etching method was recorded less than the self-etch approach. Conversely, At the dentinal margins, the self-etch method had significantly less micro-leakage compared with the total-etch method, and it was emphasized on preparing the enamel with acid etching, since the enamel acid etching leads to a micromechanical involvement and a stronger bond with the enamel (22).

A study by Peumans et al. indicated that when using Universal adhesives, the separate enamel acid etching has little effect on the bond strength. However, there are studies believing that enamel acid etching helps to increase bond strength (19, 20). Nevertheless, in our study, we etched the enamel margins separately for greater ensuring of the marginal integrity.

Moreover, a study by Marchesi et al. revealed that the dentin bonding using the Universal self-etching system is stronger over time. Although the bonding strength of the dentin appears to be initially higher in the total-etch method, but over time, it changes in favor of the self-etch approach (23). In general, some of the two-stage total-etch adhesives and single-stage adhesives are incompatible with the self-cure / dual-cure composites. This is due to the presence of hydrophilic acidic resin monomers in these adhesives (24).

In consistent with our results Oskoee and kimyai reported that low pH of 1-bottle adhesives might have contributed to high micro-leakage values (24).

In a review article by Dr Fatemeh Maleknejad et al., it was concluded that the bond strength reduction of the self-cure / dual-cure composites has an inverse relationship with the acidity level in the oxygen-inhibition layer of the adhesive system. Clinically, this means reduced polymerization and increased micro leakage (10).

The acidic monomers also react with the peroxide initiator, which produces carbon dioxide gas that generates bubbles at the interface of adhesive and composite and reduces the bonding strength.

To solve this problem, it is recommended to use an activator ingredient bottle containing a chemical curing system, benzoyl peroxide and a sulfonic acid salt (10).

The manufacturer of the Bisco-Universal Adhesives has claimed that due to the mild PH of this adhesive (PH > 3) and the presence of weak acidic monomers, this adhesive has the capability of bonding with self-cure / dual-cure composites. According to the results of this research, this claim was rejected.

**Conclusion**

According to the results of this study, the All Bond Universal adhesive agent used is not compatible with the Self Cure composite and can result in increased micro leakage.

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