Original Article

Microleakage of Dual-Cured Adhesive Systems in Class V Composite Resin Restorations

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Abstract

Objective: Microleakage is a major factor affecting longevity of composite restorations. This study evaluated the effect of polymerization mode of bonding agent on microleakage of composite restorations.

Materials and Methods: Forty-eight Class V cavities were prepared on buccal and lingual surfaces of 24 extracted human premolars. Occlusal and gingival margins were placed in the enamel and dentin, respectively. Teeth were divided into four groups as follows: Group I: Optibond Solo Plus (light-cured); Group II: Optibond Solo Plus (dual-cured); Group III: Prime & Bond NT (light-cured), Group IV: Prime & Bond NT (dual-cured). Teeth were restored using Z250 composite in three increments. After polishing the restorations, samples were thermocycled for 1000 cycles and stored in distilled water for 3 months. Then they were placed in 2% fuchsine solution for 48 hours. The samples were sectioned longitudinally and evaluated for microleakage under a stereomicroscope at ×40magnification. Dye penetration was scored on a 0-3 ordinal scale. Data were analyzed using Kruskal-Wallis, Bonferroni and Wilcoxon signed ranks test.

Results: Microleakage was significantly lower in enamel margins compared to dentin margins ($P<0.05$); multiple comparisons by Bonferroni tests revealed that the only factor with significant effect on leakage of the restoration is location of the restoration margin. Mode of adhesive polymerization had no significant influence on microleakage ($P>0.05$). Prime & Bond NT had less microleakage compared to Optibond SoloPlus, but the difference was not significant ($P>0.05$).

Conclusion: There was no difference in the amount of microleakage in Class V composite restorations using light-cured and dual-cured bonding systems. Dentinal margins of restorations exhibited more microleakage than enamel margins.

Key Words: Dental Leakage; Adhesives; Polymerization; Composite Resins

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INTRODUCTION

Maintaining the seal for the margins of adhesive restorations against microleakage is a major factor affecting clinical longevity [1]. Microleakage has been defined as the “marginal permeability to bacterial, chemical and molecular invasion at the tooth-material interface” and is the result of a breach in the tooth-restoration interface, which leads to discoloration, recurrent caries, pulpal inflammation and restoration replacement [2]. Polymerization of dimethacrylate resin composites and formation of a cross-linked polymer bring a volumetric shrinkage of 1.5-6 vol% [3]. This volumetric shrinkage results in marginal leakage especially in dentin margins of restorations.

Many attempts have been made to decrease microleakage of adhesive restorations, such as development of new resin monomers and filler systems, incremental filling technique, type of light source, light and curing mode [4] and changes in C-factor and direction of polymerization shrinkage [5-7]. Understanding the direction of polymerization shrinkage may be a solution to improve the marginal adaptation and reduce marginal leakage. Early studies on polymerization shrinkage of composite resins have stated that the direction of polymerization shrinkage is toward the center of the bulk of self-curing composites and toward the light source in light-cured resin composites [4].

However, later studies have shown that various factors are effective on the direction of polymerization shrinkage, including cavity design, the rate of polymerization reaction, mechanical and optical properties of resin composites, thickness of the layer of composite, bond strength, intensity and direction of the light [8-10].

Use of bonding systems which initiate polymerization at the dentinal wall has been reported in some studies [3, 11, 12].

In 1993, Fusayama reported that self-cured systems initiate polymerization in warmer dentinal walls [11].

Since the rate of higher chemical reactions is increased by higher temperature, in vital teeth the restorative material shrinks toward pulpal walls because of local temperature in areas close to the pulp [13]. Use of 4-META/MMA-TBB and ferric chloride in adhesive systems are further attempts to initiate polymerization from dentinal walls [12].

To obtain a restoration with maximum adaptation, bonding systems with optimum physical features should be used.

By changing the direction of shrinkage toward dentinal walls, detrimental effects of polymerization shrinkage and polymerization stress would be minimized.

In order to decrease undesirable tensile stresses caused by polymerization shrinkage, some studies have recommended dual-cured adhesive systems [7].

Theoretically, if the bond between composite and dental structure is assumed to be perfect, as in Finite Element Analysis [14], the vector of shrinkage should be entirely directed toward the bonded wall.

Dual curing systems undergo a higher degree of conversion after light irradiation than light curing systems [15] and this would affect the quality of interfacial bond between tooth structure and composite.

Therefore, it is likely that dual-cured bonding agents decrease the leakage of dentinal margins of restorations.

In addition, some oxygen scavengers and chemical co-initiators present in dual-cured adhesives can lead to a better polymerization of the composite resin bonded to the cavity wall [16].

The purpose of this study was to evaluate the effect of polymerization mode of the adhesive (light- and dual-cured) on microleakage of light-cured composite restorations in both enamel and dentin.

The null hypotheses tested were:

1-The mode of adhesive polymerization has no effect on microleakage in class V composite resin restorations.

2-There is no difference in microleakage between enamel and dentin margins of class V restorations.

MATERIALS AND METHODS

Twenty-four extracted, non-carious human premolars stored in 10% formalin solution were used in this study. One week prior to the study the teeth were cleaned from residual soft tissues and calculus and stored in distilled water at room temperature.

The teeth were then divided into four equal groups. V- shaped class V cavities were prepared on the buccal and lingual surfaces. The coronal margins were located in enamel and gingival margins 1.0 mm below the cemento-enamel junction.

The preparations were cut with a #1 cylindrical carbide bur with a diameter of 1 millimeter in a high-speed handpiece cooled with an air-water spray. The dimensions of the cavities were 3.0 mm × 3.0 mm × 1.5 mm (depth). A bevel was placed on the enamel margin (0.5 mm wide). Therefore, each group consisted of 12 class V cavities, six on the buccal and six on the lingual surfaces. All the procedures from cavity preparation to placement of composite were performed on one surface of the teeth and then the cavities on the other surface were prepared. A single operator performed all the cavity preparations and restorations.

Each group was treated by one of the following four methods:

Group one- The prepared surfaces (enamel and dentin) were conditioned with 38% phosphoric acid etchant gel (Etch-Rite, PULPDENT CO, Watertown, USA) for 15 seconds, thoroughly rinsed for 15 seconds and blot dried.

As mentioned by the manufacturer, Optibond Solo Plus (Kerr Corp., Orange, CA, USA) was applied to cavity surfaces with an applicator tip for 15 seconds using mild agitation.

The surfaces were gently air-thinned for three seconds and polymerized with an LED light source (Demi LED Light Curing System, Kerr Demetron) for 20 seconds. The resin composite (Z250, 3M, ESPE, USA) was placed in the preparations in three increments and each increment was light-cured for 30 seconds.

Group two- The process was similar to group one but dual-cured Optibond Solo Plus was used. One drop of bonding agent was mixed with one drop of self-cured activator for 3 seconds and the adhesive was applied using an applicator on cavity surfaces for 15 seconds, air-dried for 3 seconds and light-cured with an LED light source for 20 seconds.

*Group three- A*fter conditioning the cavity walls with 38% phosphoric acid gel for 15 seconds and blot drying based on the manufacturer's instructions, Prime & Bond NT (Caulk/Dentsply International Inc., Milford, DE, USA) was applied to the cavity walls and after 20 seconds, air-dried for 5 seconds and polymerized for 10 seconds. Cavities were filled with composite similar to group one.

Group four- The cavities were filled in the same manner as in group three; however, before applying the bonding agent, one drop of the activator was mixed with one drop of the bonding agent and then applied to cavity walls for 15 seconds; after 20 seconds it was air-dried for 5 seconds and light-cured for 10 seconds. Table 1 describes the composition of adhesive systems used in this study.

All the restorations were polished with Sof-Lex (3M, ESPE, St Paul, MN, USA) flexible aluminum oxide. The teeth were thermocycled for 1000 cycles in 5˚C/55˚C with a dwell time of 30 seconds. Then, they were stored in distilled water at room temperature for 3 months prior to leakage assessment. The root apices were sealed with sticky wax and then two coats of nail varnish were applied to the entire tooth surface within 1.0 mm of the restoration margins. The specimens were immersed in 2% fuchsine dye solution for 48 hours at room temperature and subsequently rinsed and sectioned buccolingually through the center of the restoration by a cutting machine (Meccatom; T201A, Presi Co, France). During sectioning, water was used for cooling and cleaning debris. The sections were examined at ×40 magnification under a stereomicroscope (PZO, Warsaw, Poland) twice by a single observer. The degree of leakage was determined based on an ordinal ranking system (0-3) as follows:

0-no leakage; 1-leakage up to one-half the length of the cavity wall; 2-leakage along the full length of the cavity wall, not including the axial surface; 3-leakage along the full length of the cavity wall, including the axial surface. The results of dye penetration test were separately scored for coronal and apical margins for statistical analysis using Kruskal-Wallis, Bonferroni and Wilcoxon signed ranks test. The level of significance was set at P<0.05.

RESULT

Microleakage scores are presented in Table 2. Kruskal-Wallis test revealed significant differences between the groups (P=0.000). Considering the results of Kruskal-Wallis test to determine the difference between groups Boneferroni adjustments for multiple comparisons were performed. Comparison of three variables showed that only the location of restoration margin had a significant effect on microleakage and the main effect of polymerization mechanism and the kind of bonding system were not significant.

Bonferroni adjustment for multiple comparisons showed that although microleakage in dual-cured bonding systems was less than light-cured bonding systems, the difference was not significant (P=0.767). Wilcoxon-sign rank test indicated that microleakage in enamel margins was less than dentin margins and the difference was significant (P=0.000). In addition, microleakage in Prime & Bond NT was less than Optibond, but the difference was not significant (P=0.14).

DISCUSSION

Microleakage and loss of marginal integrity is the primary cause of marginal staining, secondary caries and post-operative sensitivity [17]. This study compared microleakage between light-cured and dual-cured bonding agents of the fifth generation (Prime & Bond NT and Optibond SoloPlus) in enamel and dentin margins of class V composite restorations. Microleakage in dual-cured adhesives was not significantly different from light-cured ones (p>0.05). Hence, the first part of the null hypothesis was rejected.

Some studies have suggested that adhesives with chemical activators can change the path of light-cured composite shrinkage toward the dentin with higher bond strength and lower leakage [18].

As dual-cured adhesive systems polymerize via both light and chemical reactions, it seems that these systems have better and more complete polymerization [15, 19].

Table1. Composition of the Adhesive Systems Used

Dental Adhesive System	Manufacturer	Composition
Prime & Bond NT	DENTSPLY Caulk 38 West Clarke Ave.Milford, DE 19963, USA	Adhesive: di- and trimethacrylate resins, dipentacryt-hritolpentacrylate phosphate, camphorquinone, stabilizer, amorphous silicon dioxide (nanofillers), cetylaminehydrofluoride, acetone (<70% wt), urethane dimethacrylate resin. Activator: acetone (<65% wt), ethyl alcohol (45% wt), sodium p-toluenesulfinate (aromatic sodium sulfinate salts)
Optibond SoloPlus	Kerr Co, Orange, CA, USA	Adhesive: ethyl alcohol, alkyl dimethacrylate resin, barium aluminoborosilicate glass, fumed silica (silicon dioxide), sodium hexafluorosilicate Activator: ethyl alcohol, alkyl dimethacrylate resin, sodium salt of benzene sulfinic acid

It has been shown that if simplified adhesive systems with low PH are in long-term contact with light-curing composites, they would interfere with polymerization of these composites [20]. Use of dual-cured bonding agents can improve bond strength of light-cured composites by neutralization of the acidity of some simplified fifth generation bonding systems.

Among etch-and-rinse adhesives, Optibond and Prime & Bond NT have pH values of 2.1 and 2.2, respectively, which have relatively high acidity [1]. After light curing bonding systems, an oxygen inhibited layer containing unpolymerized acidic monomers exists on the surface. Because of high osmotic pressure in the oxygen-inhibited layer, the adhesive layer acts as a semi-permeable membrane that causes water flow toward the surface [20].

Water drops reaching the adhesive surface are trapped under hydrophobic composite, resulting in mechanical defects in the interface, which decreases bond strength and increases marginal microleakage. This phenomenon is known as 'osmotic blistering' [21]. This is especially important when the time needed for adapting the composite within the cavity results in some delay in light-curing [22].

Presence of acidic monomers in the oxygen-inhibited layer may also prevent appropriate polymerization of composite in the interface by interfering with the photochemical redox system of composites [7, 23]. In order to overcome this incompatibility, chemical initiators have been incorporated into fifth generation adhesives, such as aryl sulfinic acid salts, organoboron compounds and barbituric acid/cupric chloride and some oxygen scavengers. These components react with acidic resin monomers to produce phenyl or benzene sulfonyl free radicals [16, 24].

We did not obtain significant differences between microleakage of light-cured and dual-cured bonding agents in this in vitro study, which might be attributed to lack of pulpal pressure and tubular fluid in dentinal tubules. Performing the study in situations similar to vital teeth may yield different results.

Another factor influencing the amount of leakage in light and dual-cured systems, is the amount of solvent in these adhesive systems. Since the activator also contains some organic solvent, addition of the activator to light-cured adhesive system results in some increase in the total amount of solvent.

Table 2. Distribution of microleakage scores in Class V composite restorations by light-cure and dual-cure adhesive systems.

Bonding System	Polymerization Type	Microleakage / Marginal Zone	Score 0	Score 1	Score 2	Score 3
Optibond	Light cure	Enamel	9(69%)	4(31%)	0(0%)	0(0%)
		Dentin	1(7.5%)	10(77%)	1(7.5%)	1(7.5%)
	Dual cure	Enamel	9(69%)	4(31%)	0(0%)	0(0%)
		Dentin	2(15%)	8(61.5%)	1(7.5%)	2(15%)
Prime & Bond NT	Light cure	Enamel	10(77%)	3(23%)	0(0%)	0(0%)
		Dentin	3(23%)	8(61.5%)	1(7.5%)	1(7.5%)
	Dual cure	Enamel	12(92%)	1(8%)	0(0%)	0(0%)
		Dentin	4(31%)	7(54%)	1(7.5%)	1(7.5%)

High concentration of the organic solvent can prevent its complete removal from the adhesive agent. This could result in a decrease in the degree of polymerization, mechanical properties of the adhesive and bond strength [25]. Another objective of the present study was to assess microleakage in dentinal and enamel margins of class V restorations regarding differences in the structure and chemical composition of dentin and enamel. The results showed that there is a statistically significant difference in the microleakage of enamel and dentinal margins of restorations ($P<0.001$), which is consistent with the results of other studies [26-28].

Therefore, the second part of the null hypothesis was accepted.

Since enamel is structurally and chemically more homogeneous than dentin, conditioning with an etchant and use of a resin results in a stronger and more durable bond compared to dentin. Bonding to enamel is achieved by means of micromechanical retention [29]. In spite of an appropriate bond, microleakage was seen in enamel margins in this study. Thin prismless enamel and enamel crazing exists in cervical areas, which is less capable of forming an appropriate bond to resin may be a reason for microleakage in the occlusal margins of class V restorations. In agreement with this study, previous studies have reported that available dentin bonding systems are unable to produce a durable bond because of higher organic contents of dentin compared to the enamel as well as the presence of inter tubular fluid [27, 30].

Analysis of data indicated that either acetone-based (Prime & Bond NT) or ethanol-based (Optibond) bonding systems have no effect on the score of marginal microleakage ($P=0.14$). Since just two bonding systems were evaluated in this study, an overall conclusion cannot be achieved. Long-term clinical studies are recommended to evaluate the relevance of in-vitro tests results.

CONCLUSION

Based on the findings of the present study there was no difference in the amount of microleakage in class V light-cured composite restorations using light-cured and dual-cured bonding systems. Gingival margins of restorations exhibited more microleakage than enamel margins.

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