Effect of Application of Bonding Agent and Amalgam Setting on Microleakage at the Amalgam-Composite Interface

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Abstract

Background and Objectives: This study aimed to assess the effect of application of bonding agent and amalgam setting on microleakage at the amalgam-composite interface in teeth restored with the sandwich technique. **Materials and Methods:** This in vitro, experimental study evaluated 88 freshly extracted maxillary premolars. Single boxes were prepared in the mesial and distal surfaces of the teeth, and amalgam was condensed in the cervical 2 mm of the prepared cavities. The teeth were then randomly divided into 4 groups (n=22). In group 1, after primary setting of amalgam, bonding agent was applied and the cavity was filled with composite resin. In group 2, composite was applied after primary setting of amalgam without the bonding agent. Groups 3 and 4 were restored as groups 1 and 2, respectively with the difference that composite veneer was performed 24 hours after primary setting of amalgam. The teeth were thermocycled, and microleakage was quantified at the amalgam-composite interface using the dye penetration technique. Data were analyzed using the Kruskal-Wallis and Mann Whitney tests. **Results:** The frequency of microleakage score 0 (no dye penetration) was the highest in groups 1 and 2, followed by groups 3 and 4. No significant difference was noted among the four groups in microleakage scores ($P>0.05$). **Conclusion:** Microleakage occurred in all groups at the amalgam-composite interface and use/no use of bonding agent and amalgam setting condition had no significant effect on the occurrence of microleakage.

Keywords: Dental Leakage; Amalgam; Composite Resins; Sandwich Technique

INTRODUCTION

Search for an ideal restorative material in terms of esthetics and function has led to advances in composition and esthetic appearance of dental restorative materials. Advent of composite resins and introduction of the acid etching technique revolutionized restorative dentistry. Adhesive materials that provide a strong bond to the enamel and dentin can significantly enhance restorative techniques.

Selection of an ideal restorative material for restoration of carious teeth and other types of defects in the esthetic zone is still a matter of debate. Tooth-colored restorative materials such as composite resins are gaining increasing popularity since they require minimal removal of tooth structure with minimal patient discomfort. Also, they are more affordable and fast, compared with full-ceramic restorations [1]. However, application of composite resins for restoration of posterior teeth is associated with problems such as polymerization shrinkage and postoperative sensitivity and creates some concerns with regard to the long-term durability and wear resistance of these restorations. Thus, the restorative procedure should be highly precise to minimize the risk of unwanted events. The application technique is the most important factor affecting the success of posterior composite restorations [2].

Composite resins have ½ or 1/3 of the coefficient of thermal expansion of unfilled acrylic resins. Thus, their coefficient of thermal expansion is closer to that of tooth structure. Dental amalgam is a metallic restorative material composed of a mixture of silver, tin, copper and mercury in the form of an alloy. This mixture is condensed in a retentive cavity

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prepared in tooth structure and is formed to perfectly restore the anatomical contour and function of the tooth [1].

The linear coefficient of thermal expansion of amalgam is 2.5 times higher than that of tooth structure. However, this rate is still closer to that of tooth structure when compared with the linear coefficient of thermal expansion of composite resin. Although the compressive strength of amalgam is similar to that of tooth structure, its tensile strength is lower; thus, amalgam restorations are susceptible to fracture. Amalgam restorations should have adequate volume (usually 1-2 mm depending on the position of cavity in tooth structure) and a 90° (butt joint) or obtuse angle at the margins [1].

Adhesion is the interaction between an adhesive or adherent and an adherend. Dental bonding agents are used for adhesion to tooth structure. Debonding tests are often performed to assess the bond strength of adhesives to tooth structure. Bonding agents are commonly used in dentistry to bond composite resin to etched enamel surface. Bonding agents may be used to bond amalgam to tooth structure, amalgam to amalgam or amalgam to other surfaces. Since dental amalgam is highly hydrophobic while enamel and dentin are highly hydrophilic, these bonding agents should have a dual action to achieve maximal wettability, and for this purpose, they should be used in combination with a moisturizer [1].

The bond strength of adhesive systems for bonding of amalgam to dentin is relatively low. Tooth surface conditioning may improve the bond strength. In amalgam restoration of teeth, the bonding agents provide a suitable bond to tooth structure; however, a weak micromechanical bond exists between the bonding agent and amalgam. Thus, the majority of failures occur at the amalgam-bonding agent interface. Therefore, this system still needs some modifications similar to dentin bonding agents used with composite resins [1].

Dental amalgam has been used in clinical dentistry for the past 1500 years; however, its poor esthetic appearance is a major drawback especially when used for restoration of teeth in the esthetic zone (e.g. in maxillary premolars) [3].

Despite the availability of different techniques, application of composite resin alone in the posterior region has problems such as high technical sensitivity, polymerization shrinkage and inadequate seal [4, 5]. One strategy to minimize such complications is to apply a base under the composite restoration, which is referred to as the sandwich technique [6].

Several studies have reported the superiority of adhesives to copal varnishes for sealing of amalgam restoration margins and have mentioned that the varnish is dissolved and the smear layer is degraded over time [7].

Considering all the above, we used both amalgam and composite simultaneously for restoration of teeth in this study to benefit from the application of both materials. Concerning the existing controversy regarding the simultaneous application of both materials or delaying the composite veneering procedure to after adequate setting of amalgam, we also assessed the effect of amalgam setting condition on the success of these restorations. Moreover, considering the gap of information regarding the efficacy of application of bonding agents to seal the interface of the two materials, we assessed the effect of bonding agent application on the microleakage at the interface in this in vitro study with four experimental groups.

Materials and Methods

This study had an in vitro, experimental design. Tables 1 show the materials used in this study to assess the effect of bonding agent application and amalgam setting condition on microleakage at the amalgam-composite interface.

This in vitro experimental study evaluated 88 sound maxillary premolars with no caries or enamel defects that had been extracted for orthodontic treatment. The teeth were randomly divided into four groups (n=22). Sample size was calculated to be 88 teeth assuming alpha=0.05, 95% CI and d=13.3 considering 5% error rate. The study was approved by the ethics committee of Guilan University of Medical Sciences.

The collected teeth were cleaned with a scalpel and were immersed in distilled water containing 0.5% thymol solution until the experiment to prevent their dehydration. The teeth were first cleaned with water and pumice powder. Next, box-only class II cavities were prepared on the mesial and distal surfaces of the teeth using a #010 fissure diamond bur (Teeskavan, Iran) and high-speed hand-piece under air and water coolant (Figure 1).

The cavities had equal buccolingual width of 4 mm and occlusogingival height of 5 mm measured from the marginal ridge such that at the gingival floor of the box, the axial depth of the cavities was 2 mm from the dentinoenamel junction. The buccal and lingual walls were parallel. The gingival floor of the cavities was smooth and perpendicular to the longitudinal axis of the tooth. To create a retentive form, retentive grooves were created at the axiogingival line angle of the cavity. Next, a line was drawn at 3 mm distance from the gingival floor on the buccal or lingual wall using a copying pencil. The teeth were then randomly divided into four groups (n=22).

Group 1. After cavity preparation and rinsing, amalgam was applied over the cavity floor and the cavity was filled with amalgam to the line marked on the buccal and lingual walls (Sinalux, Shahid Faghihi). Next, the amalgam surface was burnished with a burnisher and excess amalgam was removed by an explorer such that a smooth amalgam surface was obtained. The amalgam-composite interface was then polished.

After primary setting of amalgam (10 minutes after condensing), the entire cavity was etched with 37% phosphoric acid (Ultradent) for 15 seconds. It was then rinsed with water spray for 15 seconds and blotted dry. Next, OptiBond Solo (Kerr) was applied on all surfaces of the cavity by a microbrush and rubbed for 15 seconds. It was thinned with gentle air spray. A second layer of bonding agent was then applied on the cavity walls, thinned and cured for 20 seconds according to the manufacturer's instructions using a LED light-curing unit (Blue Dent Smart, Bulgaria). Next, the cavity was filled with one layer of A2 shade of composite (Herculite, Kerr) with 2 mm height and light-cured for 20 seconds.

Group 2. All procedures were performed as explained for group 1 except that the bonding agent was not applied on amalgam.

Group 3. In this group, the cavity was first filled with amalgam. The teeth were then immersed in distilled water for 24 hours in order to allow final setting of amalgam. After 24 hours, the remaining box was filled as explained for group 1.

Group 4. In this group, the cavity was first filled with amalgam. The teeth were then immersed in distilled water for 24 hours. After 24 hours, the remaining box was filled as explained for group 2.

All restorations were finished and polished using composite finishing and polishing points to decrease surface roughness. Next, all samples were immersed in distilled water at room temperature for 24 hours. Then, the samples underwent 1000 thermal cycles between 4±2 to 60±2°C with a dwell time of 30 seconds and transfer time of 15 seconds. The apices were then sealed with sticky wax to prevent dye penetration through the apex. Next, all tooth surfaces except for 1 mm around the occlusal and gingival margins at the amalgam-composite interface were coated with two layers of nail varnish.

In order to assess the microleakage, the teeth were immersed in 0.5% basic fuchsine for 24 hours and were then rinsed under running water and mounted in plastic molds. The teeth were then sectioned at the center in mesiodistal direction using a cobalt-chromium cutting disc (Figure 2).

Sections were inspected under a stereomicroscope (XTS3022; Blue Light Industry, MA, USA) at x40 magnification (Figure 2) to determine the dye penetration depth at the axial and gingival margins, which was scored as follows:

Score 0: No dye penetration

Score 1: Dye penetration to ½ of the interface or less

Score 2: Dye penetration to ½ of the interface or the entire interface

Score 3: Dye penetration reaching the axial wall

Statistical analysis:

Each section was inspected under the microscope and the amount of microleakage was quantified. The quantitative variables were described with mean and standard deviation and in qualitative variables with frequency. Data were analyzed by SPSS version 18. Kolmogorov-Smirnov test showed that the distribution of data was not normal, so the Kruskal-Wallis test was used to compare groups. $P<0.05$ was considered statistically significant.

Results

The results are presented in Tables 2 and Table 3.

As shown in Table 2, scores 0 and 1 had the highest frequency in all groups. Maximum frequency of score 3 was noted in group 2 (6.8%) while minimum frequency of score 3 was noted in group 3 (2.3%). Maximum frequency of score 0 was noted in groups 1 and 3 (70.5%) while minimum frequency of score 0 was noted in group 4 (61.4%).

The Kruskal Wallis test was used to compare the microleakage scores of the groups. As shown in Table 3, the groups were not significantly different in the mean microleakage scores.

Discussion

Cervical microleakage in composite resin restorations may occur due to shrinkage and expansion of composite as the result of thermal alterations (thermocycling). The reason is the difference between the coefficients of thermal expansion of these materials and dental hard tissue. In fact, polymerization shrinkage is the main cause of dye penetration, and thermal stresses rank second in terms of significance. However, thermal cycles have greater effects on metal restorations and can accelerate microleakage [8-10].

More recent studies have demonstrated that type of amalgam, duration of storage, working time and the adhesive system used are important factors affecting the degree of microleakage [11, 12].

This study assessed the degree of microleakage in amalgam-composite sandwich technique and evaluated the effect of bonding agent application and amalgam setting condition on this variable. The results showed that delaying the conduction of composite veneer in order to ensure complete setting of amalgam mass and use of a bonding agent had no significant effect on marginal microleakage at the amalgam-composite resin interface.

The acid or conditioner present in the composition of bonding agents may eliminate the impurities from the amalgam surface and subsequently increase its surface energy and result in its better wetting [13]. In this study, similar to that of Shirani et al, [14] we found that application of bonding agent could not completely prevent the occurrence of microleakage at the amalgam-composite interface. The occurrence of microleakage at the amalgam-composite interface was probably due to the leakage at the interface of amalgam-bonding agent where the hydrophilic heads of the bonding agent molecules are in contact with amalgam [15-18]. Khoroushi and Yeganehjo [19] reported insignificant effect of an adhesive resin cement on bond strength of amalgam to composite. A 24-hour delay had no significant effect on the bond strength of amalgam to composite either. Their results were in line with our findings since our study also showed that delaying the composite veneer did not have a significant effect on the results. In the study by Cehreli et al. [20] similar to that of Hadavi et al, set amalgam without cement yielded the lowest bond strength [21]. This finding was in agreement with our results. Although we did not assess the bond strength in our study, the lowest frequency of score 0 microleakage was noted in group 4.

Diefenderfe et al. believed that type of surface conditioning affects the bond strength, and some adhesive agents may significantly decrease the bond strength [22, 23]. Fruit et al. reported much lower bond strength for fresh amalgam compared with 21-day amalgam groups. The superiority of two-session technique in providing a stronger bond has been confirmed in several studies [22-25]. However, it had no significant effect on the results in our study. In a study by Eskandari zadeh and khalilzadeh Moghaddam [26] score 0 microleakage at the amalgam-composite interface had a frequency of 77.5% and 88.1% in groups A (Iranian amalgam + bonding agent + composite resin) and B (foreign-made amalgam + bonding agent + composite resin), respectively. These values indicated clinically acceptable seal, and were more favorable than the microleakage scores obtained in our study. The reason is that they used physical interlocking (by the rough surface of amalgam) and chemical bonding mediated by Syntac bonding agent in their study to obtain a strong bond between amalgam and composite. Evidence shows that roughening the amalgam surface and direct use of bonding agent prior to the application of composite would result in lower microleakage compared with amalgam etching [16]. In our study, similar to that of Eskandari zadeh and khalilzadeh Moghaddam [26] base, liners, varnish or bonding agents were not used beneath the amalgam for the purpose of standardization and since they were not required although evidence shows that application of varnish, dentin bonding agents and other adhesive resins significantly decreases the microleakage of amalgam restorations [10, 27-29].

In an in vitro study in 1991, Hadavi et al [21]. Assessed the flexural bond strength of composite resin to amalgam using different bonding systems and concluded that the bond between amalgam and composite increases by almost 5 folds when a bonding agent is used. However, this difference was not significant in our study. The bond strength tests would definitely yield more reliable results.

Cehreli et al. [20] found no significant difference in frequency of methylene blue dye penetration scores among different study groups. In other words, they showed that microleakage occurs in mixed amalgam-composite restorations, as shown in our study. They demonstrated that the frequency distribution of microleakage score was slightly lower in the group where adhesive cement was applied on a 24-hour amalgam restoration compared with other groups. However, this difference did not reach statistical significance and this finding was in agreement with our result. Similar to the study by Cehreli et al. [20] in our study, the bond of cement to freshly mixed and set amalgam was found to be the same (in terms of microleakage score). There is a possibility that during rinsing of acid etchant gel applied to the cavity walls, the amalgam surface inside the cavity is contaminated with gel, which can affect the surface properties of amalgam. Contamination of amalgam surface with acid etchant gel can impair the bond between the adhesive and amalgam surface. On the other hand, some interactions that occur between the amalgam surface and bonding agent may effectively increase adhesion and decrease microleakage [16, 30]. Eidleman et al, [31] evaluated the marginal microleakage of class II amalgam-composite restorations and reported that the microleakage at the gingival margin of amalgam-composite restorations was significantly lower than that of conventional composite restorations. This finding was obtained in cavities where the gingival floor of the cavity was located in cementum. No microleakage was noted at the composite-enamel interface in cavities where the cervical floor was located in the enamel.

Microleakage between the amalgam and composite depends on a number of factors such as the primary adhesion between the two materials, dimensional changes of composite due to polymerization shrinkage or water sorption by the resin part of composite, dimensional changes of amalgam, difference in the coefficients of thermal expansion of the two materials and operator-dependent factors [10, 32]. It should be noted that in the clinical setting, the exact interactions that occur at the amalgam-composite interface are not well understood and these factors cannot be accurately studied and controlled for, in vitro [32]. Nonetheless, assessment of different types of cements and adhesive systems recommended for amalgam restorations can help us in better comparison of the efficacy of adhesive systems for use in combined amalgam-composite restorations.

Conclusion

In general, the results showed that none of the tested protocols could completely prevent the occurrence of microleakage at the amalgam-composite interface. No significant difference was noted in microleakage between freshly applied amalgam and 24-hour set amalgam either.

Suggestions

Although the difference in microleakage was not significant among the study groups, future studies with larger sample size and clinical trials on teeth scheduled for extraction are required in order to be able to more accurately generalize the results to the clinical setting.

Conflict of interest statement:

The authors declare no conflict of interest.

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Table 1. Characteristics of the amalgam used in this study

Materials	Brand name	Batch number	Manufacturer	Type of particles	Composition of alloy
Amalgam	Cinalux	90355	Shahid Faghihi, Iran	Spherical	Silver (49%) Tin (31%) Copper (20%) Dental mercury (< 1%)
composite resin	Herculite XR Vultra	3471898	Kerr, Italy	Nanohybrid	Bis-GMA, TEGDMA Filler (78%)
bonding agent	OptiBond Solo	4143180	Kerr, Italy		

Table 2. Frequency distribution of microleakage scores in the study groups (n= 44 section in each group)

			Score			
			Score 0	Score 1	Score 2	Score 3
Group	Amalgam + Composite 10 min	Count	30	6	5	3
		%within Group	68.2%	13.6%	11.4%	6.8%
	Amalgam+ Bonding + Composite 10 min	Count	31	9	2	2
		% within Group	70.5%	20.5%	4.5%	4.5%
	Amalgam + Bonding + Composite 24 hour	Count	31	8	4	1
		% within Group	70.5%	18.2%	9.1%	2.3%
	Amalgam + Composite 24 hour	Count	27	12	3	2
		% within Group	61.4%	27.3%	6.8%	4.5%
	Total	Count	119	35	14	8
		% within Group	67.6%	19.9%	8.0%	4.5%

Table 3. Comparison of the mean microleakage scores of the groups (n=44)

Groups	N	Mean	Std. Deviation	Median	Interquartile Range	Range	P
Amalgam + Composite 10 min	44	.5721	.96177	0.00	1.00	.00 - 3	0.812*
Amalgam+ Bonding+ Composite 10 min	44	.4182	.76410	0.00	1.00	.00 - 3	
Amalgam+ Bonding + Composite 24 hour	44	.4201	.74052	0.00	1.00	.00 - 3	
Amalgam + Composite 24 hour	44	.5297	.79295	0.00	1.00	.00 - 3	

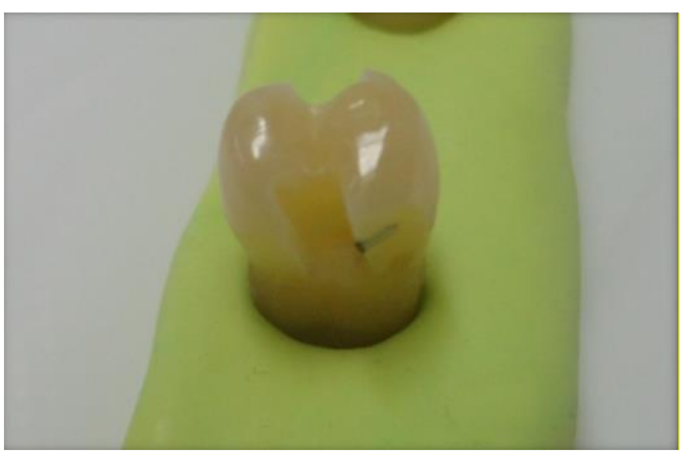

Figure 1. Prepared cavity

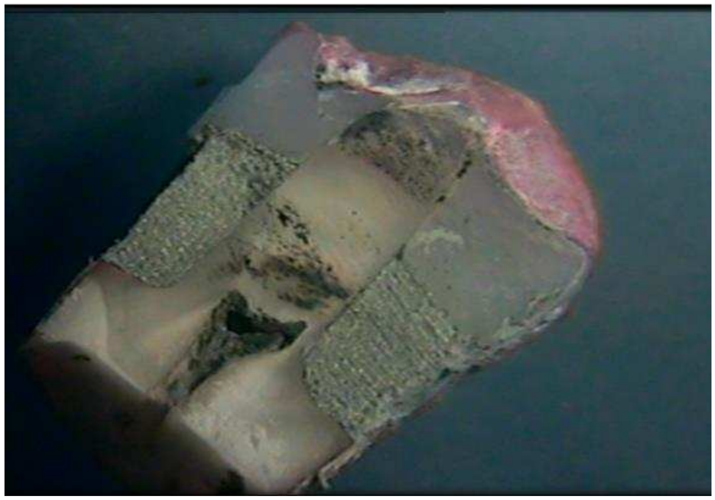

Figure 2. A sectioned tooth