Original Article

Comparative Evaluation of Microleakage in High Copper Amalgam Restorations using various Adhesive Liners in Permanent Teeth

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Received: 23rd January, 2024
Revised: 4th April, 2024
Accepted: 5th May, 2024

DOI: https://doi.org/10.51846/jucmd.v3i2.2846

Abstract

Objective: To evaluate the microleakage in four commonly used adhesives and high copper amalgam restorations and to determine the best adhesive and alloy combination with least microleakage for a long-lasting restoration.

Methodology: This study was conducted on a sample of 80 patients after obtaining the ethical approval. 320 standardized Class-I cavities were prepared in premolars indicated for extraction as part of orthodontic treatment. Various combinations of adhesive liners and high copper amalgam alloys were used to restore the cavities in vitro. Adhesive liner was applied in accordance with the manufacturer's instructions, and the cavities were subsequently filled with four different alloys. On the basis of adhesive liners used, four groups (n = 20) were formed randomly (Group A-Amalgam bond Plus, Group B-Scotch bond Multipurpose Plus, Group C-All bond 2 and Group D-Panavia EX). Four premolar teeth (one from each quadrant) were restored with one of four different amalgam alloys: Orosphere Plus, Indiloy, Oralloy or Galloy while the liner was kept same. Three months after their placement in vivo, ten patients were examined from each group, while the remaining ten were examined after six months for microleakage evaluation after extraction of the restored teeth. Quantitative microleakage was assessed as micrograms of dye per tooth through spectrophotometric analysis. Statistical analyses were performed with one way ANOVA and post-hoc Tukey tests at 5% level of significance.

Results: Among adhesives used, Amalgam bond Plus demonstrated least microleakage followed by Scotch bond Multipurpose Plus, No significant difference ($p>0.05$) was found in the degree of microleakage at three months and six months among all the 4 tested groups.

Conclusion: Indiloy and Amalgam bond Plus showed the best combination of alloy and adhesive in resisting microleakage. Bonded amalgam restorations have the ability to serve for the longer period of time successfully.

Keywords: Adhesive, Amalgam bond plus, bonded amalgam, dental amalgam, microleakage.

Introduction

Dental amalgam contains a mixture of metals, specifically liquid mercury and alloy primarily made up of silver, tin, and copper.[1] Amalgam has been widely used in dentistry for over 150 years, showing favorable clinical outcomes.[2,3] However, the last 25 years has seen notable progress in development of restorative materials, leading to a shift towards resin composite materials. This transition is attributed to apprehensions concerning the aesthetics and biocompatibility of dental amalgam.[1] Tooth preparation features to retain traditional amalgam restorations consists of parallel walls, undercuts, box forms, dove tails and grooves. These preparation features frequently require the healthy tooth structure removal and thus weakens the tooth. The idea of bonded amalgam emerged as an attempt to explore whether the merits of bonding resin composite could address certain inherent limitations linked with amalgam restorations.[4] The lack of ability to adhere to tooth structure results in an interfacial gap that permits the initial microleakage around the amalgam restorations. Cavity varnish have been used to control the initial microleakage, however, there is growing concern regarding its effectiveness to seal the amalgam restorations margin, particularly when using high copper amalgam alloys. Liners have also been recommended around freshly packed amalgam restorations to minimize marginal leakage.[3] In recent years, there has been a tendency among operative dentists to use the advantages of adhesive technology in the placement of amalgam restorations. These advantages include a reduction in microleakage between cavity wall and restorative material, which in turn causes a potential decrease in occurrence of recurrent caries, pulpal inflammation and post-operative sensitivity.[5] In research conducted in Pakistan by Hussain et al. (2020), it was found that high copper amalgam restorations demonstrated reduced microleakage in comparison to high-viscosity glass ionomer and resin-modified glass ionomer restorations.[6] However, no adhesive liner was used in this study and comparison was made with other restorative materials.

The literature search revealed that no local study has been carried out to assess the microleakage around amalgam restoration with various adhesive liners. Thus, the present study aimed to evaluate the microleakage in four commonly used adhesives and high copper amalgam restorations and to determine the best adhesive and alloy combination with least microleakage so that we can have a long-lasting restoration with clinical success.

Methodology

This in vitro and in vivo study was conducted in the Department of Operative Dentistry, de'Montmorency College of Dentistry, Lahore and Orthodontic Department of Punjab Den-

tal Hospital, Lahore. Ethical approval was obtained from the Ethical Review Committee of Post Graduate Medical Institute, Lahore (No.00/12519). Patients were selected from the Orthodontic Department of Punjab Dental Hospital, and each participant provided written informed consent. History of the patient was followed by clinical examination. Patients were chosen by non-probability purposive sampling technique based on specified inclusion and exclusion criteria. Patients aged 15 to 40 years with sound premolar teeth indicated for extraction as a part of orthodontic treatment were included. while the patients with poor oral hygiene, systemic diseases ,history of bruxism or any other para-functional habits and with any developmental anomaly, were excluded. 320 cavities were filled with different adhesive-alloy combinations in 80 patients (47 females and 33 males). Four types of high copper amalgam alloys on the basis of composition and shape of particle were used as restorative materials. Sound and healthy premolar teeth were selected for this study, indicated for extraction as a part of orthodontic treatment. On the basis of adhesive liners four groups were formed (Group A-Amalgambond Plus, Group B-Scotchbond Multipurpose Plus, Group C-All bond 2 and Group D-Panavia EX) i.e., each group was comprised of 20 patients and 4 teeth were investigated in each patient. Four teeth (one from each quadrant) were restored with one of four different amalgam alloys: Orosphere plus (admixed Ag 65%, Sn 18%, Cu 12%, Zn 1%), Indiloy (spherical Ag 60%, Sn 22%, Cu 13%, In 5%), Oralloy (spherical Ag 59%, Sn 28%, Cu 13%) or Galloy (powder - Ag 60%, Sn 28%, Cu 11%, Pt 0.05%; liquid – Gal 61%, In 24%, Sn 12%, Bi 0.05%) while the liner was kept same (adhesive from each group) in these teeth according to the symmetry as follows:Right upper premolar -Orosphere Plus ,Left Upper premolar -Indiloy ,Right Lower premolar Oralloy, Left Lower premolar -Galloy .

After detailed history and clinical examination, rubber dam was applied for isolation purpose and a standardized Class-I cavity (1.5 mm wide, 1.5 mm deep, and 3 mm long) was prepared in each tooth utilizing a handpiece (high-speed) with water coolant and a fissure carbide bur # 245. The dimensions of tooth preparation were gauged using a periodontal probe (QOW probe) to ensure uniformity. One of the adhesive liners was applied to the cavity walls following the manufacturer's instructions, and one of the alloys was utilized for the filling. After carving and polishing the restoration, patients were given the next appointment of three months and six months. Half of the teeth of each group were extracted after three months while the remaining half were extracted after six months. Following extraction, the teeth were kept in 2% formaldehyde (pH - 7) for 12 hours. Then, the teeth underwent a washing and cleaning with water and pumice using rubber cups at a slow speed, followed by storage for 24 hours in distilled water. Subsequently, the roots were sectioned using a double-faced diamond disc. The entire tooth surface leaving the restoration and 1 mm of tooth from its margins, was coated with two layers of fingernail varnish. Each tooth was immersed in a 2% methylene blue solution at 37 degrees Celsius for 12 hours. After washing, the nail varnish was removed from the tooth surface by scraping with a surgical blade. Using a double-faced diamond disc, the teeth were sectioned in dental blocks (5 mm wide, 6 mm high, 3 mm thick), with the restoration at the center. This procedure aimed to standardize the tooth volume for spectrophotometric analysis.

Before analyzing the samples in spectrophotometer (Techcomp UV-2300 spectrometer), methylene blue dye solutions at concentrations of 0, 1, 2, 3, 4, 5, and 6 micrograms per ml were prepared. These prepared standard solutions underwent centrifugation and were then read in the spectrophotometer to establish the maximum absorbance, determined to be 664 nanometers in this study. Next, a standard calibration curve was established after calibrating the spectrometer. Once calibrated, the samples were centrifuged, and readings were noted. The concentration of the dye in the samples was evaluated using the standard calibration curve. It was found that the higher the dye concentration, the greater the leakage through the tooth-restoration interface. Quantitative microleakage was measured as micrograms of dye per tooth.

Statistical Analysis

The data were entered and analyzed utilizing SPSS version 24.0. One-way ANOVA test was used to examine group mean differences among the four dental alloys. Post-Hoc Tukey tests were then applied to identify specific group mean differences. Additionally, independent t-tests were conducted to assess differences in leakage at three and six months. A p-value < 0.05 was deemed statistically significant.

Results

Out of total participants, 41.25% were males and 58.75% were females (Figure 1). The mean age was 33.25+11.2 year with minimum and maximum value of 15.0 and 40.0 respectively.

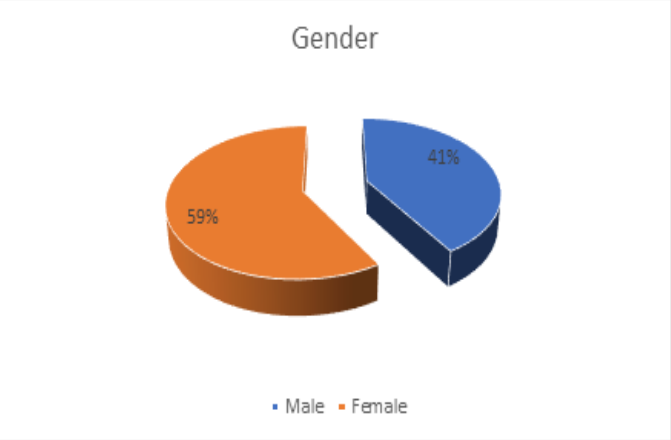

Figure 1: Showing Gender Distribution of Patients

The microleakage among different adhesive-alloy combinations at three months and six months are shown in Table 2 and Table 3 respectively. Adhesive dentin systems showed reduced microleakage in all the tested groups at three months and six months' duration.Among the adhesives, overall significant difference ($p<0.05$) was found when Amalgambond was compared with the other 3 types. ScotchbondMulti-purpose Plus also demonstrated significant difference ($p<0.05$) when compared with All bond 2 and Panavia EX at three and six months. No significant difference was found between All bond 2 and Panavia EX at

three months.However, significant differences ($p<0.05$) were found among all adhesives at six months.

Table 1: Microleakage among different adhesive-alloy combinations at three months

S. No.	Amalgambond Plus				$\bar{x}$	Scotchbond Multipurpose Plus				$\bar{x}$	All Bond 2				$\bar{x}$	Panavia EX				$\bar{x}$
	A1	A2	A3	A4		A1	A2	A3	A4		A1	A2	A3	A4		A1	A2	A3	A4	
1	1.1	1.2	1.5	1.2	1.2	2	2	2.6	2.7	2.3	3.1	3.1	3.4	3	3.1	3.2	3.1	3.9	3.1	3.3
2	0.5	0.5	2	0.5	0.8	2	2.2	2.3	2.1	2.1	3	3.1	3.2	3.4	3.2	3	3.2	4	2.9	3.2
3	2.1	1.5	1.5	2	1.7	2.9	2.1	2.5	2.4	2.4	3.5	2.9	3.6	3.5	3.4	3.7	2.9	3.6	3.2	3.3
4	1.2	0.9	1.7	1.8	1.4	3	2.4	2.6	2.7	2.6	3.5	3.2	3.7	2.9	3.3	3.2	3.1	4	3.3	3.4
5	2.5	1.5	2.5	1.5	2	3.2	2.2	2.9	2.1	2.6	3.9	3.4	3.9	3.7	3.7	3.5	3	4.5	3.1	3.5
6	2.2	1.2	2.2	1.6	1.8	3.2	2.1	3	2.2	2.6	4	2.9	4.1	3.5	3.6	4	3	4.5	3.4	3.7
7	1.5	2	2.6	0.7	1.7	2.1	2.5	2.6	2	2.3	4	3.8	4.2	3.2	3.8	4.2	3.5	4.6	3.5	3.9
8	1.9	1.5	2.7	1.8	1.9	2	2.4	2.7	2.1	2.3	3	2.9	3.7	3.1	3.2	3	3.4	4.9	3.7	3.7
9	2	1	2	2.1	1.7	3	2.3	3.5	2.2	2.7	3.1	3.5	3.9	3.2	3.4	3.6	3.6	5	3.2	3.8
10	2.5	0.5	1.5	2.2	1.6	2.5	2	3.4	2.1	2.5	3.9	3.6	4.2	3.6	3.8	4.2	3.7	5.1	3.4	4.1
$\bar{x}$	1.7	1.2	2.0	1.5		2.6	2.2	2.8	2.3		3.5	3.2	3.8	3.3		3.5	3.2	4.4	3.3	

Abbreviations: $\bar{x}$ = mean; A1 = Orosphere Plus; A2 = Indiloy; A3 = Oralloy; A4 = Galloy

Table 2: Microleakage among different adhesive-alloy combinations at six months

Sr. No	Amalgambond Plus				$\bar{x}$	Scotchbond Multipurposes Plus				$\bar{x}$	All Bond 2				$\bar{x}$	Panavia EX				$\bar{x}$
	A1	A2	A3	A4		A1	A2	A3	A4		A1	A2	A3	A4		A1	A2	A3	A4	
1	1.5	1.5	1.2	1.9	1.5	2.1	2	2.9	2.5	2.3	3	3	3.4	3.1	3.1	3.1	3	3.9	3.1	3.2
2	1.2	1.2	2.1	0.7	1.3	2.5	2	2.8	2.3	2.4	3.5	3.1	3.5	3.4	3.3	3.4	3.5	4	3.4	3.5
3	2	0.5	1.5	2	1.5	2.2	2.3	2.7	2	2.3	2.5	3.2	3.4	3	3.0	3.2	3	3.8	3.8	3.4
4	2.3	0.9	1.7	1.5	1.6	3	2.5	2.4	2.5	2.6	3.8	3	3.9	3.2	3.4	3.9	3.2	4.2	3.4	3.6
5	1.2	1.5	2.5	1.5	1.6	2.2	2.1	2.5	2.3	2.2	3	3.5	3.5	3.7	3.4	3.5	3.4	4.5	3.3	3.6
6	2.2	1.6	2.3	1.7	1.9	3	2	3.5	2.4	2.7	4	2.4	4.5	3	3.4	4.3	3.1	4.3	3	3.6
7	2.1	2	2.8	2.1	2.2	3.2	2.4	2.5	2	2.5	4.2	3.5	4.2	2.9	3.7	3.5	3.2	4.8	3.5	3.7
8	1.5	1.4	2.5	1.5	1.7	2.1	2.3	3	2	2.3	3	3.2	3	3.1	3.0	4.2	3	4.9	3.8	3.9
9	1.9	1.5	2.3	2.2	1.9	2.5	2.5	3.2	2.5	2.6	3.5	3	4	2.9	3.3	4.1	3.4	4.6	3.5	3.9
10	2	2	1.9	2	1.9	2.8	2.5	2.9	2.7	2.7	3.2	2.8	4.5	3.2	3.4	3.5	3.5	5	3.6	3.9
$\bar{x}$	1.7	1.4	2.0	1.7		2.5	2.2	2.8	2.3		3.3	3.0	3.7	3.1		3.6	3.2	4.4	3.44	

Indiloy showed the least leakage with no significant difference with the Orosphere Plus and Galloy, while significant difference ($p<0.05$) with Oralloy was found in all tested groups. Orosphere plus showed no significant difference in microleakage with Indiloy and Galloy in all groups except with Oralloy. Galloy showed significant difference with Orally in group B and D and in significant difference in group A and C at three months (Table 3). At six months, Orosphere Plus showed no significant differences when compared with Indiloy, Oralloy and Galloy in all groups. Indiloy showed significant difference with Oralloy in all groups but insignificant difference with Orosphere Plus and Galloy in all groups. Galloy demonstrated no significant difference with Oralloy in group A but significant difference with group B, C, D (Table 3).

Table 3: Microleakage among different adhesives at three and six months (n = 10 / group)

Variable	Amalgambond Plus	Scotchbond Multipurpose Plus	All Bond 2	Panavia EX	*p-value
Microleakage (At 3 months)	1.622 ± 0.096	2.470 ± 0.067	3.460 ± 0.062	3.625 ± 0.095	0.000^{*}
Microleakage (At 6 months)	1.747 ± 0.078	2.495 ± 0.060	3.345 ± 0.077	3.685 ± 0.087	0.000^{*}

Overall, both Amalgambond Plus and Indiloy demonstrated the least leakage at the three-month and six-month intervals. This indicates that these materials provided the most effective seal over time. Additionally, the study found no significant differences in leakage among all the tested groups at both the three-month and six-month intervals, suggesting that the performance of the materials was consistent over the different time periods.

*ANOVA; *p-value < 0.05 was considered statistically significant.
Abbreviations: $\bar{x}$ = mean; A1 = Orosphere Plus; A2 = Indiloy; A3 = Oralloy; A4 = Galloy

Discussion

This study was conducted both in vivo and in vitro at 3 and 6 months duration, to evaluate the microleakage in four commonly used adhesives and high copper amalgam restorations, and to determine the best adhesive and alloy combination with least microleakage for a long-lasting restoration. One of the goals of an ideal restoration is to prevent microleakage. According to Pashley7, one of the main clinical consequences of microleakage is the formation of secondary caries. This progression finally results in the failure of restorations, requiring their subsequent replacement.Various methods have been used to evaluate microleakage around restorations, with dye leakage being the most commonly used technique. This method gives the advantages of affordability and ease in application. Nevertheless, it comes with some drawbacks, including the subjective nature of result evaluation,a lack of standardization in the method and the dye having lower molecular weight.

The lack of universally accepted standards for experimental parameters makes it challenging to compare results across different studies.[7] To answer these limitations, volumetric leakage studies have been recommended as they demonstrate a more precise measurement of the actual leakage occurring around restorations.[8,9] Unlike most studies on microleakage that use dye penetration with qualitative analysis, which gives an incomplete assessment owing to its two-dimensional nature, volumetric studies provide a three-dimensional outlook on the leakage phenomenon.[9,10] The findings of the present study show that using Amalgambond Plus as a liner on cavity walls before placing amalgam restorations demonstrated superior sealing ability compared to the other tested treatments. This result is consistent with the previous studies.[11-15] It might be due to hybrid layer created by Amalgambond Plus with dental collagen which resulted in superior sealing of tubules and thus preventing dye from infiltrating dentinal tubules. The ability of Amalgambond Plus to seal the tubules early should also prevent the bacteria, which penetrates the cavity amalgam interface, from entering the dentinal tubules. High performance additive powder (HPA) in Amalgambond Plus contains polymethacrylate fibers responsible for mechanical interlocking, which also produces reinforced union between the two materials.

However, previous studies[16,17] found lower levels of microleakage when Scotchbond Multipurpose Plus was used as a liner than Amalgambond Plus, a finding contradictory to our study. This might be due to the high viscosity of the Scotchbond Multipurpose Plus making its mechanical bonding less efficient. Similarly, a study18 found no significant difference between All-Bond[2] and Amalgambond Plus adhesive systems in vitro at any intervals tested. This is in contrast to our study as there is a difference in sealing abilities of adhesives used in our study. In spite of the recognized efficacy of Panavia EX resin cement in decreasing leakage around amalgam restorations with enamel margins in different studies, the current research found that it did not demonstrate the same microleakage reduction as the hydrophilic adhesive system.[19,20]

The utilization of various adhesive liners, such as All Bond[2], Amalgambond and Panavia EX, in bonding amalgam has been known.[21] Several previous studies investigating bonded amalgam restorations have shown noteworthy improvements in reducing microleakage.[22-25] Nevertheless, Mahler et al.[26] reported minimal to no benefits in bonding amalgam restorations regarding marginal fractures and post-operative sensitivity. It's critical to highlight that these results were derived from the data collected within 1-2 weeks after placement.

In the present study, Indiloy showed least microleakage among the various alloys used. Greater microleakage was observed in Oralloy than Galloy and Orosphere Plus. Different factors are responsible for microleakage around amalgam restorations i.e., type of alloy, condensation, burnishing, use of liners/varnishes, bonded amalgam restorations etc. Condensation and burnishing, a variable factor, are under the control of operator. Use of liners and varnishes are not in use due to their nature of solubility and now have been replaced with adhesive liners. As for as type of alloy is concerned, lathe cut and admixed alloys display less leakage than spherical alloy.

Among the alloys, Indiloy, Oralloy and Galloy belong to spherical blend and Orosphere Plus belong to admixed blend. Admixed alloys display less microleakage than spherical alloys. But in this study spherical blend (Indiloy) showed least leakage, though no significant difference was found between spherical (Indiloy) and admixed alloy (Orosphere Plus). This is in consistent with the findings of Meiers et al.[25] However, Mahler et al.[27] and Chang et al.[28] in their studies, concluded that spherical alloys as a group had an increased tendency towards microleakage than lathe cut or admixed alloys. It means that factors other than the particle shape are important in microleakage like oral environment and the composition of alloys.

The assessment of oral health continues to be a vital factor for the successful performance of any restorative material. As far as oral environment is concerned, it is a variable from patient to patient and is not under operator control. Among the alloys used, the major difference in composition is the percentage of tin. The detected differences could be attributed to the higher tin content (18% in Orosphere Plus, 22% in Indiloy and 28% in Oralloy), potentially influencing the dimensional stability at the time of setting of dental amalgam. Although Galloy having a tin content of 28.05%, the formation of distinct phases during setting, mainly Ga-Cu and Ag-In, might contribute to some dimensional change.

Limitations

However, the study has the limitations as well.All the fillings in this study were done in Class-I cavity design. It must be noted that in the majority of cases, microleakage does not occur at the occlusal margins of the restorations (thick enamel) but rather initiates from the gingival margin (thin enamel) and extends toward the axial wall. Thus, using the other cavity designs may

show different results. We used the fourth-generation adhesive system; any new generation adhesives may show different behaviors. The amalgam alloys used were high copper, other alloys with different composition may show different behavior. The evaluation of amalgam retention based on adhesive liner versus retentive features was not included in the study. Time period for study was limited. Prolonged period of time may change the result. Additional long-term clinical evaluations are essential to clarify the full potential of bonded amalgam restorations.

Amalgam is still in use and bonded amalgam further ensures the success and longevity of the restoration which is directly related to its marginal seal. So ,it is recommended to use the bonded amalgam especially in third world countries like Pakistan, where poverty is prevailing and spending money on restorations that have to be replaced continuously is a financial burden.

Conclusion

Within the limitations of this study, Indiloy and Amalgambond Plus showed the best combination of alloy and adhesive in resisting microleakage. Bonded amalgam restorations have the ability to overcome the problem of microleakage successfully.

Authors' Contribution:

SN contributed in the conceptualization, design, procurement, analysis, and interpretation of data, MAH in creating the initial draft of the article and meticulously revising it to ensure essential intellectual content. NB managed the literature search and helped in writing the draft.

Conflict of Interest: The authors declare that they have no competing interest.

Funding: The present study didn't receive any funding.

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