ORIGINAL RESEARCH ARTICLE

Comparison of Efficacy of Newer Adhesive Systems with Conventional Liners under Silver Amalgam Restorations – An *In vitro* Trial

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ABSTRACT

Background: Use of newer adhesives to improve adhesion and reduce microleakage between tooth-amalgam interface is the need of the hour, to promote the clinical use of diminishing silver amalgam restorations. **Aims and Objectives:** This study aims to evaluate and compare the efficacy of conventional liners and newer bonding adhesives, namely, Optibond, self-etch adhesive system, and Single Bond Universal Adhesive system in minimizing the microleakage under amalgam restorations. **Materials and Methods:** Class I cavities were prepared on occlusal surfaces of 40 premolars and were randomly divided into four groups of 10 teeth each, which were lined with dental varnish, Bifluorid varnish, Optibond, and Single Bond Universal Adhesive and restored with silver amalgam. The specimens were subjected to microleakage testing through dye penetration method, observed under ×30 stereomicroscope. **Results:** Amalgam restorations lined with Single Bond Universal Adhesive showed significantly higher ($P < 0.001$) microleakage score (mean rank = 34.50) when compared to restorations lined with Bifluorid varnish (mean rank = 22.40), dental varnish (mean rank = 15.70), and Optibond (mean rank = 9.40). **Conclusion:** The study concluded that among all the cavity lining materials used, Optibond All-In-One self-etch adhesive significantly minimized microleakage under silver amalgam restorations.

Key words: Bonded silver amalgam, dental varnish, dentin adhesives, microleakage

INTRODUCTION

Silver amalgam has been used to restore teeth since G.V. Black described the classification of cavities.[1] There is evidence from clinical studies that bonding of amalgam can be favorably used to extend the range of usage of amalgam to non-retentive conservative preparations as well as an adjunct to other forms of retention in large compound restorations.[2]

Microleakage under silver amalgam restorations causes hypersensitivity, marginal breakdown, secondary caries, and pulpal irritation. Various materials were employed to seal the tooth-amalgam interface to minimize microleakage which is more detrimental to its longevity. To overcome the disadvantages of amalgam and reap the benefits of bonding composite, the concept of bonded amalgam was introduced in 1976 by Zardiackas.[3] This technique involves adhesive systems that reliably bond to enamel and dentin. Several studies have concluded that bonded amalgam restorations result in reduced marginal leakage at the tooth-amalgam interface compared to conventional amalgam restorations.[2,4-6]

There is lack of literature on the efficiency and the sealing ability of new generation adhesives, namely, Single Bond Universal Adhesive system (3M ESPE) and Optibond All-In-One self-etch adhesive (Kerr) under silver amalgam restorations. Hence, an *in vitro* study was undertaken to compare the efficacy of Copalite varnish, fluoride varnish,

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Optibond All-In-One self-etch adhesive, and Single Bond Universal Adhesive in minimizing the microleakage under silver amalgam restorations.

MATERIALS AND METHODS

A total of 40 non-carious premolars extracted for orthodontic reasons were collected, and only those teeth without any surface defects were taken into the present study. The debris on extracted teeth was cleaned and then stored in 0.1% thymol solution at room temperature until future use. Class I cavities were prepared on occlusal surfaces of premolars using a round bur and a straight fissure diamond bur in a high-speed airotor handpiece with water coolant. The cavity dimensions were 3 mm mesiodistally, 2 mm buccolingually, and with 2 mm depth which were standardized using Vernier calipers. All cavosurface margins were prepared to create a butt joint. The prepared cavity was rinsed thoroughly with air-water spray and dried, one operator prepared all cavities to ensure a consistent calibrated size and depth to minimize preparation variability. While using bonding adhesives self-etch technique, based on the simultaneous etching, priming and adhesion of the dentin surface using a single solution was employed.

The teeth were divided randomly into four groups of 10 teeth each. In Groups I and II, Copalite dental varnish (Namuvar IDP, India) and Bifluorid 12 varnish (VOCO, Germany) were applied, respectively, in two thin layers for 10 teeth each, allowing the first layer to dry for 30 s without the use of compressed air before applying the second layer. In Group III and Group IV, Optibond All-In-One self-etch adhesive system (Kerr, Copenhagen, Denmark) and Single Bond Universal Adhesive (3M ESPE, Minnesota, USA) were applied, respectively, and photocured for 20 s.

In all groups, remaining cavity was filled with silver amalgam (DPI Alloy, India) and carving was performed using 3S Hollenback carvers. All the silver amalgam restorations were burnished and polished after 24 h to a fine sheen using prophy paste and rubber cup in a slow speed micromotor handpiece.

The restored teeth were subjected to thermocycling in water baths for 500 cycles between 5 °C and 55 °C with a dwell time of 30 s at each temperature with a transfer time of 10 s to simulate thermal conditions. Then, each tooth was covered with two layers of nail varnish except on restorations and leaving 1 mm surrounding them to avoid false-positive results through dye penetration from another point rather than the restorative margins. Root apices were sealed with sticky wax and immersed in 0.5% methylene blue dye for 24 h. The teeth were taken out and rinsed with tap water, and nail polish was removed with a sterile #15 disposable scalpel blade. Each tooth was mounted in acrylic block and sectioned buccolingually through the center of restoration using a hard tissue microtome. The sectioned specimens were observed under the stereomicroscope (×30) for dye penetration in the cavity margins and scored for microleakage by a calibrated examiner using the Williams *et al.* score (1978) for dye penetration.[7]

The scores of microleakage are as follows:

Grades	Dye penetration
• Grade 0	No dye penetration between the tooth surface and the sealant [Figure 1]
• Grade 1	Dye penetration into less than one-third of the entire length of the surface between the sealant and the tooth structure [Figure 2]
• Grade 2	Dye penetration into one-third to two-thirds of the entire length of the surface between the sealant and the tooth structure [Figure 3]
• Grade 3	Dye penetration into more than two-thirds of the entire length of the surface between the sealant and the tooth structure [Figure 4].

Results were tabulated and subjected to statistical analysis. Non-parametric Kruskal–Wallis test was used for assessing the differences in microleakage in the test and control groups followed by Mann–Whitney U-test for pair-wise comparison to identify any statistically significant differences at the significant level of 0.95 ($P < 0.05$).

RESULTS

The mean microleakage scores in microns were 1.0 ± 0.67 (Group I), 1.70 ± 0.95 (Group II), 0.40 ± 0.52 (Group III), and 3.00 ± 0.00 (Group IV) [Table 1]. The mean rank of 34.50 in Group IV is suggesting that there are more number of restorations with high microleakage score in this group when compared to the microleakage scores in other three groups. This is statistically highly significant ($P < 0.001$).

Microleakage scores of silver amalgam restorations lined with Copalite dental varnish (Group I) and Bifluorid 12 varnish (Group II) showed

the mean rank of 8.30 and 12.70, respectively. However, this difference is not statistically significant (*P* = 0.076), whereas comparison of Group III with mean rank 5.50 and Group IV with mean rank 15.50 showed highly significant difference (*P* < 0.001) [Table 2].

DISCUSSION

Silver amalgam has often been discussed for its longevity as well as for its lack of tooth adhesion and microleakage. Microleakage is defined as the flow of oral fluid and bacteria into the microscopic gap between a prepared tooth surface and a restorative material.[8] It is associated usually with invasion from the external environment through the margins of the restoration, but microleakage can also occur internally.[9] Microleakage, leading subsequently to marginal breakdown and secondary caries, is one of the major disadvantages of silver amalgam restorations. Bacterial microleakage at the tooth-restorative interface was the most common cause of pulpal inflammation in the experimental cavities with different materials.[10]

Various *in vitro* techniques have been employed to test the cavity-sealing properties of direct restorations. *In vitro* studies include the use of dyes, chemical tracers, radioactive isotopes, neutron activation analysis, scanning electron microscopy, artificial caries techniques, and electrical conductivity.[11] In most of the studies, dye penetration test was chosen as it is a simple technique, relatively

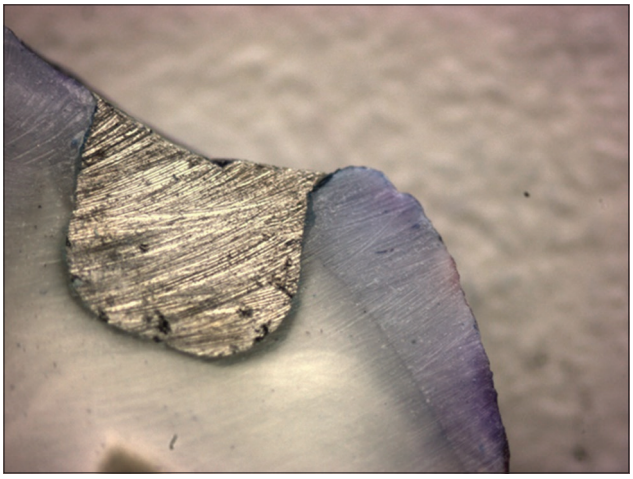

Figure 1: Stereomicroscopic image with no dye penetration (score 0)

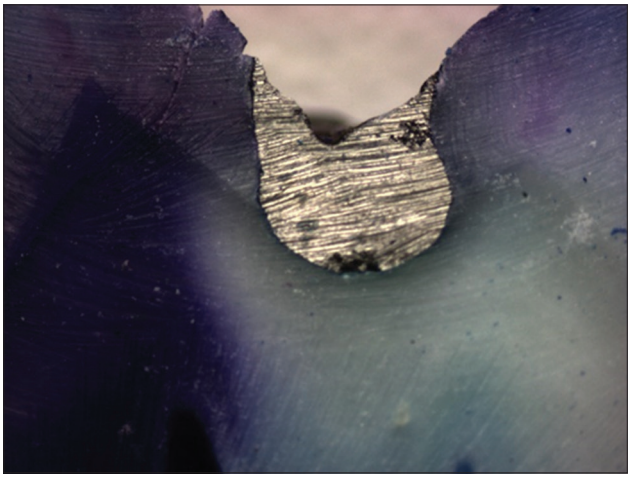

Figure 3: Stereomicroscopic image with dye penetration up to 2/3rd of cavity wall (score 2)

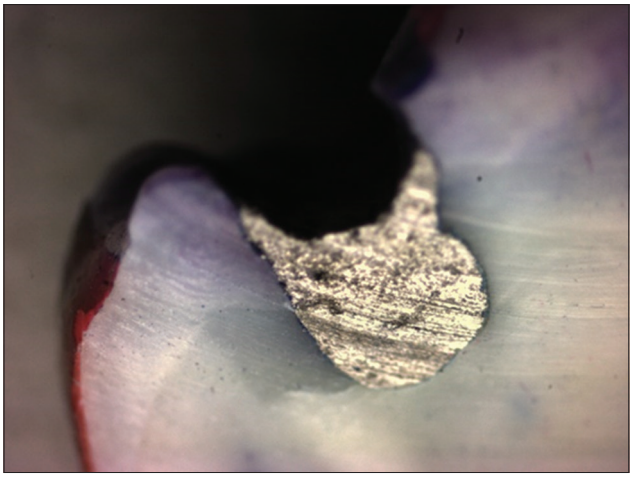

Figure 2: Stereomicroscopic image with dye penetration up to 1/3rd of cavity wall (score 1)

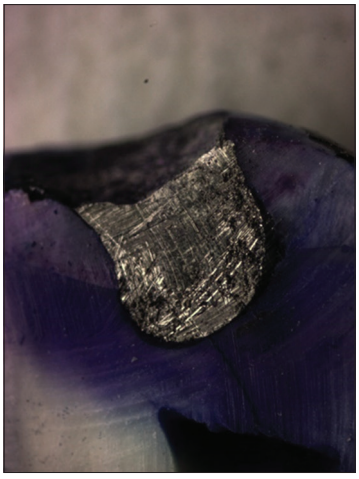

Figure 4: Stereomicroscopic image with dye penetration up to cavity floor (score 3)

Table 1: Mean microleakage scores for all four groups lined with different liners under silver amalgam restorations (Kruskal–Wallis test)

Score of microleakage	Group I	Group II	Group III	Group IV
Score 0	2	1	6	0
Score 1	6	3	4	0
Score 2	2	4	0	0
Score 3	0	2	0	10
Mean±SD	1.00±0.67	1.70±0.95	0.40±0.52	3.00±0.00
Mean rank#	15.70	22.40	9.40	34.50
P value	Chi-square=27.374; df=3; *P*<0.001**			

**: Highly significant, df: Degree of freedom. #Mean Rank - *P*<0.001, highly significant, in Group III and Group IV

Table 2: Comparison of microleakage scores between Optibond All-In-One self-etch adhesive (Group III) and Single Bond Universal Adhesive (Group- IV) (Mann–Whitney U-test)

Score of microleakage	Group III	Group IV
Score 0	6	0
Score 1	4	0
Score 2	0	0
Score 3	0	10
Mean±SD	0.40±0.52	3.00±0.00
Mean rank#	5.50	15.50
P value#	Z=4.119; *P*<0.001**	

**: Highly significant. #Group IV is greater than Group III

economical, qualitative, and comparable method of evaluating the efficacy of the various restorative materials.[12] In the present study, methylene blue dye was used to evaluate microleakage because it is readily available and inexpensive. As methylene blue has affinity to glycosaminoglycans present in dentin, it has better penetration results than eosin or other radioisotope traces.[13,14]

In an effort to simulate diversified oral environmental temperatures, thermal cycling was employed to detect microleakage. The temperatures used for *in vitro* thermocycling ranges from 0 °C to 68 °C. The time used for the alternate immersion of specimens in hot and cold solutions is ranged between 10 s and 120 s.[11] In the present study, the restored teeth were subjected to 500 cycles between 5 °C and 55 °C with a dwell time of 30 s at each temperature. Thermocycling was used to accelerate aging of the restoration and to force the earlier appearance of microleakage.

Several methods have been proposed and used for accurate detection of microleakage. Stereomicroscope-based microleakage studies are clinically well proven.[15] In these studies, the method is based on the interpretation of the leakage of dye on the cavity wall, and in this semi-quantitative approach, the leakage is calculated solely at the surface where the section is made.[10] In the present study, stereomicroscope is used in detecting microleakage as it was found to be observer friendly, accurate, and cost-effective method.

The findings in the present study are supporting the findings of the previous studies, in which Copalite varnish had been compared against resin lined amalgam restorations. Among all the groups, silver amalgam using Optibond (Group-III) showed significantly less microleakage, followed by Copalite dental varnish (Group-I), Bifluorid 12 varnish (Group-II), and Single Bond Universal Adhesive (Group-IV). The results are similar to a study by Winkler *et al.* who compared varnish and dentin bonding agents under amalgam restorations and concluded that the dentin bonding adhesives significantly reduced microleakage at cementum margin but not at the enamel margin.[12]

In the present study, among the varnishes, Copalite dental varnish (Group I) performed well in preventing microleakage when compared to the Bifluorid 12 varnish (Group II). In an *in vitro* study done by Marchiori *et al.* on different lining materials (an adhesive system, a topical fluoride gel, a cavity varnish, and a glass-ionomer cement), under amalgam restorations, the author concluded that "the use of liners does not reduce microleakage of amalgam restorations when the cavity margins remain on enamel, whereas on dentin margins, a glass-ionomer liner can reduce microleakage."[16] This is due to the formation of calcium fluoride ions and low-molecular-weight substances along the tooth-restorative interface, while using fluoridated lining materials, hence, there is higher leakage

under Bifluorid 12 varnish.[16] However, in the present study, Bifluorid 12 varnish (Group II) showed superior performance than Single Bond Universal Adhesive (Group IV). The reason behind this is due to the fact that single bond adhesives have greater bonding efficiency on uncut enamel surfaces when compared to prepared enamel surfaces.[17]

In the present study, among the seventh-generation bonding systems, namely, Optibond self-etch adhesive and Single Bond Universal Adhesive, Optibond showed better results. The superior performance of this bonding system over Single Bond Universal Adhesive is accredited to the ternary solvent system which contains water, acetone, and ethanol, whereas single bond system contains acetone alone in its monomer.[17] Acetone is more volatile than ethanol because acetone has vapor pressure of 200 mmHg at 25 °C, whereas ethanol has 54.1 mmHg.[18] As Optibond contains both acetone and ethanol, its bond to tooth structure is strong which helps in preventing the microleakage.

The seventh-generation bonding agents use the smear layer as a bonding substrate. Since the etched surface is not rinsed, the demineralized smear layer is incorporated into the hybrid layer. The acidic primer and adhesive monomers also infiltrate collagen fibers as the primer decalcifies the inorganic component in dentin to the same depth, which should minimize voids, potential microleakage, and post-operative sensitivity.[19] Optibond has performed better due to its excellent penetration into dentin tubules that provide exceptional bond strength and protect against microleakage and post-operative sensitivity. Its unique nanoetching capability enables the most effective enamel etching of any existing single-component adhesive, creating a deeper etched surface for higher mechanical retention and chemical bonding. Hence, it is recommended for adhesion of amalgam restorations in minimally invasive preparations as well as large complex amalgam restorations. However, few evidence-based reviews have disclosed that there is lack of evidence on the additional benefit of adhesively bonding amalgam restorations when compared with non-bonded amalgam restorations.[20]

CONCLUSION

The following conclusions were drawn from the present study:

1) Among the varnishes, in reducing microleakage under amalgam restorations, significant difference was found between Copalite dental varnish and Bifluorid 12 varnish. Copalite dental varnish performed better
2) Among bonding agents, amalgam restorations lined with Single Bond Universal Adhesive had shown the highest microleakage, whereas amalgam restorations lined with Optibond had shown the least microleakage
3) Among all the cavity lining materials used in the present study, Optibond significantly minimized microleakage under silver amalgam restorations. Hence, it can be recommended as an ideal adhesive liner under bonded amalgam restorations.

These results should be correlated with the quite challenging clinical evaluation of microleakage, which is possible, only after being substantiated by sufficient in vivo evidence obtained from long-term clinical studies.

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