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Short-term Evaluation of Resin Sealing and Rebonding on Amalgam Microleakage: An SEM Observation

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Abstract

Aims: The aim of this study was to evaluate the effect of two different sealing agents on the microleakage of Class V amalgam restorations with and without resin rebonding.

Methods and Materials: Sixty extracted premolars were divided into six groups with ten teeth in each group. Class V cavity preparations were prepared on the facial surfaces of each tooth with the coronal margins placed in enamel and apical margins in cementum (dentin). The preparations in three groups were treated with Copalite, Scotchbond Multi-Purpose (SBMP), and no sealing agent, respectively. The other three groups received the same sealing agents in conjunction with a rebonding process. This arrangement of specimens provided for a comparison of the groups with and without a rebonding procedure. Amalgam was used as the restorative material. Specimens were thermocycled, stained, and sectioned. Microleakage was graded (0-3) using a stereomicroscope at 40x magnification. A scanning electron microscope (SEM) was used along with a high resolution elemental analysis. Data were analyzed with Kruskal-Wallis, Mann-Withney, and Wilcoxon pair wise statistical tests (α=.05).

Results: The bonded amalgam groups demonstrated significantly less microleakage, whereas the unsealed groups showed the highest microleakage (P=0.001). A significant difference between the mean rank of the microleakage of enamel and dentin margins was observed (P=0.037). Insignificant, lower microleakage was observed in groups receiving a rebonding procedure (P=0.085).

Conclusion: Copalite and a multi-step adhesive system had a significant effect on microleakage of Class V amalgam restorations. The influence of the multi-step adhesive system was significantly greater than Copalite. The rebonding of the amalgam restorations did not have a significant effect on microleakage.

Keywords: Rebonding, microleakage, amalgam restorations

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Introduction

Dental amalgam has been used successfully for almost two centuries as a restorative material.[1] The two main disadvantages of amalgam restorations are lack of adhesion to tooth and marginal microleakage (particularly high-copper alloys or non-gama-2). Microleakage and its subsequent complications include postoperative sensitivity, discoloration, pulp irritation, and secondary caries.[2]

Microleakage of amalgams can be reduced by increasing mix plasticity (increase Hg/alloy ratio), decreasing setting contraction, and/or decreasing surface roughness.[3] Using dentin bonding agents with amalgam restorations is still a debatable issue. One short-term clinical report supports amalgam bonding;[4] however, longer clinical studies have reported no difference between bonded and conventional amalgams in terms of post-operative sensitivity, marginal integrity, and restoration success.[5]

The concept of "rebonding" restorations to seal marginal gaps was suggested by Garcia et al. when they reported a microleakage evaluation with resin composite. They defined the rebonding procedure as an application of an unfilled resin bonding agent over the margins of a finished restoration. A scanning electron microscope (SEM) study conducted by Mertz et al.[7] demonstrated fissure sealant resin penetrated an interface gap when placed over the etched margins of a freshly placed amalgam restoration. As a result, they suggested margins of freshly placed amalgams may be sealed and protected from 'ditching', extending the life of the restoration and protecting the tooth from recurrent caries. Ben-Amar et al.[8] in an *in vitro* study reported two coats of a dentin bonding agent (Scotchbond, 3M ESPE Dental Products, St. Paul, MN, USA) placed on the walls of the preparation significantly reduced microleakage at the gingival floor of Class II amalgam restorations and was significantly more effective in reducing microleakage than copal varnish.

The null hypothesis tested was the microleakage at the enamel and dentin margins of an amalgam restoration is not affected by the type of sealing material, with or without sealing, or rebonding.

Methods and Materials

Sixty intact human maxillary premolars freshly extracted for orthodontic purposes were employed in the study. The teeth were disinfected and their surfaces cleaned with a hand scaling instrument and pumice in a rubber prophylaxis cup. Class V cavity preparations were then cut on the facial surfaces at the cementoenamel junction (CEJ) with the coronal margins located in the enamel, whereas the apical margins were located in cementum (dentin). The preparations were cut with a No. 56 straight fissure bur (Midwest Dental Products Corp., Des Plaines, IL, USA) in a high-speed handpiece (Star Futura 2, Star Dental, Valley Forge, PA, USA). Burs were discarded following preparation of ten teeth. Each preparation was made to the following dimensions:

- Mesiodistal width = 3.0-3.5 mm
- Occlusogingival width = 2.0-2.25 mm
- Axial depth of occlusal wall =1.5-2.0 mm
- Axial depth of gingival wall = 1.25-1.75 mm

Preparation dimensions were measured with a periodontal probe to maintain uniformity. One operator prepared all teeth to ensure a consistent calibrated size and depth in order to minimize preparation variability. The 60 prepared teeth were randomly distributed into six groups of ten teeth. Each of the six groups received different treatment as to sealer placement and resin rebonding as follows:

Group 1: Two coats of Copalite (Cooley & Cooley, Ltd., Houston, TX, USA), followed by amalgam placement. No rebonding was done.

Group 2: The enamel and dentin layers were etched for 15 secs, rinsed with water for 15 secs, and dried for 5 secs. This was followed by an application of SBMP (Scotchbond Primer and Adhesive, 3M ESPE Dental Products, St. Paul, MN, USA), light cured then amalgam placement. No rebonding was done.

Group 3: Amalgam placement only (no sealer used). No rebonding was done.

Group 4: Copalite application and amalgam placement as in Group 1. Amalgam rebonding was done.

Group 5: Etching, Scotchbond MP Primer and Adhesive application and amalgam placement as in Group 2. Amalgam rebonding was done.

Group 6: Amalgam placement only with no sealer placement. Amalgam rebonding was done.

For the Copalite application, the preparation was washed with water and thoroughly dried, then Copalite was applied with a blotted cotton pellet, dried with gentle air from an air syringe, reapplied, and again dried. The Scotchbond MP was applied according to the manufacturer's instructions. Then adhesive resin was polymerized for 20 secs using an Optilux 500 light curing unit (Demetron-Kerr, Orange, CA, USA) at 500mW/cm^2. After placement of sealers, GS 80 dental amalgam (Southern Dental Industries Limited, Bayswater, Victoria, Australia) was hand condensed into the preparations covering all walls and cavosurface margins, then carved to the tooth contour with a sharp carver.

The rebonding procedure consisted of applying 37% phosphoric acid gel (Scotchbond Etchant) to the amalgam and tooth structure at the restoration margins for 15 secs, rinsing with water for 15 secs, drying, then applying Scotchbond MP Adhesive resin to the margins and polymerizing for 20 secs.

When specimens were not being prepared, restored, or tested, they were immersed in distilled water at room temperature. After restoration, specimens were stored for 24 hrs in distilled water at room temperature, then thermocycled from 5°C to 50°C for 1000 cycles with a 30 sec dwell time.

Specimens were then painted with two coats of finger nail polish to within 0.5 mm of the restoration margins. Then they were immersed in 0.5% basic fuchsin dye solution for 24 hours at 37°C. The specimens were then removed from the dye and brushed for 20 secs under running tap water to remove excess dye. Each specimen was sectioned longitudinally, in a faciolingual direction in at least two locations on the restoration, for examination. Sections were examined with a Nikon SMZ 10 stereoscopic microscope (Nikon Inc., Garden City, NY, USA) at a 40x magnification by two examiners.

Microleakage Evaluation

Each section was graded for microleakage at both occlusal and gingival walls as follows:

0 = No marginal penetration by the dye.
1 = Dye penetration up to half the length of the lateral walls.
2 = Dye penetration to more than half of the lateral wall length but not onto the axial wall.
3 = Dye penetration onto the axial wall.

Data were analyzed with Kruskal-Wallis, Mann-Withney, and Wilcoxon pair wise statistical tests (α=.05).

SEM and EDS Evaluation

Two specimens of each group were randomly selected for SEM evaluation to determine the presence or absence of marginal gaps along the entire tooth-restoration interface. The analysis of the interface was carried out using a Model VP1450 LEO (Germany, resolution 2.5 nm) SEM and an energy dispersive X-ray spectroscopy unit (EDS) (Oxford, Model 7353, English, resolution 133 ev).

One sectioned surface produced from each restoration was gently polished using 600-grit silicon carbide abrasive paper under hand pressure and water to remove surface debris. After acid etching, the surfaces were treated with 10% polyacrylic acid for 10 secs to remove the smear layer. The specimens were then washed with deionized water and gently dried with oil-free compressed air. Sections were then prepared for SEM examination by thorough desiccation in a Sample Dry Keeper (Samplatec Co., Tokyo, Japan). Sputter coating with gold-Palladium was done by means of a Polaron Equipment Limited SEM Coating Unit E 500 (Comercial Assens Llofriu, S A, Barcelona, Spain). Examination of all sections under the SEM was performed at an accelerating voltage of 15 KV, 10 spot sizes, and a 12 mm working distance. Micrographs were taken at 400 and 6000 operating magnifications. Images were coated and compared in a blind fashion.

Assessing the composition of fillings can be done by using EDS coupled to the SEM. The elemental composition can be determined across the region of interest and matched to the corresponding SEM image. X-rays are generated when the SEM's primary beam interacts with the sample surface. All elements have their own unique 'family' of energies, represented by peaks on an EDS spectrum. Identification of all peaks in a family enables the identification of elements in a sample.

Results

Microleakage

The mean rank of marginal microleakage in Class V cavities at enamel and dentinal margins for the six experimental groups in addition to the results of Kruskal-Wallis test are presented in Tables 1 and 2. Less than 5.5% of observations had a difference of one grade between examiners.

There was no interaction between resin sealing and rebonding except in the group sealed with Copalite and rebonded along the enamel margin

Table 1. Mean rank microleakage within each group in enamel margin and P-value.

Group	Mean Rank	P-value
Non-rebonded groups:		P=0.02
Copalite sealed	32.10	
Scotchbond MP sealed	20.35	
Unsealed	40.00	
Rebonded groups:		P=0.001
Copalite sealed	25.20	
Scotchbond MP sealed	19.35	
Unsealed	46.00	

Table 2. Mean rank microleakage within each group in dentin margin and P-value.

Group	Mean Rank	P-value
Non-rebonded groups:		P=0.003
Copalite sealed	32.30	
Scotchbond MP sealed	18.30	
Unsealed	39.50	
Rebonded groups:		P=0.001
Copalite sealed	36.20	
Scotchbond MP sealed	17.20	
Unsealed	39.5	

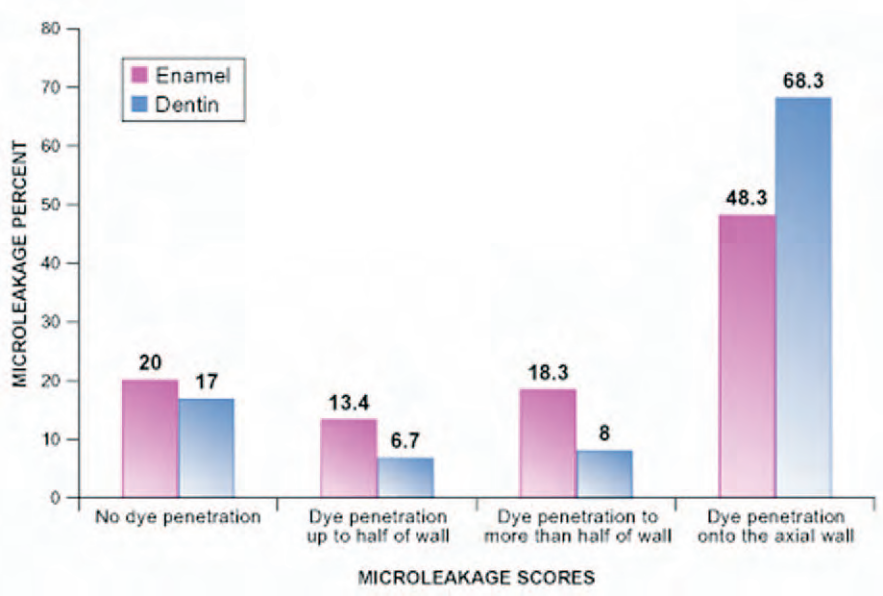

Figure 1. Percent of dye penetration scores as an indicator of marginal microleakage in the enamel and dentin walls.

(P=0.012). Regardless of whether rebonding was done or not, or the type of margin involved, specimens sealed with Scotchbond MP had the least mean rank of microleakage whereas the unsealed groups had the greatest mean rank of microleakage (P<0.001). In addition, there was significant difference between the unsealed and copal sealed groups (P=0.002). Rebonding showed no significant effect on microleakage (P=0.085). The Wilcoxon pair-wise test revealed significantly higher microleakage in dentin margins than in enamel margin (P=0.037) (Figure 1).

SEM Results

The tooth-amalgam interface was observed using SEM, and the elements were analyzed using EDS. Figure 2 indicates the sample is similar in terms of a standard tin-silver-copper amalgam, tooth tissue, and a hybrid layer.

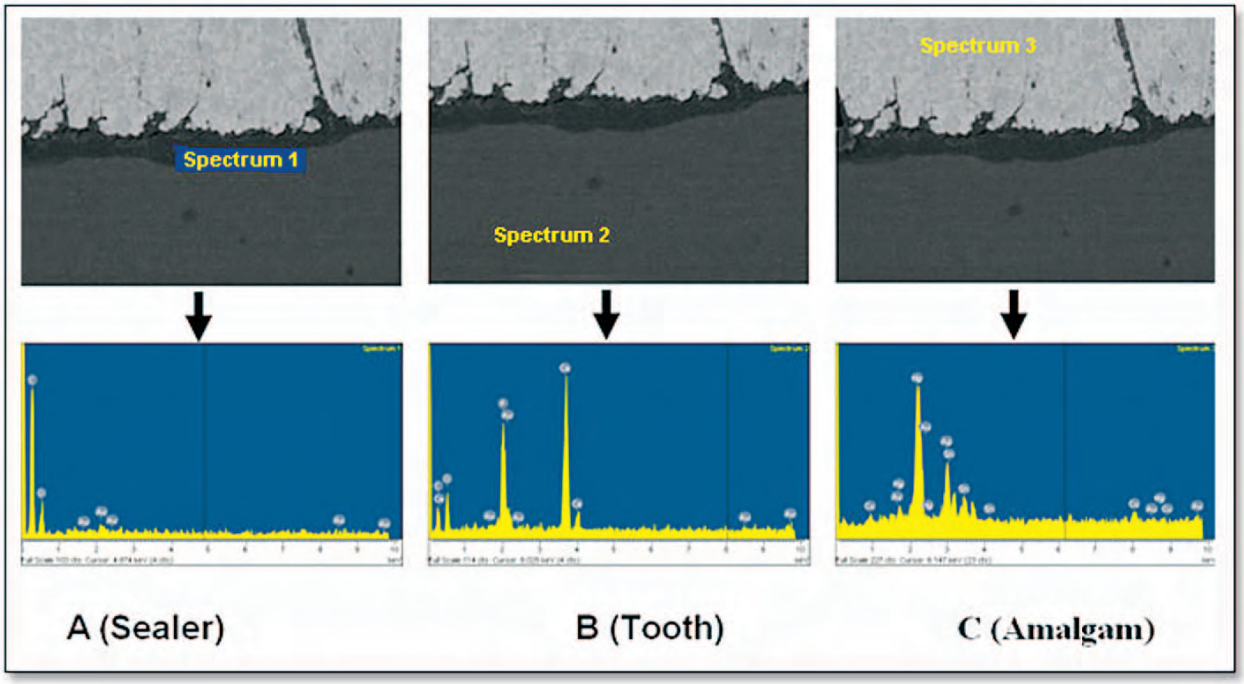

Figure 2. SEM images of Group 2, A, B, C (1000X magnification) and the corresponding EDS analysis.

Typical SEM images in one pair of different groups in various magnifications are shown in Figure 3. At lower magnification, there were no differences between bonded and unbonded amalgam regardless of the rebonding. At higher magnification, the teeth restored with unbonded amalgam had more spaces and artifacts at the amalgam-tooth structure interface. None of the samples showed a completely bonded interface. Groups 2 and 5 (sealed with SBMP) demonstrated higher bond failures between the amalgam and adhesive system (Figure 3).

In all cases some bonding failures or separations could be observed with the gap consistently present at the axial wall of the cavity preparations. The interface between the Scotchbond MP and dentin showed bonded sites but some separations were also seen.

Discussion

Different methods have been employed to evaluate microleakage around restorations with the dye penetration test probably being the most widely used technique. The principal advantages of this technique are the low cost and ease of application. The disadvantages are the subjective evaluation of the results,[9] the low molecular weight of the dye being less than bacteria, and the poor standardization of the method. Comparison of the results from different studies is problematic, since there are no generally accepted standards for experimental parameters, such as the type and concentration of the storage solution, time of storage, temperature during storage, type and duration of thermal cycling and/or mechanical cycling, and the scoring criteria.[10] The use of an adhesive system under amalgam restorations has been used instead of copal varnish as it would be with an ordinary restorative procedure.[2,11] The results of the present study showed adhesive material reduced microleakage when compared with the copal varnish sealer and unsealed groups. Similar findings have been reported when comparing copal varnish to resin-sealed amalgam restorations.[12,13,14]

Several low-viscosity resins, called surface sealers, are available for use in rebonding. These resin sealants are applied over the margins of a freshly carved amalgam restoration which penetrates the interface gap between the tooth and the amalgam restoration raising hope such a technique may have clinical significance.[7] However, the present study rejected this concept.

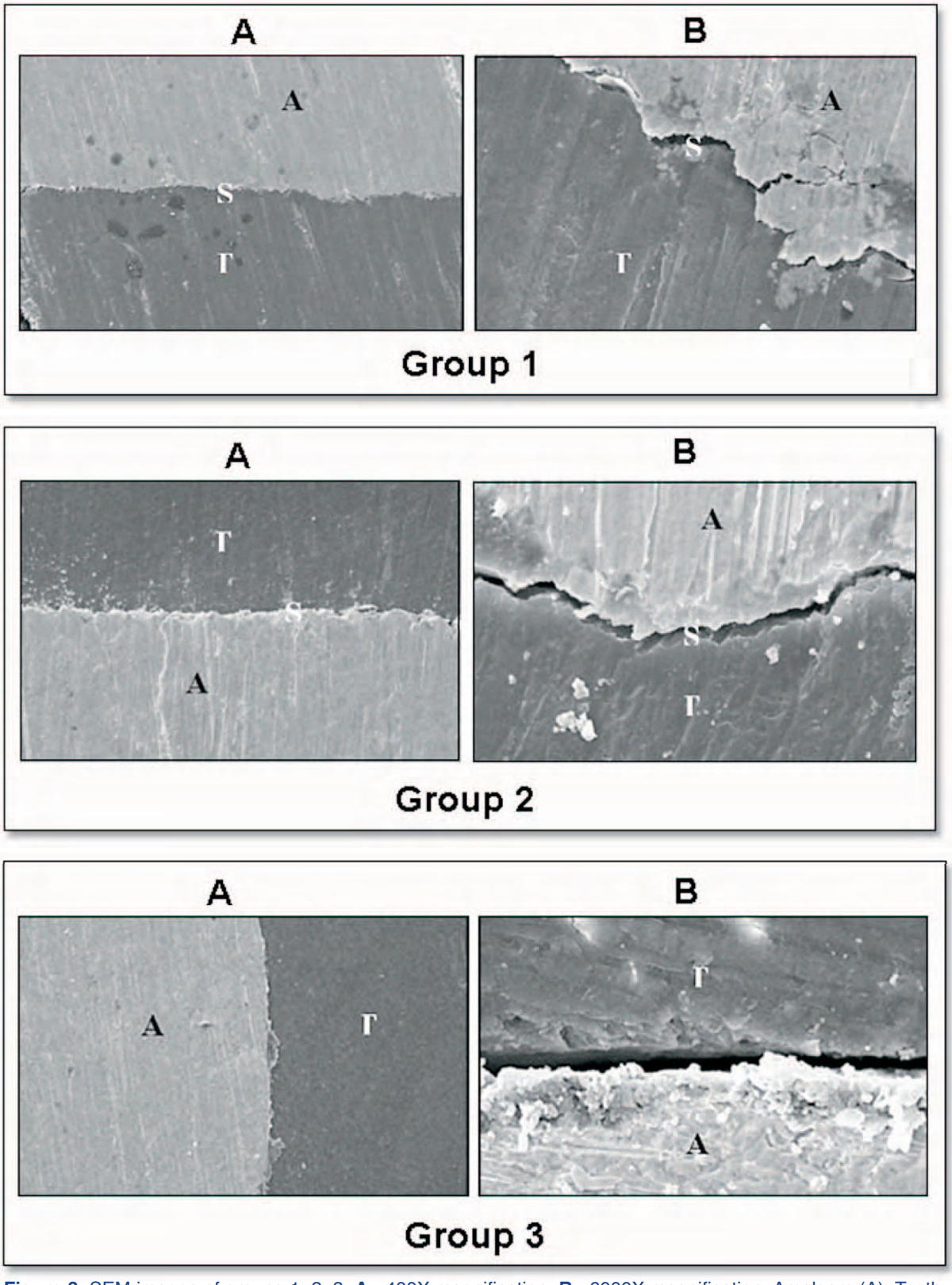

Figure 3. SEM images of groups 1, 2, 3. **A** =400X magnification; **B** =6000X magnification. Amalgam (A), Tooth (T), Sealer (S).

The need for etching before rebonding is somewhat controversial. The rebonding technique used in this study involved etching the margins of the tooth and amalgam restoration prior to applying the rebonding resin. In this study the acid etching was used to enhance resin adhesion and to remove any acid-soluble substances that may have contaminated the amalgam and adjacent tooth structure during restoration. The etching was not performed in the Garcia-Godoy and Malone study.[6] Rebonding has been demonstrated to significantly reduce wear and prolong marginal integrity in clinical studies.[15,16,17] The results of the present study support Garcia-Godoy and Malone[6] in their conclusion which states rebonding reduces the degrees of microleakage *in vitro*. However rebonding might not reduce microleakage in the long-term. The present investigation showed rebonding does not have a significant effect on microleakage, although microleakage was less than in unbonded groups. It has been suggested a chemical coupling mechanism and mechanical intermingling of polymer and amalgam are the principles at work in bonding. The chemical bonding between amalgam and polymer seems to be correlated with specific monomers able to bond with metallic restorations, such as 4-META.[18] However, rebonding was done in the present study with an unfilled resin (Scotchbond MP) that contained no 4-META monomer, therefore, no chemical bonds were formed. This may be a reason for the insignificant effect of rebonding in this study. In a previous study, Dutton et al.[19] concluded all rebonded specimens showed less microleakage along enamel margins than the non-rebonded groups. The study also showed cementum/dentin margins, restorations sealed with UB3 Primer, and rebonded amalgam restorations showed significantly less microleakage than the other groups. The opposite was found to be the case in the present study. In the current project none of the methods tested completely eliminated microleakage, and greater leakage was observed in cementum/dentin margins than in enamel margins which was in agreement with Vesna et al.[20] The difference between leakage in enamel and cementum/dentin margins could be attributed to the fact cementum and dentin are less mineralized than enamel. Dentin contains tubules and is a moist tissue making adhesion less stable than in the more highly mineralized enamel. The greater permeability of dentin to dyes has been reported as a confusing factor in microleakage tests at the cementum/dentin margin. In enamel margins there is more confidence in results because of the relative impermeability of this tissue.[21] In enamel etching with phosphoric acid and the higher mineral content of the tissue might allow better sealing. The present study did not use a corrosive storage medium to facilitate amalgam corrosion. Such conditions may replicate long-term intraoral conditions. Nevertheless, the overall results suggest amalgam corrosion provides the best long-term marginal seal either with or without amalgam bonding. The effect of the rebonding procedure on the corrosion of dental amalgam and the effects of the corrosion on the seal are unknown. However, if marginal leakage should occur at some point in time causing internal amalgam surfaces to be exposed to oral fluids, then it is likely corrosion will result in reduced leakage.

Bonded amalgam restorations have two important interfaces: the tooth-adhesive interface and adhesive-amalgam interface. When the specimens were observed under the SEM, some adhesive failures at the tooth-resin junction were found (Figures 2 and 3). SEM observation has shown a well-defined line distinguishing amalgam and adhesive. This is evidence no intermingling between both materials occurred when the adhesive was light cured prior to amalgam condensation, which was in accordance with the finding of Staninec et al.[22] Unfortunately, the results of this study cannot be extrapolated for admix high copper alloys because these alloys possess a greater trend toward less microleakage. Furthermore, there is lack of correlation between *in vitro* and *in vivo* studies, since *in vivo* studies present some conditions that cannot be reproduced *in vitro*. Nevertheless, results of *in vivo* studies are often less negative than *in vitro* studies. *In vitro* testing is essential for developmental purposes. Thus, *in vitro* results should be viewed as a theoretical level of maximum leakage which might be expected *in vivo*.

Conclusion

Within the limitations of this study, it was determined for the short-term there was significantly less microleakage under bonded amalgam restorations to warrant the use of

Scotchbond MP primer and adhesive as a sealer under spherical high copper amalgam.

The rebonding process did not have a significant effect on microleakage. The enamel margins had significantly less microleakage than dentin margins.

Clinical Significance

In a short-term evaluation bonded amalgam was an effective restorative technique when used with spherical high copper amalgam. However, the rebonding process did not have a significant effect on microleakage and its use remains questionable.

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