ORIGINAL ARTICLES

Microleakage of various amalgam bonding systems

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الهدف: هدف هذه الدراسة المخبرية دراسة مدى تأثير وفعالية ثلاثة من أنظمة الإلصاق الراتنجي هو: ١- الإسمنت الزجاجي الشاردي . ٢- الإسمنت الراتنجي وذلك من حيث تقليل التسرب الحفافي لحشوات الأملغم من الصنف الخامس. الطريقة : إثنان وسبعون ضاحك علوي والتي تم قلعها في سياق المعالجة التقويمية اعتمدت هذه الدراسة.قسمت هذه الأسنان إلى ستة مجموعات، ضمت كل مجموعة ١٢ سن. تم تطبيق الراتنج اللاصق على جدران الحفر المهيئة في ثلاث مجموعات منفصلة، أما الإسمنت الزجاجي الشاردي والإسمنت الراتنجي فتم تطبيقه على الجدران المحورية للحفر المهيئة قبل رص وذلك حشوات الأملغم في مجموعتين.أما المجموعة الأخيرة هي مجموعة المقارنة، تم دهن جدران الحفر المهيئة مرتين بمادة الفارنش الكوبالتي قبل رص وذلك حشوات الأملغم. تم تلوين الأسنان المراد فحصها، وقطعت بشكل شرائح وفحصت تحت المجهر الضوئي المكبر، واعتمدت مقاييس معينة لقياس نسبة التسرب الحفافي. النتائج: أظهرت النتائج حسب المقاييس المقررة بأن نسبة التسرب الحفافي كانت أقل بشكل ملحوظ في الأسنان المرممة والتي استخدم بها الراتنج اللاصق مما هو عليه بتلك المستخدم بها الفارنيش الكوبالتي وكانت نسبة التسرب في الحواف اللثوية للحفرة في كل الأسنان المرممة أكثر مما هو عليه في الحواف القريبة من السطح الطاحن بشكل ملحوظ. الإستنتاجات: إن التسرب الحفافي في الحواف اللثوية والإطباقية يختلف بحسب المادة المستخدمة. باستخدام نظام الإلصاق الراتنجي (الاحادي المفرد أو الإثنين واحد) أظهروا فعالية عالية في تقليل نسبة التسرب الحفافي بالمقارنة مع مجموعات للمقارنة والإسمنت الزجاجي الشاردي والإسمنت الراتنجي.

This study evaluated the effectiveness of three resin bonding systems, one glass -ionomer cement and one resin cement in reducing microleakage in Class V amalgam restorations. Seventy-two maxillary premolars that were extracted for orthodontic purposes were utilized. The teeth were divided into six groups of 12 each. Three groups were assigned for use with the adhesive resins which were applied onto the prepared cavity walls of these respective groups; the fourth groups was assigned for use with glass-ionomer cement and for the fifth group, resin cement was applied onto the axial wall of the cavity prior to amalgam condensation. In the sixth, control group, the cavity walls were painted with Copalite varnish and air-dried prior to placement of the amalgam restoration. The dye penetration method was employed and the restored teeth were sectioned and examined under reflected-light stereomicroscope. The degree of microleakage was scored using standard scoring criteria. Kruskal-Wallis test with non-parametric post hoc test indicated that microleakage was less in restorations treated with adhesive systems than in those with Copalite varnish ($P<0.05$). Wilcoxon Ranks test for non-parametric samples indicated that microleakage was more extensive at the gingival margins in all of the restorations than at the occlusal margins ($P<0.05$). At both margins, the extent of microleakage varied among the investigated materials. The two resin bonding systems (Single Bond and Prime *&* Bond 2.1) demonstrated superiority in reducing microleakage compared to the controls, the glass-ionomer (Vitrebond) and the resin cement (Time Line). Adhesive resin treatment significantly reduced microleakage indicating improved bonding of Class V amalgam restorations. None of the studied systems bonded adequately at the gingival aspect of the cavity as they did occlusally. At the occlusal margin, Single Bond and Prime *&* Bond 2.1 compared favorably to the glass- ionomer (Vitrebond) and the resin cement (Time Line).

Introduction

Amalgam has served effectively as a dental restorative material since its introduction to Europe in the 19th century. It is one of the least technique-sensitive direct restorative materials and it tolerates a great deal of misuse without obvious failure. However, apart from aesthetics and the public concern about possible amalgam toxicity, amalgam has its own distinct set of disadvantages, in particular, microleakage and lack of adhesion to tooth structure. The detrimental effects of microleakage include post-operative sensitivity, staining and discolouration.[1] It is also believed that microleakage may lead to secondary caries and pulp irritation.[1] However, this is not supported in other studies which reported that "microleakage" does not per se lead to secondary caries.[2]

Various approaches have been introduced to reduce microleakage in amalgam restorations. Cavity liners, bases and glass-ionomer cements which bond to dentine, have been reported to produce less microleakage under both composite and amalgam restorations.[3]

Recently, adhesive resins have also been used as cavity liners in an attempt to reduce leakage and to provide retention of amalgam restorations. The usage of adhesives is aimed at forming an effective bond between amalgam and tooth structure. This bond is not merely mechanical, but it includes a molecular interaction.[4,5] Resins based on bisphenol A-glycidyl methacrylate (Bis-GMA) monomer or the 4-methacryloxyethyl trimellitate anhydride (4-META) monomer have been used as adhesives for amalgam restorations.[6]

A review of the literature[3-5,7,8] indicated that marketed adhesive systems and glass-ionomer

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cements based on light-initiated polymerization are effective in improving the marginal seal of amalgam restorations compared to the conventional method of treating cavity walls with varnish prior to placement of amalgam. However, disagreement on the ideal adhesive systems[8,9] for the purpose calls for further investigation.

The aims of this study were to evaluate and compare the degree of microleakage of Class V amalgam restorations with dental adhesives, glass -ionomer cements and copalite varnish as liners, and study the pattern of microleakage at the occlusal and gingival margins of Class V restorations.

Materials and Methods

Seventy-two sound human maxillary premolars that were extracted for orthodontic reasons were collected for this study. The teeth were divided into six groups of twelve each comprising five test groups and a control group.

The test materials comprised three dentine adhesive systems (Table 1), a resin modified glass-ionomer lining cement and a resin cement (Table 2). Copalite varnish* was used as the control material.

All the prepared cavities were filled using admixed amalgam.** The degree of microleakage was later evaluated using 2% methylene blue.***

A Class V cavity was prepared on the buccal surface of each tooth (Fig. 1A). The cavity was approximately 3 mm mesiodistally, 2 mm occlusogingivally and 2 mm in depth.

In order to compare the extent of microleakage at the occlusal margin with that of the gingival margin, the cavity was prepared in such a way that its coronal part was in enamel-dentine while gingivally, it was in dentin-cementum.

Prior to placement of amalgam restorations, the surfaces of the prepared cavity walls were acid-etched or treated with surface conditioner and the investigated dentine-amalgam bonding systems placed according to the individual manufacturer's instructions.

The cavities were filled with amalgam and the margins were burnished before carving. The amalgam was then carved and the margins

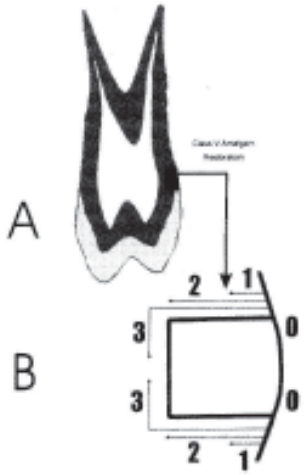

Fig. 1. Illustrating microleakage criteria. (A) Longitudinal section showing Class V amalgam restoration in an extracted maxillary premolar. (B) Diagrammatical representation of microleakage scoring system used. Arrows indicate depth of dye penetration for each ordinal score.

reburnished. All specimens were stored in distilled water at 37° C for 24 hours.

The specimens were dried and the root apices were sealed with the light-cured glass-ionomer cement, Vitrebond. All surfaces of the specimens were then painted with two coats of nail polish except the restoration and approximately 1mm beyond its margins. The specimens were subjected to 1500 thermal cycles by successively immersing them in 5°C and 50°C water baths[10] with 30 seconds dwell time at each temperature. Specimens were immersed in 2% methylene blue at room temperature for 4 hours.

On removal from the dye, they were gently washed in tap water. Each specimen was sectioned longitudinally in a bucco-lingual direction using a diamond wheel‡ in order for the sectioning plane to pass through the amalgam restoration. The sectioned specimen was examined under light stereomicroscope‡‡ at 4x magnification. The extent of dye penetration was measured three times by the same examiner and the degree of microleakage rated according to a scoring system previously described[5,7] and as shown in Table 3 and Figure 1B.

Data Analysis

The frequency of scores was calculated as a percentage to reflect the number of specimens

* Cooley & Cooley Ltd., USA
** Dispersalloy, Caulk Dentsply, USA
*** BDH Laboratory Supplies, UK
‡ Heico, Switzerland
‡‡ Carl Zeiss, SV6, Oberkochen, Germany

Table 1. Dentine adhesive systems used.

Bonding agents	Main constituents	Manufacturers	Batch No.
Single Bond	Etching gel: 35% phosphoric Acid. Adhesive: Bis-GMA, HEMA, ethanol, dimethacrylates and methacrylate functional copolymer of polyacrylic Polyitaconic acids	3M Dental Products, U.S.A, -	Etchant: 7523 Adhesive: 3411
Clearfil Liner Bond 2	Primer: Phenyl-P, HEMA, 5NMSA adhesive monomer MPD, hydrophilic monomer (HEMA), microfiller, ethanol and water	Kuraray Dental Co. Ltd. Japan	LB Primer A, LB 124 LB Bond: 0029
Prime and Bond 2.1	Conditioner: 36% phosphoric acid Adhesive: PENTA, dimethacrylate resin, cetylamine hydrofluoride, elastomeric urethane, modified Bis-GMA, photo-initiator and acetone	DeTrey Gmb H Dentsply, Germany	Conditioner: 102704/2 Adhesive: 107346/2

Table 1. Scoring system used in evaluation of microleakage

Score	Description
0	No dye penetration.
1	Dye penetration up halfway the distance from the margin to the axial wall.
2	Dye penetration more than halfway to the axial wall.
3	Dye penetration along the entire axial wall.

Manufacturers
M Dental Products, U.S.A
aulk, Dentsply, U.S.A

aluminosilicate glass, barium sulfate silicon dioxide. Adhesive promoter: dipenta-erythritolpentaacrylate phosphate, iron oxide, photo-initiators, photo-accelerators

which leaked to a given degree in each group. The reliability of measurements made at different times was evaluated using Kappa statistics. Differences among the independent groups' medians were evaluated using Kruskal-Wallis test with non-parametric post hoc test, and those

Results

The same examiner evaluated the sample thrice at different times and intra-examiner reliability was found to be satisfactory (Kappa value > 0.8). Overall, significantly less microleakage was observed ($P<0.05$, Kruskal-Wallis) in the investigated groups compared to the control group (Fig. 2). However, none of the studied materials was able to eliminate microleakage

completely. All materials demonstrated a significantly better performance at the occlusal margin than at the gingival margin of the restorations (P<0.05, Wilcoxon Ranks). The exception was the behaviour of Clearfil Liner Bond 2 whose microleakage scores were poor occlusally as well as gingivally. Single Bond score was not significantly different from that of Clearfil Liner Bond 2 group (P=0.242). Also, no statistically significant difference was found between the Single Bond and the Prime & Bond 2.1 groups (P=0.078). Microleakage scores measured at the occlusal margin of the restorations that were lined by the glass-ionomer lining cement, Vitrebond, and those lined by the resin cement, Time Line, were not significantly different (P=0.671). Vitrebond showed significantly less microleakage (P=0.024) than Copalite varnish control (Fig. 2).

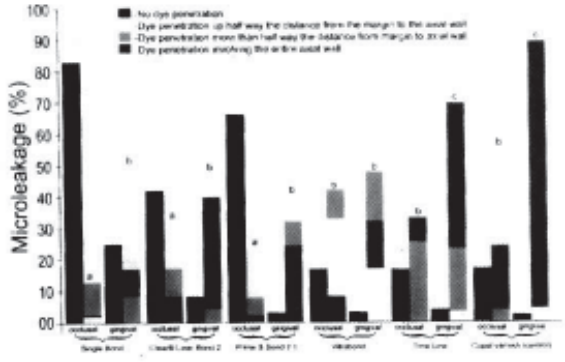

Fig. 2. Percentage frequency of microleakage occurring at the occlusal margin and the gingival margin of amalgam restorations. The different alphabets denote significant differences(P<0.05).

Materials

The results revealed that all the investigated systems leaked at the gingival margin of the restorations and the difference among their performance indicated by their microleakage scores was insignificant.

Discussion

Laboratory studies that are designed to evaluate the possibility and extent of fluid percolation at the tooth-restorations interface provide an understanding of the etiological factors of post-operative sensitivity, long-term staining and possibly the initiation of secondary caries.[2] However, extrapolation of *in vitro* findings to *in vivo* situations is not easy and may often lead to incorrect conclusions due to the differences between the laboratory test environment and the true clinical situation. But despite the difficulty in correlating the findings of microleakage testing and those obtained from clinical observations, the former, although empirical in nature, continue to have some important predictive value.

In the present investigation, it was clear that microleakage at the occlusal margin of the cavity preparations was significantly less than that of the gingival margin. This finding concurred with those reported by other investigators.[3] All the investigated adhesive systems were similar in their poor performance at the gingival margin of the restorations where none of them was able to prevent microleakage across the tooth-estoration interface. At the occlusal margin, the surface area available for bonding is wider than it is gingivally, where the margin is comprised of dentin/cementum. Previous studies[4,9,11,12] reported that better adaptation was achieved between bonded amalgam restorations and the occlusal cavity walls where enamel is present.

The difference in the degree of microleakage in the studied adhesive materials may be explained by the differences in the chemical composition of the resin systems. One of the chemical components in the Prime & Bond 2.1 system is acetone. Acetone evaporates faster than ethanol which was in Single Bond. It is possible that the adhesive resin of Prime & Bond 2.1 was more viscous during its application than Single Bond. Thus, making the penetration of opened dentinal tubules less efficient. This finding concurs with a previous study' which used viscous cavity liners in addition to the dentin bonding systems, and indicated a potential difference between a resin-lined versus resin-bonded amalgam techniques in preventing microleakage.

This study showed that the total-etching technique gave better results than the self-etching technique as regards reducing microleakage. It has been found that phosphoric acid demineralized dentine to a depth of 5 microns, while the surface conditioner agent demineralized dentine to a depth of 5 microns.[12,13] Thus, limiting the penetration of resin into the opened dentinal tubules. It has also been reported that the resin tags produced by Clearfil Liner Bond are narrower at the apertures of the tubules than those of other adhesives although all of them formed a hybrid layer.[14]

The adhesive resin systems utilized in this study gave better results than both glass-ionomer and resin lining cement materials. This can be attributed to the sites of application. The adhesive resin was applied to all cavity walls for bonding to be achieved and to seal all the dentinal tubules. On the other hand, the glass-ionomer lining and the resin cements were applied only to the axial wall of the cavity covering a small area of the adjacent walls and leaving in some cases part of the dentine on the walls exposed. However, Vitrebond showed better reduction in microleakage when compared with the control. As for Copalite varnish, although it was applied to all the cavity walls, it had no ability to bond to tooth substance.

In the present study, it was noted that leakage was mainly concentrated at the amalgam-liner interface in the specimens lined with Vitrebond. This was probably due to the high initial adhesion of Vitrebond to dentine which prevented deeper dye penetration. This had been reported in previous studies[13,14] where the leakage was restricted in most of the specimens to the dentine margin with no deep invasion of the dye into the pulp.

The microleakage pattern in specimens lined with Vitrebond was less severe compared to Time Line. However, the difference was not statistically significant at the occlusal margin. All the Time Line specimens showed severe leakage of level 3 score at the gingival margin. It was worse than the control group indicating poor sealing ability at the gingival margin. Similar results were found by other investigators[15,16,17] who reported that Vitrebond demonstrated significantly less leakage than the conventional glass-ionomer (Ketac Bond), which in turn produced less leakage than Time Line.

In the present study, it was found that adhesive resins performed better than glass-ionomer cement, followed by resin cement lining in reducing microleakage around amalgam restorations. Nevertheless, this observation cannot be generalized to all glass-ionomers or to other lining cements and adhesive systems. Further studies are necessary to investigate a larger number of adhesives and lining cements.

The promising results demonstrated by Single Bond and Prime & Bond 2.1 can only be considered of potential clinical benefit if substantiated by *in vivo* evidence. Future clinical investigations are required in order to evaluate the role of these materials in reducing postoperative sensitivity when used with amalgam restorations.

Conclusions

Within the limitations of this study, the following conclusions can be drawn.

1. Microleakage was more severe at the gingival aspect of the amalgam restorations than at the occlusal aspect.
2. Microleakage was less at both occlusal and gingival aspects of amalgam restorations treated with adhesive resin systems compared to those treated with the conventional Copalite varnish-lined amalgam restorations.
3. Single Bond significantly inhibited microleakage at the occlusal margin of the amalgam restorations compared to Clearfil Liner Bond 2, glass-ionomer, resin lining cement and Copalite varnish.
4. There was no significant difference among the materials tested with regard to the microleakage at the gingival margin of amalgam restorations.

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