

The effects of bonding agents and retention grooves on the retention of approximal slot amalgam restorations

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ABSTRACT

The retention of approximal slot amalgam restoration was measured in this *in vitro* study. Two bonding systems (All-Bond 2 and Scotchbond Multi Purpose Plus) in addition to Copalite varnish (as a control liner) were used as lining materials and compared in non-retentive and retentive approximal slot cavities using spherical and lathe cut alloys. Significantly higher retention values obtained with the retentive cavities. No significant difference was found between spherical and lathe cut alloys. Retention of the bonded restorations was significantly more than that of non-bonded groups, with All-Bond 2 was significantly more retentive than Scotchbond Multi Purpose Plus. Non-retentive cavity with varnish was the least retentive group while retentive cavity with All-Bond 2 was significantly more retentive than all other groups. When the restorations were bonded to the tooth, modes of failure were shifted toward mixed type (adhesive + cohesive failure) rather than complete dislodgment from the cavity.

The results of this study indicated that bonding agents can be used to enhance the retention of amalgam restoration instead of the traditional mechanical retention means thus conserving the sound tooth structure. Also, the combination of mechanical retention means and bonding agents has an additive retentive effect.

Key Words: Amalgam bonding, approximal slot, retention grooves.

INTRODUCTION

Amalgam was used for more than two hundred years in restorative dentistry as

الخلاصة

تم في هذه التجربة المختبرية قياس ثبوتية حشوات الاملغم الشقية وذلك باستخدام نوعين من أنظمة اللواصق (All-Bond 2 و Scotchbond Multi Purpose Plus) بالإضافة إلى (Copalite varnish) كبطانة قياسية تقليدية، حيث تمت المقارنة في نوعين من التجاويف الأول هو تجويف شقي غير مثبت والثاني تجويف شقي مثبت (مع أخاديد التثبيت) وباستخدام نوعين من سبائك الاملغم إحداهما ذات الذرة الكروية والثانية ذات ذرات قطع المخرطة. كانت قدرة التجاويف المثبتة أكثر على التثبيت وبشكل معنوي من التجاويف غير المثبتة. لم يكن هناك فرق معنوي بين سبيكة الذرات الكروية وسبيكة ذرات قطع المخرطة. وكانت الثبوتية المستحصلة باستخدام اللواصق كمادة مبطنة أفضل من ثبوتية الحشوات المبطنة بمادة (Copalite varnish) وكان (All-Bond 2) أكثر قدرة على التثبيت من (Scotchbond Multi Purpose Plus). كانت قدرة تثبيت التجويف غير المثبت مع (Copalite varnish) أقل من المجموع الأخرى كلها، بينما كانت قدرة تثبيت التجويف المثبت مع (All-Bond 2) أكثر وبشكل معنوي من المجموع الأخرى كلها. كما أن نمط الفشل قد توجه نحو النوع المخلوط (فشل اللاصق + فشل تماسك الاملغم) بدلاً من الخلع الكلي للحشوة وذلك عند لصق الحشوة بالسن. تشير نتائج هذه الدراسة أنه بالإمكان استخدام اللواصق لتعزيز ثبوتية حشوات الاملغم بدلاً من طرق التثبيت الميكانيكية التقليدية وهذا مما سيؤدي إلى المحافظة على الأجزاء السليمة من السن بالإضافة إلى أن كلتا طريقتي التثبيت - الميكانيكية واللاصق - لهما تأثير إضافي أو جمعي فيما لو تم استخدامهما معاً.

one of the most employed material in direct restoration of posterior teeth. However, as dental amalgam by itself lacks the capacity

to bond to tooth structure, the preparation of a tooth for traditional amalgam restoration must incorporate mechanical features to retain the restorative material. This often requires the removal of sound dental tissues that may further weaken the tooth.⁽¹⁾ If amalgam could be effectively bonded to tooth structure, tooth preparation could greatly be simplified and would require the removal of much less tooth structure.⁽²⁾ Until few years ago, no material was available to bond amalgam to tooth structure, but marked developments have been made in dental adhesive resins that can bond a freshly mixed amalgam to tooth structure.⁽³⁾

Bonding of amalgam is believed to provide at least intracoronal support of weakened tooth structure and improve resistance to fracture^(4, 5) and reduce micro-leakage.⁽⁶⁾ Several researches assessed the effects of bonding agents on retention of amalgam restorations and they reported that amalgam restorations that bonded with adhesive resins require greater load to fail than those restored without bonding.⁽⁷⁻¹⁰⁾ These findings strongly suggested the implication of adhesive technique as a more conservative technique in comparison to mechanical retention techniques.

The effect of preparation design on resistance and retention form of class II amalgam restoration has been evaluated by several researchers.⁽¹¹⁻¹⁴⁾ When proximal caries has been diagnosed that has no occlusal caries, approximal slot amalgam restoration may be the restoration of choice. The benefits of the approximal slot amalgam restoration over the traditional class II with occlusal dovetail are the maintenance of tooth strength, maintenance of occlusal enamel, limiting the cavo-surface (restoration margins) length.^(15, 16) Many *in vitro* studies have supported the effectiveness of the retention grooves in class II amalgam restorations. But, however, researches on the retention to occlusal loading of approximal slot amalgam restoration with adhesive systems have been studied by a smaller number of researchers.

This study was designed to evaluate the effects of adhesive systems and mechanical retention grooves on the

retention of approximal slot amalgam restoration when the marginal ridge was subjected to a load.

MATERIALS AND METHODS

One hundred forty four extracted, intact and non carious human mandibular molars of approximately the same size were selected. Teeth were stored in tap water at room temperature after being extracted and between restorative and testing procedures. The selected teeth were thoroughly washed with tap water, cleaned and polished to remove debris. Then they were embedded in cold cure acrylic resin (Major Repair 2, Italy) in a polyvinyl plastic ring of 2×2 cm to a depth of 1mm apical to cemento-enamel junction. Specimens were divided into twelve groups as follows: The total number of specimens were equally divided into two cavity design groups, the first design was approximal slot cavity without retention grooves (non-retentive), while the second was approximal slot with two retention grooves (retentive cavity). Then, each cavity group was subdivided into two subgroups, one of them restored with spherical alloy (Vivacap, Vivadent, Germany) and the other restored with lathe cut alloy (21st Century, Dentsply, Milford, USA), and each of these two subgroups was further divided into three subgroups of a different lining materials [Copalite varnish (Cooley & Cooley Ltd. USA); Scotchbond Multi Purpose Plus (SBMP) bonding agent (3M, St Paul, MN 55144, USA); All-Bond 2 bonding agent (Bisco, Inc. Schaumburg, Ill 60193, USA)].

Mesial surface of each tooth received approximal slot cavity that is prepared with no. 245 carbide bur by high speed handpiece (with air-water coolant) that is held by the vertical arm of the surveyor in such away that the bur is perpendicular to the occlusal surface of a tooth to be prepared. The specimen was grasped by a plastic ring fixture that was attached to the adjustable table of the surveyor. The carbide bur was only allowed to move at a fixed horizontal space (a template representing the cavity shape from the occlusal view) that is prepared within a stainless steel plate. The template was

adjusted to be exactly over the marginal ridge of the tooth to be prepared. Internal line angles were slightly rounded as produced by bur. In the retentive cavities, two long retention grooves were prepared at the axiobuccal and axiolingual line angles from the internal point angles to the occlusal surface by no. ¼ round bur to a depth of 0.3–0.5 mm. Cavity height was 3.5 mm, and other dimensions and shape as shown in Figures (1a) and (1b).

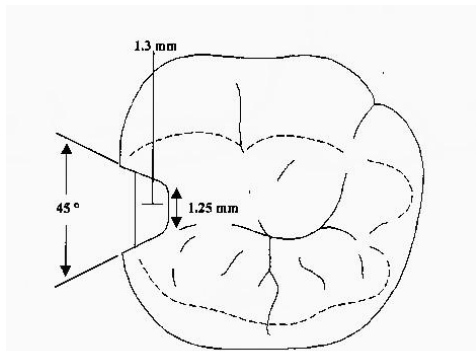


Figure (1a): The retentive cavity design (occlusal view)

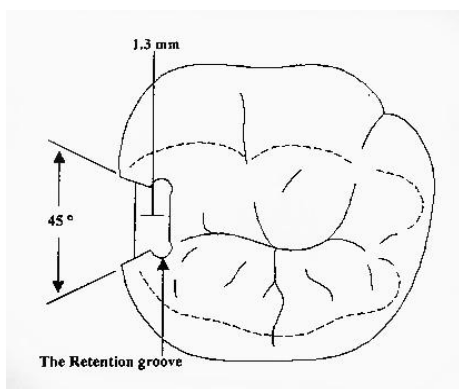


Figure (1 b): The retentive cavity design (occlusal view)

alloys were mechanically triturated and carried into the cavity by a three increments, each increment condensed for 20 seconds by ultrasonic condenser (Supra-sson P-Max, France). Then restoration carved by Hollenback carver to proper anatomy but leaving marginal ridge slightly more bulky to aid in testing, then the specimen thoroughly rinsed and stored in tap water for 7 days, then they were thermocycled for 300 cycles (between 5–55 °C, with a dwell time of 30 seconds) and stored in tap water at room temperature for 5 days before testing.

For testing procedure, the specimens were grasped by a special fixture and adjusted to be in 45 degree angulation with the blunt stainless steel testing rod that was used for loading of the marginal ridges of the restorations (Figure 2) with a crosshead speed of 5 mm/minute by a Universal Compression Machine until the restorations were failed or dislodged from the tooth. The load required to produce failure (in kilograms) and modes of failure were recorded.

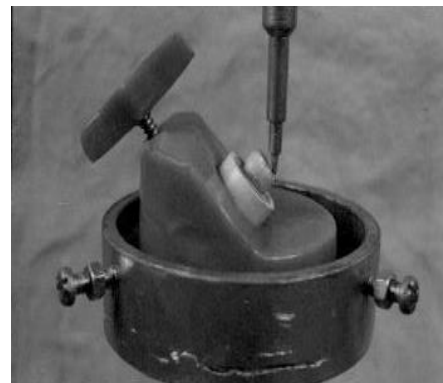


Figure (2): Loading the marginal ridge of the restoration with testing rod

RESULTS

The mean and standard deviation of the load required to produce failure for each tested group are listed in Table (1).

Table (1): The mean and standard deviation of the load required to produce failure for each tested group

Groups	No.	Means (kg)	± SD
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Non-retentive Cavity, Spherical Alloy, Varnish	12	2.1	± 0.97
Non-retentive Cavity, Spherical Alloy, SBMP	12	13.8	± 2.15
Non-retentive Cavity, Spherical Alloy, All-bond 2	12	21.2	± 6.09
Non-retentive Cavity, Lathe cut Alloy, Varnish	12	2.28	± 1.07
Non-retentive Cavity, Lathe cut Alloy, SBMP	12	14.3	± 2.15
Non-retentive Cavity, Lathe cut Alloy, All-bond 2	12	21.7	± 4.16
Retentive Cavity, Spherical Alloy, Varnish	12	14.4	± 3.14
Retentive Cavity, Spherical Alloy, SBMP	12	21.9	± 1.72
Retentive Cavity, Spherical Alloy, All-bond 2	12	25.1	± 3.26
Retentive Cavity, Lathe cut Alloy, Varnish	12	13.6	± 2.07
Retentive Cavity, Lathe cut Alloy, SBMP	12	22.1	± 3.52
Retentive Cavity, Lathe cut Alloy, All-bond 2	12	27.2	± 5.36

No. = Number of samples; SD = Standard deviation; SBMP: Scotchbond Multi Purpose Plus.

A three factor analyses of variance (ANOVA) with $p \leq 0.05$, indicated that there were significant differences between cavity designs, and between lining materials as well as at the level of cavity-liner interaction. No significant differences were found between alloy types, cavity-alloy interaction, alloy-liner interaction and cavity-alloy-liner interactions. Duncan's Multiple Range Test was used to compare between the significantly different groups. For cavity design, it was indicated that the retentive cavity (20.78 ± 6.08) was more retentive than the non-retentive cavity (12.58 ± 8.61). For lining materials (Table 2), both of the bonding agent lined groups were

significantly more retentive than varnish lined restorations, with All-Bond 2 gave significantly higher values than SBMP. For cavity-liner interaction (Table 3), retentive cavity with All-Bond 2 was significantly more retentive than all other groups, while non-retentive cavity with varnish was significantly less retentive than all other groups. No significant difference was found between non-retentive cavity with All-Bond 2 and retentive cavity with SBMP, also no significant difference was found between non-retentive cavity with SBMP and retentive cavity with varnish.

Modes of failure in the retentive and non-retentive cavities were as shown in Tables (4) and (5).

Table (2): Duncan's Multiple Range Test for the effect of lining materials on retention of approximal slot amalgam restorations

Liners	No.	Means (Kg)	± SD	Duncan Grouping
Varnish	48	8.11	± 6.30	C
SBMP	48	18.08	± 4.71	B
All-bond 2	48	23.84	± 5.31	A

No. = Number of samples. SD = Standard deviation.

The same letters are not significantly different.

SBMP: Scotchbond Multi Purpose Plus.

Table (3): Duncan's Multiple Range Test for the effect of cavities-lining materials interaction on retention of approximal slot amalgam restorations

Cavity	Liner	No.	Means (Kg)	± SD	Duncan Grouping
Non-retentive	Varnish	24	2.19	± 1.01	D
	SBMP	24	14.07	± 2.12	C
	All-Bond 2	24	21.47	± 5.11	B
Retentive	Varnish	24	14.04	± 2.64	C
	SBMP	24	22.08	± 2.71	B
	All-Bond 2	24	26.21	± 4.47	A

No. = Number of samples. SD = Standard deviation.

The same letters are not significantly different.

SBMP: Scotchbond Multi Purpose Plus.

Table (4): Modes of failure in the non-retentive cavities (percentage of failure)

Groups	Modes of Failure			
	Complete Dislodgment	Amalgam Cover Gingival Floor	Amalgam Cover Axial Wall	Amalgam Cover Gingival and Axial Walls
Varnish	100	-	-	-
SBMP	58	4	17	21
All-Bond 2	33	8	21	38

SBMP: Scotchbond Multi Purpose Plus.

Table (5): Modes of failure in the retentive cavities (percentage of failure)

Groups	Modes of Failure		
	Amalgam Retained in The Grooves	Amalgam Remained Cover Axial Wall	Both Gingival and Axial Walls Remain Covered
Varnish	46	46	8
SBMP	12	50	38
All-Bond 2	0	37	63

SBMP: Scotchbond Multi Purpose Plus.

DISCUSSION

The results of this study indicated that retention grooves significantly increase the resistance to failure when the marginal ridge of the approximal slot amalgam restorations was subjected to a load. This finding is in agreement with many researchers,^(8, 9, 11, 13, 18) but generally the

mean values in these studies were higher than that obtained by the current study and this may be due to the differences in the proximal divergence of buccal and lingual walls of the slot cavity as in those studies they were slightly diverged in contrast to 45 degree proximal divergence in the current study. Also the difference in the

testing rod angulation which was 13.5 degree compared with 45 degree angulation in the current study may contribute to this higher mean values.

Bonding systems that designed to bond amalgam to enamel and dentin have been introduced in an effort to compensate for some of the disadvantages presented by amalgam, namely microleakage and lack of adhesion that necessitate the removal of sound tooth structure to create a mechanical retention features.^(18, 19) The effectiveness of bonding agents used in approximal slot cavity has been studied by a number of investigators. It was found that bonded approximal slot amalgam restorations without mechanical retention means could perform as those retained with mechanical retention means (dovetail and retention grooves),^(7, 10) or even may perform better⁽⁸⁾ and this is dependent on the type of bonding agent used. The comparable retention values of restorations that lined with SBMP without retention grooves to those without bonding but with retention grooves, as well as the higher retention values of All-Bond 2 lined restorations in comparison to SBMP lined restorations (within the same cavity design) or in comparison to retentive cavity without bonding in the current study supported these findings.

However, under the conditions of this study, the obtained data support the hypothesis that the mechanical retention means plus bonding techniques give superior results than the use of each retention mean alone.^(8, 20-24)

The shifting of failure mode from 100% complete dislodgment of the restorations in the non-bonded restorations toward mixed type failure may be due to the formation of a hybrid layer at the tooth-bonding interface and micromechanical interlocking of bonding agent with amalgam at amalgam-bonding interface.^(4,7,25-28) These characteristics at both interfaces may prevent dislodgment of restoration without being fractured. Also as the failure modes were shifted toward amalgam remains covering the axial and gingival walls rather than amalgam remains only in the retention grooves. This result supported the idea of that amalgam bonding technique results in stress

dis-tribution rather than being concentrated at a specific areas.^(29, 30) Fracture of chunks of enamel that separated from the tooth and remained attached to the dislodged restoration (Figure 3) indicated that the bond of amalgam to enamel mediated by bonding liners may exceed the cohesive strength of enamel.^(7, 10, 18)

CONCLUSIONS

Retention grooves significantly increase the retention of approximal slot amalgam restorations.

Bonded approximal slot amalgam restoration is significantly more resistant to dislodgment than non-bonded restoration.

All-Bond 2 provides significantly higher retention than SBMP.

The combination of mechanical retention means with bonding agents provides a retention level higher than that provided by mechanical means or bonding agents alone.

The choice of amalgam alloy appeared to be less important than the choice of bonding agent.

Proximal caries that not involving occlusal surface of the tooth can be treated successfully by approximal slot amalgam restoration with retention grooves and bonding agents.

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