***ISSN:* 1812–1217**

The effect of amalgam alloy types, surface treatments, and bonding agents on the shear bond strength between amalgam and resin composite

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ABSTRACT

Aims: To evaluate the effect of amalgam alloy types, surface treatments, bonding agents, on the shear bond strength between set amalgam and resin composite restorative materials. **Materials and Methods**: Three hundred and thirty eight holes (6 mm in diameter and 2 mm depth) prepared in a 2x2.5 cm cold cure acrylic resin blocks in which amalgam was condensed. The 338 samples were divided into two groups, the control group which consisted of 26 intact amalgam samples, and the repair group consisted of 312 repair amalgam samples. Each group (intact, and repair) was subdivided into two groups according to the type of amalgam alloy. Half of the samples were filled with spherical amalgam alloy and the other were filled with admixed amalgam alloy. The repair samples then divided in to four groups according to the surface treatment, in turn each sub-group divided into three groups according to the bonding agent. The samples were thermocycled, before shear bond strength was tested. The mode of failure was observed for each specimen. **Results and Conclusion**: The statistical analysis showed that the repair strength was 50% of the intact strength, and the admixed amalgam samples showed higher shear bond strength than spherical amalgam samples. The group roughened with diamond bur showed higher repair bond strength than the groups received other surface treatment. The use of dentin bonding agent (All–Bond 2 and Alloybond) would increase the repair bond strength between the amalgam and the composite restorative materials. And the mode of failure was mostly an adhesive type.

Key word: Amalgam–composite combined restoration, composite veneered amalgam restoration, Bonding agent.

Rasheed RA, Suliman AA. The effect of amalgam alloy types, surface treatments, and bonding agents on the shear bond strength between amalgam and resin composite. *Al–Rafidain Dent J*. 2006; 6 (Sp Iss): 38S-47S.

Received:17/5/2005 ***Accepted for Publication:*** 29/5/2005

INTRODUCTION

It is not surprising that mechanical failures of amalgam restoration can occur clinically. Such failures often begin as amalgam fractures and cusp or tooth fracture, which are considered the common problems in dental practice that may be caused by inappropriate cavity preparation, technical errors, contamination, physical trauma or occlusal prematurities.(1–4) Occasionally, it is not economically feasible to replace the defective amalgam restoration with new amalgam or even crown. Doing so, causes dentists to spend about half of their chair time replacing restorations, and makes further loss of the tooth structure that lead to large size cavities that lead to reeducation in restoration longevity. Also here is the risk of further pulp irritation and even pulp exposure and post–operative sensitivity.(5–7) Repair will cause less iatrogenic damage than complete replacement. Amalgam restorations can be repaired with a new amalgam or with composites. Many studies showed that when there is necessity to place a new amalgam adjacent to an existing amalgam restoration, the patient may complain from a metallic taste caused by corrosion that may result from a galvanic shock between the two different types of alloys that were joined together in a restoration which in turn further weaken the bond between the two alloys in addition to the post–operative sensitivities.(3,8,9)

Since the aesthetic qualities of the restoration may be important to the mental health of the patient, the repairing with resin composite may be considered more acceptable than repairing with amalgam. Combined amalgam–resin composite restorations have been advocated to mask the unaesthetic appearance of amalgam restorations and to overcome difficulties associated with the composite restorations of posterior class II cavities.(10–14)

For the repair to withstand functional loads, the bond between the repairing material and remaining restoration must be strong and durable.(15) Various repair techniques have been suggested in the literature, many of which are based on either mechanical and/or chemical techniques. Mechanical means include roughening the amalgam surfaces with burs, sandblasting with aluminum oxide particles or acid etch with phosphoric acid. These retentive means can produce macro– or micromechanical retention of amalgam or composite to existing amalgam surfaces. Also additional retentive means can be added like undercut, grooves, dovetails or even pins when there is sufficient remaining tooth structure as auxiliaries aid in the retention of repaired segments. (2,15–18)

The method of repairing an existing amalgam restoration with composite restorative materials may prevent the premature replacement of good functioning amalgam restorations with porcelain–fused to metal crown or resin composite restorations for only esthetic reasons.(3,19,20)

The composite–veneered amalgam restoration is a method of treatment at the visible areas in the mouth, incorporating both the desired mechanical properties of amalgam and the aesthetic qualities of composites.(9,21,22)

The purpose of this in vitro study was to estimate the best method for amalgam repair.

MATERIALS AND METHODS

A precapsulated high coppers non–gama2 spherical alloy (Vivcap, Vivadent, Ets., Germany) and admixed alloy (Septalloy NG 70, Specialites Septodont, France), were repaired with a Tetric composite (Vivadent, Ets., Germany) which is a fine–particle hybrid resin composite. The bonding agents used are two of the fourth generation, which are multipurpose dentin bonding systems. These are All–Bond 2 (Bisco, Inc., USA) and Alloybond (SDI Ltd., Australia) which are a fluoride releasing amalgam bond.

A total of three hundred and thirty eight undercut cylindrical cavities 6 mm in diameter and 2 mm in depth were cut at the centers of self cured acrylic resin blocks of 2x2.5 cm dimension. Specimens were randomly divided according to the repair procedure into two groups (control groups, which consisted of twenty six intact amalgam specimens, and repair amalgam groups which consisted of three hundred and twelve repair amalgam samples). The samples in each group were subdivided randomly according to the amalgam alloy types into two subgroups, group filled with spherical amalgam alloy (Vivacap) and the other with admixed amalgam alloy (Septalloy). Then each repair group was subdivided randomly according to the surface treatments (carbide finishing bur, diamond round bur, carbide cross-cut fissure bur, stainless steel inverted cone bur) into four groups of thirty nine samples in each. In turn these groups were randomly subdivided according to the bonding agents into three subgroups of thirteen samples in each subgroup.

For intact samples preparation the precapsulated amalgam was condensed mechanically against the cavity walls, the cylindrical cavity was over filled then carved with a Hollenback carver flush with the acrylic surface. Then immediately a rubber mold with 4x4 mm cylindrical central hole was applied over the fresh amalgam surface and fixed by two wax points to the acrylic block. The rubber mold was split vertically in one place to its half thickness, then immediately corresponding type for the amalgam base were mechanically condensed through the cylindrical hole in the rubber mold against the fresh amalgam base and allowed to harden for one hour at room temperature. Then the rubber mold removed, and the amalgam cylinder then released carefully, thus created a cylinder of amalgam 4x4 mm dimensions at a 90° angle to the amalgam base. The samples were stored in distilled water at 37° C in an incubator for 37 days.

For the repair samples preparation, building the amalgam base was carried out as for intact samples, then the repair samples stored in distilled water at 37ºC for one month. After one month storage time the surface layer of each amalgam base was ground wet with 400, 800, then 1200 grits silicon carbide grinding papers and then underwent one of the four surface roughening using a surveyor (Quayle Dental MFG Co., England), with 147.5 gm weight attached to the handpiece, and 91.5 gm load at bur tip. Each labeled sample was randomly taken from the container and received the roughening with the corresponding bur for 10 seconds, amalgam surface treatment was done as follow:-

Carbide Finishing Bur (F): Aged amalgam surface was finished with a 12–fluted tungsten carbide finishing bur, using high–speed handpiece with air–water spray, in such a way that the long axis of the bur was parallel to the occlusal amalgam surface and by using wiping bur movement.

Diamond Round Bur (D) :Aged amalgam surfaces were roughened with a friction grip diamond round bur No. 1014, using high–speed handpiece and air–water spray, in such a way that the long axis of the bur was nearly perpendicular to the occlusal amalgam surface. The bur was moved in two different directions at 90° angle to each other to achieve visually roughened surfaces.

Carbide Cross–cut Fissure Bur (C) : Aged amalgam surfaces were roughened with a tungsten carbide cross–cut fissure bur No. 557, using a high–speed handpiece with air–water spray, in such a way that the long axis of the bur was parallel to the occlusal amalgam surface using wiping bur movement to achieve visually roughened surfaces.

Inverted Cone Bur (I) :Aged amalgam surfaces were notched with a latch type stainless steel inverted cone bur No. 33½ using slow–speed handpiece in such a way that the long axis of the bur was nearly perpendicular to the occlusal amalgam surface to achieve a visually roughened surfacees.

Then a circular area 4 mm in diameter was demarcated at the center of the amalgam base surface through the application of an adhesive tape. Then each adhesive system was carefully prepared and applied according to the manufacturer's recommended steps to attach the composite to the prepared amalgam surfaces. For the Syntac Adhesive Samples, the demarcated amalgam surface was acid etched with 37% phosphoric acid for 15 seconds, then wash the amalgam surface for 30 second with copious water to remove the phosphoric acid then air dry with oil free air. A thin layer of Syntac Single–Component was brushed on the demarcated amalgam surface, and left undisturbed for 20 second, then excess material was dispersed with oil free air until movement of the liquid is no longer visible. Subsequently light polymerized for 20 seconds, then a second layer of the Syntac Single–Component was applied and immediately dispersed with oil free air and polymerized with light for 20 seconds. For the application of All–Bond2 Adhesive One drop of primer A and one drop of primer B of All–Bond 2 adhesive were dispensed and mixed in the mixing well. Then two coats of mixed primers were brushed on the demarcated amalgam surface, and dried gently for 5–6 seconds with an oil free air spray to ensure thorough solvent removal and leave surface glossy. If surface was not glossy, a priming procedure was repeated, then a thin layer of Dentin/Enamel bonding resin was brushed onto the demarcated area and lightly air thinned to prevent pooling, and light cure for 20 seconds. While for Alloybond adhesive application Alloybond primer was brushed on the demarcated amalgam surface, and dried gently with oil–free air for 2 seconds to evaporate solvent and leave the surface glossy. If the surface was not glossy, a priming procedure was repeated, then light cure for 10 seconds. Subsequently one drop of Alloybond base and one drop of Alloybond catalyst were dispensed and mixed in the mixing well, then a thin layer of mixture was brushed over the demarcated amalgam surface.

After that the rubber mold was applied over the adhesive tape that was placed over the amalgam base and attached in its positions by two points of wax to the acrylic block. The mold was split vertically in one place through its entire thickness. Tetric composite shade B3 was packed directly against the demarcated amalgam surface through the rubber hole with a plastic instrument and according to the manufacturer's, thus created a cylinder of resin composite 4 mm in diameter and 4 mm in height bonded to the amalgam surface at 90 °C angle. Then all the experimental samples were thermo cycled for 500 times between 5–55 ± 2 ºC at 15 seconds dwell times. All samples subjected to shear bond strength (SBS) using universal testing machine with a knife–edged rod of 0.5 mm width at a cross head speed of 1.0 mm/min that applied to the amalgam–composite interface. The amalgam–composite interface was examined with stereo dissecting microscope at X40 magnification to determine the fracture modes.

Data were collected and statistically analyzed using analysis of variance (ANOVA) and Duncan's multiple range test were prepared.

RESULTES

The mean shear bond strength results of intact and repair samples are presented in Table (1). Table (2) showed that there was a significant difference in SBS at the amalgam–resin composite interface between the group filled with spherical amalgam alloy and the group filled with admixed amalgam alloy, and among groups with different surface treatment, and among groups with different bonding agents.Duncan's multiple range test for comparing the two amalgam alloys that was presented in Table (3) indicated that the admixed amalgam alloy (irrespective of the surface treatment and bonding agent) has significantly higher mean SBS (4.15 ± 1.72 Mpa) than the spherical amalgam alloy (3.98 ± 1.67 Mpa).

Duncan's multiple range test for comparing the four surface treatments that was presented in Table (4) and represented histogramically in Figure (1), showed that the group in which amalgam surfaces received treatment with friction grip diamond round bur has significantly higher mean SBS (6.36 ± 0.61 Mpa irrespective of the alloy type and bonding agent) followed by the groups in which the amalgam surfaces received treatment with stainless steel inverted cone bur (4.70 ± 0.41 Mpa), then followed by the group prepared with tungsten carbide cross–cut fissure bur (2.87 ± 0.63 Mpa). While the groups that received treatment with tungsten carbide finishing bur showsed the lowest mean SBS (2.34 ± 0.67 Mpa).

Duncan's multiple range test for comparing the three bonding agents that was presented in Table (5), showed that the groups in which amalgam surface lined with Alloybond (4.39 ± 1.58 Mpa), or lined with All–Bond2 (4.34 ± 1.57 Mpa) have significantly higher mean SBS than groups lined with Syntac–Single Component (3.47 ± 1.77 Mpa irrespective of the amalgam type and surface treatment) and there was no significant difference between groups lined with Alloybond, and those lined with All–Bond2 in SBS.

Analysis of variance (ANOVA) Table (2), showed that the interaction between the surface treatment and the bonding agent significantly affected the SBS at the amalgam–resin composite interface, Duncan's multiple range test for the interaction between the surface treatment and bonding agent was performed to determine the best interaction and the results are presented in Table (6). The test showed that the interaction of surface treatment with friction grip diamond round bur and Alloybond (6.66 ± 0.39 Mpa) or friction grip diamond round bur and All–Bond2 (6.62 ± 0.43 Mpa) has significantly higher mean SBS than all other groups. While the interaction of surface treatment with tungsten carbide finishing bur and Syntac-Single Component (1.48 ± 0.24) Mpa showed a significantly lowest mean SBS, and there was no significant difference between All–Bond2 and Alloybond in mean SBS with the same surface treatment.

The percentage of mode of failure among the experimental groups showed that the group filled with admixed amalgam, received treatment with diamond bur and lined with All–Bond2 showed the lowest adhesive failure (76.92%) and the highest mixed failure (23.08%). The group that was filled with admixed amalgam and received treatment with diamond bur and lined with Alloybond give about (84.62%) adhesive failure and (15.38%) mixed failure, the group that was filled with spherical amalgam, received treatment with diamond bur and lined with Alloybond present (92.31%) adhesive failure and about (7.69%) mixed failure, other combineds presented (100%) adhesive failure.

Table (1): The mean shear bond strength in MPa repair and intact tested groups.

Groups	N	Mean	±SD	Minimum	Maximum
RS F Syntac	13	1.43	0.21	1.07	1.76
RS F All	13	2.71	0.29	2.24	3.12
RS F Alloy	13	2.73	0.41	2.15	3.32
RS D Syntac	13	5.66	0.51	5.07	6.53
RS D All	13	6.53	0.33	6.05	7.12
RS D Alloy	13	6.59	0.39	6.14	7.31
RS C Syn	13	2.13	0.38	1.65	2.82
RS C All	13	3.15	0.42	2.44	3.80
RS C Alloy	13	3.17	0.33	2.44	3.61
RS I Syntac	13	4.36	0.33	3.90	4.88
RS I All	13	4.64	0.38	4.09	5.26
RS I Alloy	13	4.70	0.44	4.29	5.36
RA F Syntac	13	1.53	0.27	1.07	1.95
RA F All	13	2.80	0.28	2.43	3.22
RA F Alloy	13	2.83	0.25	2.44	3.22
RA D Syntac	13	5.88	0.55	5.17	6.73
RA D All	13	6.71	0.51	6.05	7.51
RA D Alloy	13	6.74	0.40	6.24	7.31
RA C Syntac	13	2.24	0.40	1.66	2.82
RA C All	13	3.24	0.46	2.44	3.80
RA C Alloy	13	3.27	0.43	2.44	3.90
RA I Syntac	13	4.54	0.33	3.99	4.97
RA I All	13	4.96	0.39	4.39	5.55
RA I Alloy	13	4.99	0.26	4.58	5.36
IS (control)	13	14.44	0.33	13.95	15.02
IA (control)	13	13.79	0.50	12.97	14.63

N: Number of Sample; SD: Standard Deviation; RS: Repair Spherical Amalgam; RA: Repair Admixed Amalgam; F: Groups Treated with Carbide Finishing Bur; D: Groups Treated with Diamond Round Bur; C: Groups Treated with Carbide Cross-cut Fissure Bur; I: Groups Treated with Inverted Cone Bur; Syntac: Groups with Syntac Single Component Adhesive System; All: Groups with All-Bond2 Adhesive System; Alloy: Groups with Alloybond Adhesive System; IS: Intact Spherical Group; IA: Intact Admixed Group;

Table (2): Analysis of Variance (ANOVA) for levels of alloy type, surface treatment, bonding agent, and their interaction.

Source of Variance	DF	Sum of Square	Mean Square	Cal. F	Tab.F	Significance
Amalgam alloy	1	2.15	2.15	14.32	6.63	0.01**
Surface treatment	3	787.53	262.51	1749.58	3.78	0.01**
Bonding agent	2	55.66	27.83	185.49	4.61	0.01**
Amalgam alloy x surface treatment	3	0.40	0.13	0.88	3.78	N.S
Amalgam Alloy × Bonding Agent	2	0.01	0.00	0.02	4.61	N.S
Surface treatment × bonding agent	6	7.68	1.28	8.54	2.80	0.01**
Amalgam alloy× surface treatment × bonding agent	6	0.08	0.01	0.08	2.80	N.S
Error	288	43.21	0.15			
Corrected Total	311	896.71				

DF: Degree of Freedom; Cal.F: Calculated F.value; Tab.F: Tabulated F.value; **: Highly Significant; N.S: Not Significant

Table (3): Duncan's Multiple Range Test for the effect of amalgam alloy types on the SBS at amalgam–composite interface.

Amalgam Alloy Types	N	Mean (Mpa)	± SD	Duncan Grouping
Admixed	156	4.15	1.72	A
Spherical	156	3.98	1.67	B

Note: Means with Different Letters are Statistically Different; N: Number of Sample; Mpa: Mega Pascal; SD: Standard Deviation

Table (4): Duncan's Multiple Range Test for the effect of surface treatments on the SBS at amalgam–composite interface.

Surface Treatment	N	Mean (Mpa)	±SD	Duncan Grouping
Diamond Round Bur	78	6.36	0.61	A
Inverted Cone Bur	78	4.70	0.41	B
Carbide Fissure Bur	78	2.87	0.63	C
Carbide Finishing Bur	78	2.34	0.67	D

Note: Means with Different Letters are Statistically Different; N: Number of Sample; Mpa: Mega Pascal; SD: Standard Deviation

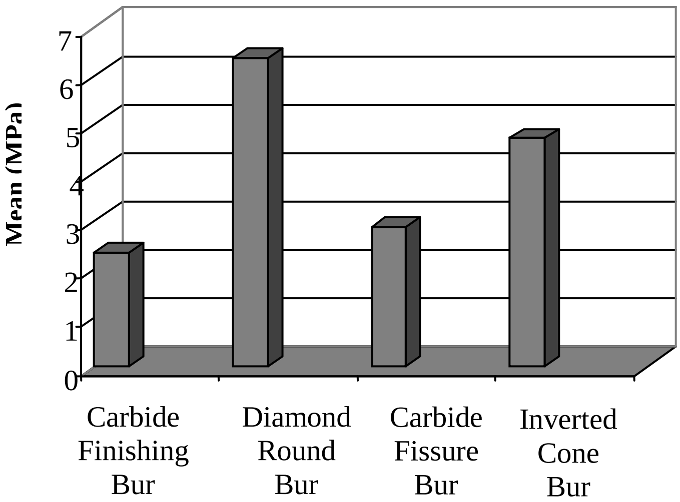

Figure (1): Mean SBS for the four type of surface treatment

Table (5): Duncan's Multiple Range Test for the effect of bonding agents on the SBS at amalgam–composite interface.

Amalgam Alloy Types	N	Mean (Mpa)	±SD	Duncan Grouping
Alloybond	104	4.39	1.58	A
All-Bond 2	104	4.34	1.57	A
Syntac–Single Component	104	3.47	1.77	B

Note: Means with Different Letters are Statistically Different; N: Number of Sample; Mpa: Mega Pascal ; SD: Standard Deviation

Table (6): Duncan's Multiple Range Test for the interaction between surface treatment and bonding agent.

Groups	N	Mean (Mpa)	±SD	Duncan Grouping
D Alloy	26	6.66	0.39	A
D All	26	6.62	0.43	A
D Syntac	26	5.77	0.53	B
I Alloy	26	4.85	0.38	C
I All	26	4.80	0.41	C
I Syntac	26	4.45	0.34	D
C Alloy	26	3.22	0.38	E
C All	26	3.19	0.43	E
F Alloy	26	2.78	0.34	F
F All	26	2.75	0.28	F
C Syntac	26	2.19	0.39	G
F Syntac	26	1.48	0.24	H

Note: Means with Different Letters are Statistically Different; N: Number of Samples; Mpa: Mega Pascal; SD: Standard Deviation; F: Groups Treated with Carbide Finishing Bur; D: Groups Treated with Diamond Round Bur; C: Groups Treated with Carbide Cross–cut Fissure Bur; I: Groups Treated with Inverted Cone Bur; Syntac: Syntac–Single Component Adhesive System; All: Groups receive All–Bond2 Adhesive System; Alloy: Groups receive Alloybond Adhesive System

DISCUSSION

The repair bond strength obtained in this study was about 29% of the intact bond strength, other study reported bond strength about 24.94%, 7 to 18%, 40%, 13.34%, 15%.[17,18,23,24,25]

The mean shear bond strength results between composite and set amalgam obtained in this study, range between 1.43 to 6.74 Mpa, other study reported about 0.31 to 13.37 Mpa, 4.30 to 4.34 Mpa, 1.58 to 1.61 Mpa, 3.19 to 7.47 Mpa, 2.99 to 5.78 Mpa, and 4.72 to 16.36 Mpa.[12, 24,26,27,28,29] These variations in reported SBSs may result from the difference in the experimental conditions. Various studies on the strength of repaired amalgam reported different results. This can be attributed to various factors that affect the repair strength, such as the time of repair, type, morphology and surface chemical composition of the amalgam alloy, surface treatments at the site of fracture, the use of repair adhesive resins with different elastic modulus between the two repair segment, and the contamination at the repair surfaces.[5,30,31]

The results of this study showed that shear bond strength of admixed amalgam bonded with resin composite is significantly higher than those of spherical amalgam, admixed alloys are made by mixing silver-tin irregular shape particles with silver–copper spherical shape particles. Irregular particles pack together relatively poorly while spherical alloys consist of small, smooth–edged spherical particles that are packed more efficiently.[32,33,34] This may lead to more mechanical spaces for adhesive interlocking within admixed amalgam than within spherical amalgam.[9,23]

The results of the present study showed that roughening of an old amalgam surface is an essential step when repair amalgam restorations is indicated. Roughening the amalgam surface can increase the surface area and facilitate mechanical interlocking of the adhesive by reducing the contact angle and improving the wettability subsequently stronger bond strength was resulted. However, excessive roughness may hinder the even flow of the liquid adhesive and result in an air pocket being entrapped at the interface, which may in turn weaken the bond strength.[3,12,35]

Although the specimens, which received treatment with, inverted cone bur showed a rougher surface texture, they also displayed SBSs less than specimens roughened with diamond bur, this may be explained by the fact that treatment with inverted cone bur produced deep irregularities. As a result, the primer and adhesive resin had difficulty to wet deeply into the full depth of notched surface and the adhesives would not be uniformly distributed into the amalgam surface and an incomplete or short resin tag would be formed in addition to air entrapment that might result during dryness and thinning of the resins. This would further reduce the bond strength.[30,35]

The real effect of a low modulus material is probably its contribution to a more equal distribution of tensile and shear stresses over the adhesive interface. This material could dissipate the shear peak stress and generate no high polymerization shrinkage stress on the adhesive layer.[36,37]

In this study, most failure modes were adhesive (at amalgam-resin interface). This indicates that the micromechanical retention is considered the most likely mechanism of resin-amalgam bonding, and the existence of a true chemical bond between amalgam and adhesive resins is not verifyed. [9,26,38]

CONCLUSIONS

The combination of roughening the amalgam surfaces with diamond round bur and the use of either All–Bond 2 or Alloybond bonding agent significantly increased the SBS of repaired samples.

Modes of failure were mostly adhesive (amalgam–adhesive interface) in all tested groups. However, the mode of failure changed to mixed type in–groups received surface preparation with diamond round bur, and use of either All–Bond 2 or Alloybond adhesive systems.

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