INTERFACIAL BOND BEHAVIOR OF COMPOSITE RESIN-VENEERED AMALGAM AS A FUNCTION OF TEMPERATURE UNDER WATER IMMERSION

Khamis Hassan, BDS, MSD, PhD*; Salwa Khier, BDS, MSD, MSc, PhD**
Maha Nahass, BDS***

يعد وجود إلتصاق راتنجي قوي مع حشوات الأملغم من المتطلبات الأساسية لنجاح حشوات الأملغم المغطاة بمادة «الكومبوزيت» وقد وجد إختلاف في قيم قوة الإلتصاق بين نتائج الأبحاث التي أجريت واستخدمت فيها أنواع مختلفة من هذه الراتنجات اللاصقة كما كان الإختلاف كبيراً بين الطرق المعملية التي استخدمت لاختبار عمر هذه الحشوات في ظروف مماثلة للبيئة الفموية هذا وقد أجريت غالبية تلك الأبحاث عند درجة حرارة ثابتة (٣٧ درجة مئوية) أو باستخدام طريقة التسخين ثم التبريد الدوريين وقد أجرى هذا البحث بغرض دراسة تأثير التغيرات الحرارية على قوة الألتصاق بين مادتي الأملغم والكومبوزيت وذلك باستخدام أنواع مختلفة من المواد اللاصقة. وقد تم إعداد عينات من مادة الأملغم ثم تخشين سطحها بواسطة حبيبات أكسيد الألمنيوم المختلطة بالهواء (باستخدام المراملة)، وبعد ذلك تم طلاء تلك الأسطح المخشنة بمواط لاصقة، ثم تغطيتها بمادة «الكومبوزيت» وقد تم تخزين جميع العينات في الماء لمدة أسبوع عند درجة حرارة ٣٧ مئوية وذلك قبل إجراء إختبار القص عند منطقة الإلتصاق. ولد تم قياس قوة الإلتصاق باستخدام جهاز الاختبار الموحد وذلك أثناء غمر العينات في الماء عند درجات حرارة تتراوح ما بين ٢٠ و ٧٠ درجة مئوية.
وقد دلت نتائج هذا البحث بصفة عامة على أن هناك تغيراً طفيفاً في قوة الإلتصاق بين مادتي الأملغم والكومبوزيت مع تنوع درجات الحرارة وذلك باختلاف المواد اللاصقة المستعملة وقد يعزى هذا التغير إلى عدم التجانس بين معاملات التمدد الحراريلمواد الأملغم والكومبوزيت واللاصق الراتنجي، وكذلك للاختلاف في التركيب الكيميائي للمواد اللاصقة المستخدمة في هذا البحث.

Abstract

A durable resin bond to dental amalgam is required for the clinical success of composite resin-veneered amalgam restorations. The reported bond strengths differ for various adhesive resins. Laboratory procedures utilized to simulate aging of these restorations in the oral cavity vary widely. Water storage at a constant temperature (37°C) or thermal cycling are the conditions most often used. The objective of this study was to investigate the bond strength of composite resins to amalgam using different dental adhesives at various temperatures while immersed under water. Sandblasted amalgam samples were prepared and composite resins were bonded to them using three different dental adhesive systems. All bonded samples were stored in water at 37°C for 1 week before testing. Shear bond strength was determined while bonded samples were immersed in water with temperatures ranging from 20-70°C using universal testing machine. Each sample was held at its test temperature for 5 min. before testing to establish temperature equilibrium. The results revealed that, in general, shear bond strength slightly changed with temperature variations among the three adhesive systems. This change could be explained by the mismatch in the coefficients of thermal expansion of bond components and differences in the chemical composition of the adhesive systems.

Introduction

Extensive amalgam restorations involving portion of facial surfaces are judged to be distracting. Esthetic corrections can be made with posterior composite resins placed in cavities cut in existing set amalgam restorations to remove the offensive facial portions.[1-4] Application of dental adhesives onto roughened amalgam surfaces was used to increase interfacial bond of composite resins to dental amalgam.[5-7]

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* Professor , Department of Restorative Dental Sciences, College of Dentistry, King Saud University.
** Associate Professor, Department of Removable Prosthetic Dental Sciences, College of dentistry, king Saud University, P.O.Box 60169, Riyadh 11545, Saudi Arabia
*** Riyadh Central Hospital, Ministry of Health, Riyadh, Saudi Arabia.
Address reprint requests to : Prof. K. Hassan.

Composite resins bonded to dental amalgam, as all other restorative materials, function in a complex environment. The clinical performance of these restorative materials is dependent on externally imposed variables, such as temperature, oral medium and applied loads. The interactive effect of these variables, often unpredictable and transient in nature, affects the short- and long-term stability of such restorations.[8]

A durable resin bond to dental amalgam is required for the clinical success of composite resin-veneered amalgam restorations. The reported bond strengthens of such restorations differ for various adhesive resins.[6,9,10] Laboratory procedures utilized to simulate aging of these restorations in the oral cavity vary widely.[4,8,11] In addition, water storage at a constant temperature (37 °C) or thermocycling are the most often used conditions.[10,12,13] The effect of thermomechanical variables on the strength of bonding composite resins to amalgam has not yet been investigated.

It was the objective of this study to investigate the bond strength of composite resins to amalgam at discrete temperatures in the oral temperature range under water immersion test conditions using different dental adhesives.

Materials and Methods

A high copper dental amalgam, two hybrid VLC posterior composite resins with different chemical character, additives and resin matrix structures, and three dental adhesives were used in this study and are listed in Table 1.

A total of 180 amalgam samples were fabricated. Cylindrical amalgam samples, 8 mm in diameter and 3 mm long were prepared with flat surfaces in especially designed plexiglass molds. The amalgam alloy was triturated in Varimex III amalgamator* according to the manufacturer's instructions. Prepared amalgam samples were allowed to age for 24 hours under room conditions. Set amalgam surfaces were roughened by sandblasting** using 50 pjn $A1_2 0_3$ for 10 sec. at an air pressure of 0.6 MPa and a distance of 4.5 mm, closely reproducing recommended intraoral procedure. Sandblasted amalgam surfaces were then rinsed with water and air dried. Sandblasted amalgam samples were divided into three groups of 60 each. Each of the three dental adhesives was applied to the sandblasted surfaces as instructed by the respective manufacturer, except that no acids were used on the amalgam surfaces after sandblasting was completed. A summary of the procedure for each system is presented in Table 2.

Amalgam samples in each group were further divided into two subgroups of 30 each. Each of the two composite resins was applied to the sandblasted and adhesive treated samples using a previously described procedure.[6]

All composite-bonded amalgam samples were stored in distilled water at 37<»C for one week prior to being tested. Shear bond strength testing was performed using a universal testing machine*** with a temperature-controlled chamber containing water. The chamber had a heating unit with a thermocouple surrounding the sample to keep it at the designated temperature during testing. The load range was 0-200 kg and the crosshead speed was 0.5 mm/min. The samples were each mounted in such a way that they were sheared at the composite-amalgam interface using a unibevelled steel blade. Shear testing was conducted with samples immersed in water at temperatures ranging

Table 1- Materials investigated

Brand	Type	Manufacturer
Duralloy	High copper Amalgam	degussa AG Frankfurt, Germany
Herculite XR	Resin matrix: Bis-GMA/TEGDMA* Filler : Ba glass - Pyrogenic $Si0_2$ vol % 55 - 57	Kerr Manufacturing Co. Detroit, MI, USA
Prisma APH	Resin matrix: UDMA Mod. Bis-GMA/TEGDMA* Filler: Ba glass-colloidal Si02 vol % 49.7	Caulk Dentsply Milford, DE, USA
All-Bond 2	NTG-GMA primer and BPDM in acetone*	Bisco, Inc. Itasca, IL, USA
Amalgam bond Plus	Med. 4 - META-based bonding system	Parkell Farmingdale, NY, USA
Optibond	GPDM and HEMA in ethanol*	Kerr Manufacturing Co. Romulus, MI, USA

* Caulk Dentsply, Milford, DE, USA.

** MicroEtcher Model er/erc, Danville Eng. Inc., San Ramon, CA, USA.

*** Lloyd instruments Ltd. Segenswarth W, Fareham, England.

Table 2. Summary of the procedures for adhesive systems used.

System	Agent Applied	Procedure
All-Bond 2	(1) Apply Primer A & B, 2 coats (2) Apply dentin/enamel bonding agent (3) Apply composite resin	Air Dry 6 sec Light cure 20 sec Light cure 80 sec
Amalgambond Plus	(1) Apply adhesive agent (2) Apply mix of 2 drops base and 1 drop catalyst (3) Apply composite resin	Thin with air, let stand 30 sec Let stand 60 sec Light cure 80 sec
Optibond	(1) Optibond Primer (2) Optibond adhesive (3) Apply composite resin	Air dry 10 sec and light cure 20 sec Light cure 30 sec Light cure 80 sec

from 20-70°°C where 20°°C was used as the control. Each sample was held at its test temperature for 5 min. before testing in order to establish temperature equilibrium. Five bonded samples of each adhesive-composite combination were used at each test temperature.

The bond strength values for the three dental adhesives as well as those calculated for each adhesive at the different test temperatures were statistically analyzed using two-way analysis of variance (ANOVA) and Scheffe test at $P<0.05$. Comparisons between the two composite resin brands were done using Student's t-test.

Results

Shear bond strength values calculated at different test temperatures for the bonded samples using the three dental adhesives together with statistical analysis are presented in Tables 3 and 4 for amalgam veneered with Herculite XR and Prisma APH composite resins, respectively.

The tables indicate a decrease, with a few exceptions, in the shear bond strength values between 20 and 70°°C for each dental adhesive. Optibond dental adhesive showed significantly higher values ($F=66.70$, $P<0.05$) than those obtained for All-Bond2 and Amalgambond Plus at all test temperatures. Using the values at 20°°C as a control, the percent reduction in shear bond strength exhibited by

Table 3. Shear bond strength (kg/cm^2)* of Herculite XR composite resin-veneered amalgam.

Temp CO	DENTAL ADHESIVES		
	All-Bond 2	Amalgambond Plus	Optibond
20	75.48 ± 1.12^{ABb}	$83.64 \pm i.54^{FGHIa}$	151.47 ± 1.41
30	$80.58 \pm 2.18^{A,C,Db}$	90.78 ± 0.80^{FJb}	145.35 ± 2.43
40	86.70 ± 3.13^{Cc}	$77.52 \pm 2.51^{GK,L,C}$	136.17 ± 1.68
50	$77.52 \pm 0.62^{B,Dd}$	86.70 ± 2.23^{HJMd}	$108.12 \pm 0.73^{\circ}$
60	65.28 ± 0.21^{E}	$86.70 \pm 0.43^{IK,MN}$	$100.98 \pm 2.11^{\circ,P}$
70	55.08 ± 2.11^{E}	73.44 ± 0.18^{LN}	96.59 ± 1.10^{P}

* Mean + SD
Mean Values designated with the same superscript letter are not statistically different at $P>0.05$. Uppercase letters indicate no difference within columns; lowercase letters indicate no difference within rows.

Table 4. Shear bond strength (kg/cm2)* of Prima APH composite resin-veneered amalgam.

Temp CC)	DENTAL ADHESIVES		
	All-Bond 2	Amalgambond Plus	Optibond
20	65.28 + 2.10 ^{Aa}	70.38 +3.15 ^{EFGHa}	130.56+ 1.30 ^{N}
30	69.36 ± 0.70 ^{ABCb}	73.44 ± 1.00 ^{EUb}	125.26 +0.52 ^{NO}
40	72.42 ± 3.20 ^{BDc}	64.26 ± 2.25 ^{FKLc}	121.38+ 1.17 ^{0P}
50	66.30 ± 1.10 ^{CDd}	72.82 ± 3.10 ^{GH,Ud}	116.28 +2.43 ^{P}
60	52.83 ± 2.03	68.34 + 0.91 ^{KM}	101.92 + 2.11 ^{Q}
70	44.89 ± 0.28	62.22 ± 0.43 ^{LM}	97.52 +0.98 ^{Q}

*Mean± SD
Mean Values designated with the same superscript letter are not statistically different at P>0.05. Uppercase letters indicate no difference within columns; lowercase letters indicate no difference within rows.

bonded samples of Herculite XR.composite [Table 3, Fig. 1] for a rise in temperature from 20 to 70°°C was about 27% for All-Bond2, 12% for Amalgambond Plus and 36% for Optibond dental adhesive. A significant reduction (F=83.33, P<0.05) in shear bond strengths was observed for the three adhesives from 20 to 70ooC test temperatures.

At 40°°C (close to the normal temperature of the oral cavity), the shear bond strength value for Amalgambond Plus was found to be the lowest. However, at 20°°C (control), All-Bond2 exhibited the lowest value. Optibond adhesive showed the highest strength values at 20 and 40°°C.

At 60°°C (close to the temperature of the oral cavity when drinking hot beverages), All-Bond2 attained the lowest strength value while Optibond showed the highest value. Similar behavior by All-Bond2 and Optibond adhesives was noted at 20«»C. The differences in the

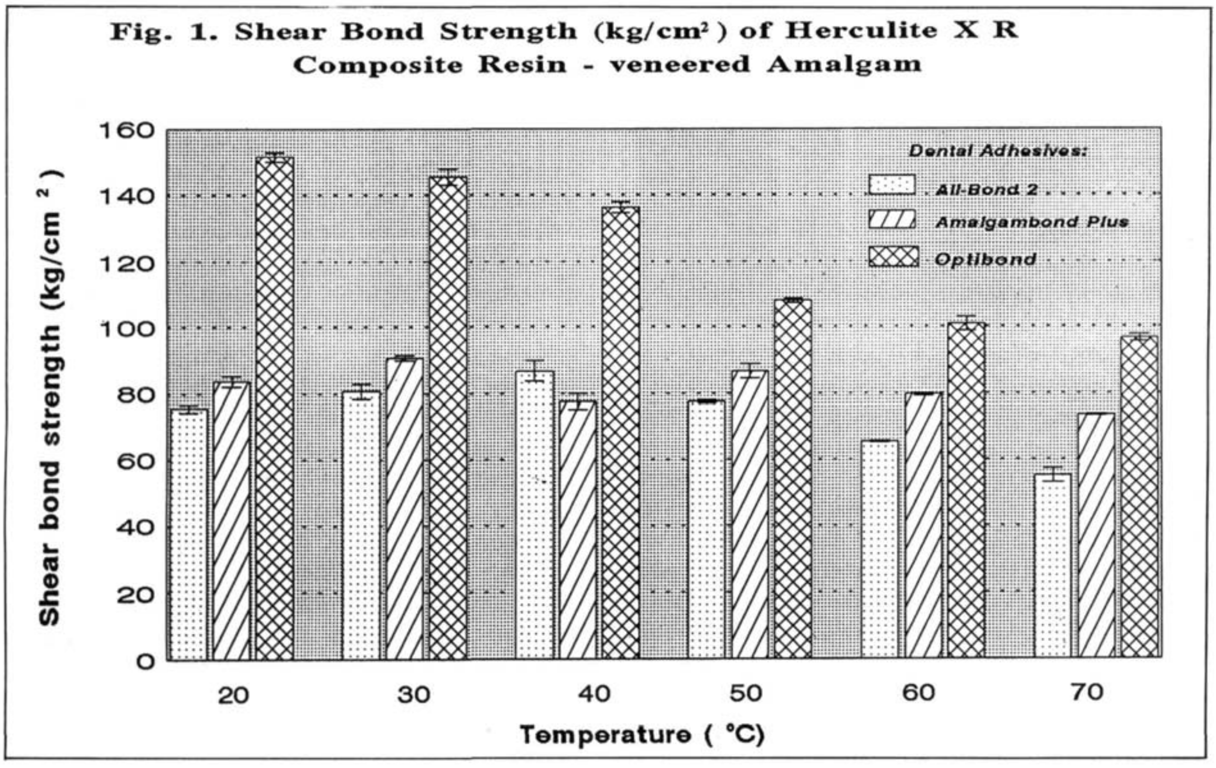

Fig. 1. Shear bond strength (kg/cm2) of Herculite XR composite resin-veneered amalgam.

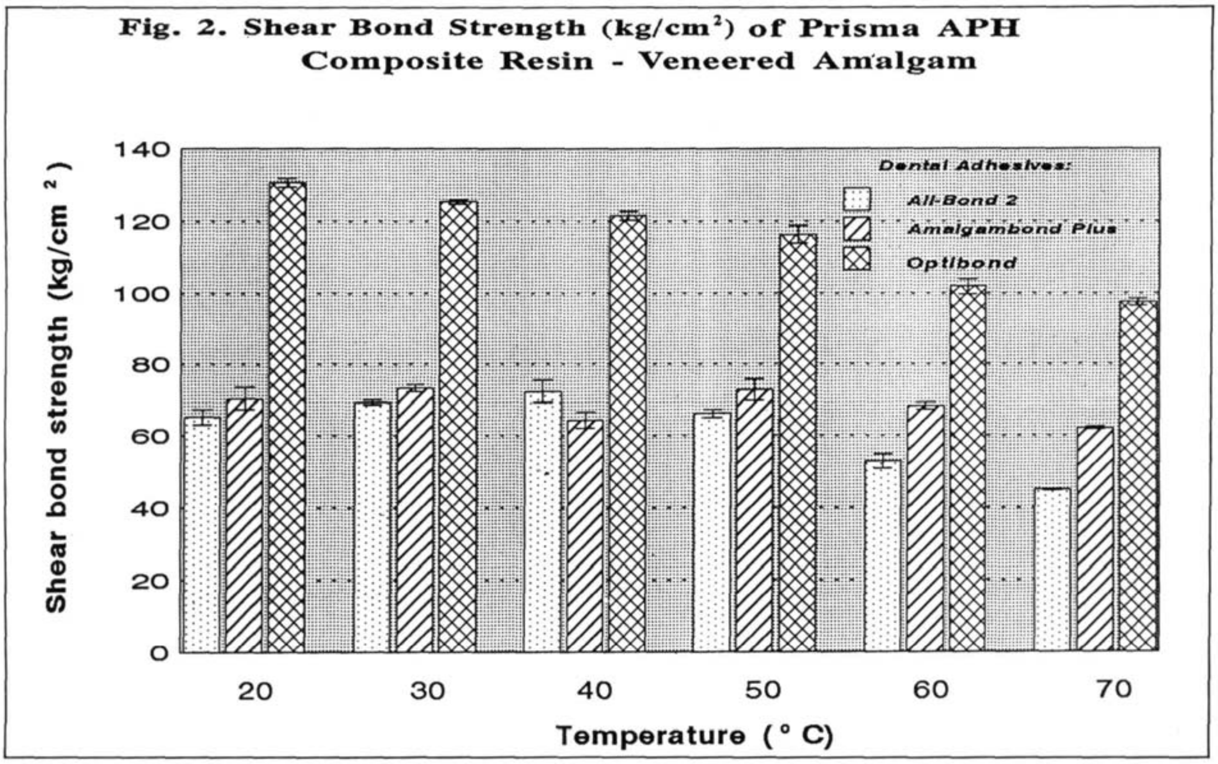

Fig. 2. Shear bond strength (kg/cm2) of Prisma APH composite resin-veneered amalgam.

strengths between 20 and 60°°C were found to be statistically significant (F=37.86, P<0.05).

Samples veneered with Prisma APH composite resin [Table 4, Fig. 2] showed trends in shear bond strengths comparable to those calculated for Herculite XR with each adhesive at all test temperatures. Strength values exhibited by Herculite XR composite resin were generally higher and the difference was found to be statistically significant (P<0.05).

Discussion

The ultimate objective of an analysis of bond strength is a prognosis of deterioration with time as a function of environmental conditions such as temperature. In the present study, it was clearly found that there was a decrease in shear strength of bonding composite resins to dental amalgam with a rise of temperature from 20 to 70ooC among all dental adhesives. This decrease could be attributed to the differences in the thermal diffusion and the mismatch of coefficients of thermal expansion of bond components at the interface. The thermal diffusion was found 14 to be appreciatively slower through composite resins than through amalgam, while the slowest rate of thermal diffusion was associated with the unfilled resins. The results of the present study indicate that the thermomechanical effects on bonding composite resins to amalgam at all test temperature with All-Bond2 are less than those with Amalgambond Plus and Optibond dental adhesives. These variations could be explained by the differences in the chemical composition of the adhesives and composite resin matrix as presented in Table 1.

Optibond dental adhesive showed the highest bond strengths of composite resin to amalgam at all test temperatures as compared to those obtained with the other two adhesives. The different behavior at the interface among the adhesive resins can be understood in the light of the variations in water diffusion as well as absorption kinetics[14,15] which depend on the temperature and stress built-up in the polymeric materials.

The variation in the shear bond values with temperature between the two investigated composite resins could be attributed to the differences in the matrix resin composition as summarized in Table 1. At the lower temperatures (20-40°°C), the higher shear bond strength values could be explained by the ability of the bonded materials to relax the applied shear stresses at the interface. This stress relaxation would depend on the ability of the resin matrix (softer phase) to accommodate crack tip stresses by local deformation under loading situations.[12] At higher temperatures (40-70°°C), the reported values of bond strength were lower. This finding is not in accordance with the polymeric materials enthalpy contributions[18] that would be expected to reduce the stress intensity factor through an increased ability for stress accommodation.

Further studies are needed to investigate the relationship between the thermo-mechanical effects on the bond strength of the investigated components and their dimensional changes as well as their coefficients of thermal expansion.

Conclusions

Based on the findings of this study, the following conclusions can be drawn :

1. The shear bond strength values of composite resin-veneered amalgam decreased as a function of temperature. This decrease in shear bond strength was statistically significant.
2. The Optibond dental adhesive provided the highest bond strength values of composite resins to amalgam. However, this bond was greatly affected by temperature changes during the short-term immersion in water.
3. The shear bond strength values exhibited by amalgam veneered with Herculite XR composite resin were generally higher than those calculated for Prisma APH composite resin. The difference in shear bond strength was statistically significant.
4. Further investigation is needed to correlate between the thermomechanical effects on bond strength of composite resin-veneered amalgam and their dimensional changes as well as their coefficients of thermal expansion.

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