Evaluation of the effect of Poly Vinyl Pyrrolidone addition on the shear bond strength of acrylic resin artificial teeth to heat cured acrylic resin denture base material

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ABSTRACT

Background: The most common materials used for fabrication of denture bases are poly methyl methacrylate (PMMA). Fracture or debonding of plastic teeth from denture base are common clinical problems which are facing both the patient and the dentist. The aim of this study is to evaluate and compare the shear bond strength of acrylic resin artificial teeth treated by different chemical surface treatments (solvents like acetone & thinner) to the experimental prepared material and to the control material before and after thermocycling.

Materials and methods: Preparation of modified heat cured denture base acrylic resin was carried out by preparing of (PMMA) (80%) and poly vinyl pyrrolidone (PVP) (20%) and the liquid part composed of methyl methacrylate (MMA) monomer. Control: poly methyl methacrylate (PMMA) + methyl methacrylate (MMA) as control group (2.5 : 1) by weight (1). Experimental: PMMA (80%) + PVP (20%) + MMA as experimental group (2.5 : 1) by weight. Sixty artificial acrylic teeth were prepared and cured by control and experimental denture base acrylic resin, then teeth were divided into three groups and treated with different surface treatment; first group received no further treatment (control), second group treated with acetone and third group treated with thinner. The denture teeth were flasked and wax was eliminated with running hot water. Denture resin was packed and cured according to manufacturer's instructions and specimens were deflasked upon the completion of resin processing. Then half of specimens from all surface treatments were tested by using Instron machine and subjected to shear force until failure. The other half of specimens which also include the surface treatments groups were thermocycled. Teeth surfaces after treatment and fracture sites were examined and photographed visually and under reflecting light microscope.

Results: The results showed that all surface treatments produced significantly high improvement in shear bond strength (SBS). Control group had shown significantly lower (SBS) than experimental group bonded to artificial acrylic teeth. On the other hand, experimental denture base resin bonded to artificial acrylic teeth were affected more significantly by thermocycling than the same teeth bonded to control denture base resin. Results indicated that thinner treatment for acrylic teeth is recommended prior to denture base processing.

Conclusion: higher SBS of artificial acrylic teeth bonded to experimental denture bases rather than to control denture bases.

Key words: Poly Vinyl Pyrrolidone, Shear Bond Strength and thermocycling. (J Bagh Coll Dentistry 2011;23(1):1-7).

INTRODUCTION

The failure rate of acrylic resin dentures due to fractures have been reported to be an acceptable high[(2)] and the most common type of failure encountered was de-bonding fracture of the teeth[(3)]. Plastic denture teeth are often preferred over porcelain teeth due to the chemical bond to the denture base material and easier to be adjust[(4)]. The lack of adequate bonding is believed to be the result of incompatible surface conditions at the tooth-base interface. This incompatibility is brought about by the following factors:

1. The degree of cross-linking of the materials[(5)].
2. Contamination of the surface (bond area), particularly by wax and possibly by sodium alginate mould seal as a separating medium.
3. The difference in the structure of the two components due to their different processing routes [(6)].
4. Lack of free monomer in the acrylic resin dough at the packing stage.
5. Rate of closure of the flask and the pressure applied by the press[(7)].
6. Thermal stress, cyclic flexural stress during mastication and water present in the denture base have been recognized as a cause for insufficient bond strength and durability[(8)]

previous researches have indicated that chemical or mechanical preparations or modifications of the denture teeth surface of artificial teeth prior to bonding improved bond strength[(9)].Chemical modifications promote the penetration and diffusion of monomers into denture teeth[(10)]. Organic solvents include methylene chloride [(11)], chloroform [(12)], methyl methacrylate[(13)] and acetone[(14)].

MATERIALS AND METHODS

Sixty artificial teeth from the same version of central incisors right and left (Shang Hai cross-linked acrylic teeth) were prepared and bonded to denture base materials (control and

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experimental), these specimens were classified according to the type of teeth surface treatments as the following:

First group: acrylic teeth without any surface treatment (control).

Second group: acrylic teeth conditioned with acetone.

Third group: acrylic teeth conditioned with thinner.

Preparation of teeth: All teeth were cut at the neck (gingival portion) in order to remove the highly cross-linked layer of acrylic teeth which decreases the bond strength. The rubber mould was put on the surveyor table and fixed in position parallel to the horizontal plane (zero tilt).Dental stone was mixed according to the manufacturer instructions and poured in the rubber mould. About 4mm of the incisor portion of each central incisors (which were measured and marked previously) embedded in the stone thick mixture in such away that the gingival portion of the tooth was parallel to the horizontal plane. The stone bases with teeth were fixed on surveyor table by screws after the complete set of the stone.

Figure 1: The stone base with teeth.

The portable engine hand piece which was fixed on surveyor arm and operated with constant speed (4000 rpm) was used for cutting the ridge lap portion of each tooth by using a stone disk and in one way direction; the depth of the cut was 1.5mm which was previously marked on the tooth by using digital vernier.

Mould preparation: The test samples comprised blocks with a 45-degree taper on the long side of which the ridge lap surface of the tooth is bonded. A load is applied to the incisal edge of the tooth at a crosshead speed of 0.5mm.min-1.A metal mould was made from a brass contained a rectangular hollow. The dimensions of this hollow were (17mm base, 7mm upper boarder, 9mm beveled boarder, 3mm lateral boarder and 10mm opposite lateral boarder) with a3mmdepth hollow in.

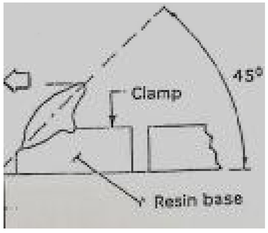

Figure 2: Configuration of the specimen Metal mould for a rectangular wax block.

The wax was melted and poured inside the metal mold. When the wax was solidified, the wax block was removed by using metal ejector with holder having the same dimensions of the metal mould hollow, then the artificial teeth were waxed on the beveled surface of the rectangular wax block; the slope of the beveled surface aligned each denture tooth so that the long axis of the tooth was at a 45 degree from the base of the wax block and measured by vernier for standardization.

Figure 3: The waxed denture teeth before being deflasked.

Flasking: theconventional flasking technique for complete denture was followed in the specimens preparation.

Figure 4: The lower half of the flask with waxed denture.

Table 1: The previously selected groups of teeth were underwent surface treatments.

Groups	Surfaces	Type of treatments	Number of teeth	Type of teeth
1	Plane	No treatment (control)	20	Acrylic
2	Plane	Acetone (180 sec.)	20	Acrylic
3	Plane	Thinner (180 sec.)	20	Acrylic

Proportioning, mixing & packing of acrylic resin: Table 2: all materials were mixed and manipulated according to the manufacturer instructions.

Materials	Powder\liquid ratio	Curing cycle
Superacryl Plus (Heat cure)	2.25 mg powder 1 ml liquid	As recommended by manufacturer. Flasks were placed in water bath, heat source was operated for 90 min at 74Cº then boiled for 30 min. The flasks allowed to cooling down slowly in the water bath for 30 min. followed by complete cooling of the metal flask with tap water for 15 min. before deflasking.
80% Superacryl Plus (Heat cure) + 20%PVP	١.٨mg heat cure + ٠.٤٥mg PVP Powder 1 ml liquid	

All samples had the same sizes which were checked by vernier for standardization, also materials were handled by the use of disposable plastic gloves to reduce contamination at all times.

Artificial Saliva Preparation: an electrolyte composition similar to that of human saliva was used in this study [15] which includes:
1. [1 g] Sodium carboxy-methyl-cellulose. 2. [4.3 g] Sorbitol. 3. [0.1 g] Potassium chloride. 4. [0.1 g] Sodium chloride. 5. [0.02 mg] Sodium fluoride. 6. [5 mg] Magnesium chloride. 7. [5 mg] Calcium chloride. 8. [40 mg] Potassium phosphate. 9. [1 mg] Potassium thio-cyanate. 10. [100 ml] Distilled de-ionized water.

After finishing the preparation of artificial saliva, the specimens became ready to be stored in it. Before testing, all specimens were stored in artificial saliva substitute [16] in incubator at (37Cº) for 7 days[17]. Then half of the specimens, thirty including all surface treatments groups and subgroups for acrylic teeth bonded to control and experimental denture bases were tested by using Instron universal testing machine and subjected to shear force until failure. The other half of the specimens in each test group which also include thirty acrylic teeth (including all surface treatments) bonded to control and experimental denture bases were thermocycled between (5Cº to 55Cº ±2Cº) in a 60 sec cycles for 3 days (approximately 1000 cycle) with an immersion time of 30 sec/bath and a total cycle of time of 1 min [18]. In the first two days the specimens were stored again in artificial saliva in an incubator at 37Cº for the rest of the day after the end of thermocycling, while for the third day the specimens were tested immediately after the end of the procedure in the Instron universal testing machine to avoid the stress relaxation and subjected to shear stress until failure [19].

Shear Bond Strength and Mode of Failure: After storage, the specimens were held in a metal fixture (grasping unit) manufactured especially for this study. The metal fixture was held firmly to an Instron universal testing machine model 1195 **(Instron corporation, canton mass).**

Figure 5: Instron universal testing machine and grapher.

The control & experimental blocks were held in the fixture and the test holder oriented in such a manner that the crosshead applied a force parallel to the bonding surface of the acrylic denture teeth. The shear load is applied by knife-edged rod positioned at the base of the bonded surfaces by using 1000 N load cell with a crosshead speed of 0.5 mm/min**.**Specimens were loaded until fracture and the load of fracture was recorded from the Instron graph reader in Newton [20].The shear bond strength was calculated based on the force **(F)** in **(N)** at fracture and adhesive surface area **(S)** in **(mm^2)** and converted to **(Mpa)**.

[[B.S= F/S]]

S= (π / 4) * D^2, π= 22/7 OR 3.14 , S= 19.64 mm^2.

D (diameter)= 5mm.

B.S= Bond Strength (N/mm^2) or (Mpa).

F= Force at failure (N).

S= Surface area of cross section in (mm^2) [21].

Visual examination and a reflecting light microscope (X40 magnification) evaluated the fracture site.

RESULTS

The effect of thermocycling technique on the S.B.S. of artificial acrylic teeth bonded to control and experimental denture bases as a function of different surface treatments was tested and evaluated.

Table 3: Descriptive Statistics.

Control	**Control (10)**		**Acetone (10)**		**Thinner (10)**	
	Before(5)	**After(5)**	**Before(5)**	**After(5)**	**Before(5)**	**After(5)**
Mean	11.690	11.588	11.731	11.619	13.146	13.004
Max.	11.965	11.812	11.914	11.812	13.289	13.187
Min.	11.456	11.354	11.405	11.303	13.034	12.881
Range	0.509	0.458	0.509	0.509	0.255	0.306
Standard Deviation	0.195	0.185	0.205	0.211	0.097	0.117
Standard Error	0.087	0.083	0.091	0.094	0.043	0.052
Experimental	Control (10)		Acetone (10)		Thinner (10)	
	Before(5)	After(5)	Before(5)	After(5)	Before(5)	After(5)
Mean	12.749	12.617	13.105	12.963	13.604	13.441
Max.	12.881	12.729	13.187	13.085	13.696	13.492
Min.	12.678	12.525	12.983	12.830	13.492	13.340
Range	0.203	0.204	0.204	0.255	0.204	0.152
Standard Deviation	0.085	0.075	0.077	0.105	0.083	0.062
Standard Error	0.038	0.033	0.034	0.047	0.037	0.027

Comparisons between Groups:

Effect of Surface Treatments:

Table 4: Acrylic Teeth Bonded to Heat Cured Denture Bases (Control).

Surface treatment groups	**Control denture bases Before thermocycling**			**Control denture bases After thermocycling**		
	T-test	**P-value**	**Sig.**	**T-test**	**P-value**	**Sig.**
Acetone	0.321	0.757	N.S.	0.243	0.814	N.S.
Thinner	14.868	0.000	H.S.	14.414	0.000	H.S.

Table 5: Acrylic Teeth Bonded to Reinforced Heat Cured Denture Bases (80% PMMA + 20% PVP)(Experimental).

Surface treatment groups	**Experimental denture bases Before thermocycling**			**Experimental denture bases After thermocycling**		
	T-test	**P-value**	**Sig.**	**T-test**	**P-value**	**Sig.**
Acetone	6.931	0.000	H.S.	5.964	0.000	H.S.
Thinner	16.018	0.000	H.S.	18.832	0.000	H.S.

Table 6: Effect of Denture Base Materials (Control & Experimental).

Surface treatment groups	**Control & Experimental denture bases before thermocycling**			**Control & Experimental denture bases after thermocycling**		
	T-test	**P-value**	**Sig.**	**T-test**	**P-value**	**Sig.**
Control	11.086	0.000	H.S.	11.473	0.000	H.S.
Acetone	13.999	0.000	H.S.	12.731	0.000	H.S.
Thinner	7.955	0.000	H.S.	7.374	0.000	H.S.

Table 7: Effect of Thermocycling.

Surface treatment groups	**Control denture bases before & after thermocycling**			**Experimental denture bases before & after thermocycling**		
	T-test	**P-value**	**Sig.**	**T-test**	**P-value**	**Sig.**
Control	0.844	0.423	N.S.	2.600	0.032	S.
Acetone	0.850	0.420	N.S.	2.437	0.041	S.
Thinner	2.087	0.070	N.S.	3.491	0.008	S.

Microscopical Studies:

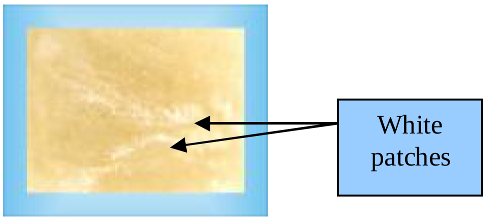

Figure 6: Acrylic tooth treated with acetone.

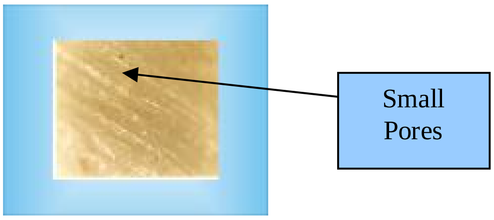

Figure 7: Acrylic tooth treated with thinner.

Mode of failure:

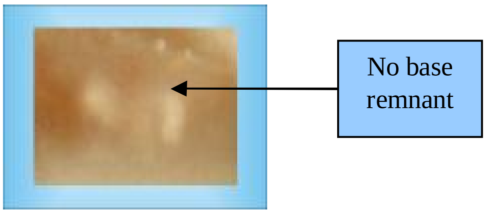

Figure 8: Adhesive failure mode showing acrylic tooth side.

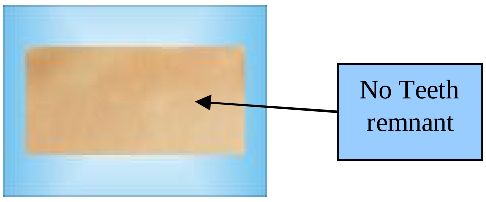

Figure 9: Adhesive failure mode showing denture base side.

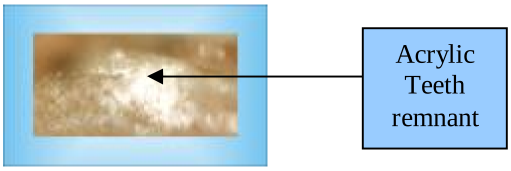

Figure 10: Cohesive failure mode showing acrylic tooth remnants on denture base side.

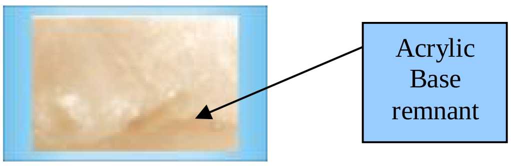

Figure 11: Cohesive failure mode showing denture base remnants on acrylic tooth side.

Table 8: Mode of failure and no. of acrylic teeth bonded to control denture bases.

Control Denture Bases Bonded To Acrylic Teeth	Control		Acetone		Thinner	
	Before	After	Before	After	Before	After
Adhesive	3	3	2	2	1	1
Cohesive Teeth	0	1	1	2	2	1
Cohesive Denture Base	1	1	1	1	1	2
Mixed	1	0	1	0	1	1

Table 9: Mode of failure of acrylic teeth bonded to control denture bases In Percentage.

Control Denture Bases Bonded To Acrylic Teeth	Control		Acetone		Thinner	
	Before	After	Before	After	Before	After
Adhesive	60%	60%	40%	40%	20%	20%
Cohesive Teeth	0%	20%	20%	40%	40%	20%
Cohesive Denture Base	20%	20%	20%	20%	20%	40%
Mixed	20%	0%	20%	0%	20%	20%

Table 10: Mode of failure and no. of acrylic teeth bonded to experimental denture bases.

Experimental Denture Bases Bonded To Acrylic Teeth	Control		Acetone		Thinner	
	Before	After	Before	After	Before	After
Adhesive	1	1	1	0	1	0
Cohesive Teeth	0	0	1	0	0	0
Cohesive Denture Base	4	3	2	5	3	2
Mixed	0	1	1	0	1	3

Table 11: Mode of failure of acrylic teeth bonded to experimental denture bases In Percentage.

Experimental Denture Bases Bonded To Acrylic Teeth	Control		Acetone		Thinner	
	Before	After	Before	After	Before	After
Adhesive	20%	20%	20%	0%	20%	0%
Cohesive Teeth	0%	0%	20%	0%	0%	0%
Cohesive Denture Base	80%	60%	40%	00%	60%	40%
Mixed	0%	20%	20%	0%	20%	60%

DISCUSSION

The Effect of Surface Treatments:

A. Thinner Wetting: thinner wetting improve the (S.B.S.) significantly high **($p \leq 0.001$)** in all thinner conditioned acrylic teeth bonded to both control and experimental denture bases before and after thermocycling, these effects were due to that thinner wetting which is a strong solvent since it is chemically composed from multiple solvents could dissolve the polymer in an amount more than acetone. So that the teeth conditioned with thinner debonded in a cohesive mode which could be proved as evidence that the solvents effect had facilitated the diffusion of the polymerizable monomer from the denture base to the surface treated tooth and enhanced the creation of a more extensive interwoven polymer network. These findings were in agreement with[(22)].

B. Acetone Wetting: a non-significant improvement **($p > 0.05$)** in acrylic teeth conditioned with acetone bonded to control denture bases before and after thermocycling, while a high-significant improvement **($p \leq 0.001$)** in acrylic teeth conditioned with acetone bonded to experimental denture bases before and after thermocycling; these effects were due to that acetone is a strong solvent, so treating the tooth surface with acetone would dissolve away most of the microdebris, smooth out the adhesive and produced sponge like structure while enhance the mobility of monomer units of the denture base leading to an increase in the number of active sites and then there will be physical interaction (Vander Wall Forces), although these forces provide a good bond strength but did not produce chemical cross-linking reaction, so acetone surface conditioning produced lower bond strength mean value compared with thinner surface conditioning in the polymerization reaction for both control and experimental denture bases before and after thermocycling. These findings were in agreement with [(23)].

The Effect of the Type of Denture Base Materials: a high-significant improvement **($p \leq 0.001$)** of (S.B.S.) of acrylic teeth bonded to both control and experimental denture bases before and after thermocycling. The mean values of (S.B.S.) of artificial acrylic teeth bonded to experimental denture bases were significantly higher at level **($p \leq 0.001$)** than that of control denture bases before and after thermocycling; this may be attributed to the presence of P.V.P in the experimental group that appear to be capable of diffusing effectively into the tooth surface to ensure a satisfactory bond due to good wetability as a result of low viscosity exhibited by this material. P.V.P has excellent wetting properties and film forming, hygroscopic absorbs up to 18% of its weight of atmospheric water; also P.V.P combines both good initial tack and good adhesion (i.e. maintain the parts together and keep them in position). P.V.P is capable of swelling in polar solvents such as water which leads to more interpenetrating polymer network formation and thus increasing the bond strength.

The Effect of Thermocycling Technique:

A. Acrylic Teeth Bonded to Control Denture Base:a non-significant decrease in the (S.B.S.) **($p > 0.05$)** in acrylic teeth bonded to control denture bases in the control, acetone and thinner groups after thermocycling. This might be due to that the acrylic teeth and the acrylic resin denture base have nearly the same coefficient of thermal expansion ($80\text{-}81 \times 10^{-6}$\C°); therefore, this similarity reduced the chance for the creation of thermal stress, so the bond strength was not affected by such thermal fluctuation [(24)]. Also, the smooth untreated surface had facilitated a closer adaptation of denture base to tooth surface during adaptation of resin to the tooth ridge lap during packing, thus minimizing voids creation. So due to the absence of such voids in an untreated tooth surface, there will be less opportunity that the material absorbed water during thermocycling that may be peculate directly into the bond site and accumulates in the voids at the interface, leading to swelling and consequently stress build up at the denture base interface leading to decreased bond strength. These findings were in agreement with [(25)]. Acetone and thinner treatments of acrylic teeth lead to the creation of channels and pores and also voids formed during solvent evaporation as revealed by microscopic examination which prevents a close adaptation of the tooth to the denture base resin during packing [(26)].Moreover, since thermocycling cause hydration of the specimens, so the material absorbed water and this had a damaging effect on the bonding. The water may peculate directly into the bond site, accumulates in the voids at the interface leading to swelling and consequently stresses build up at the denture base interface, so this will lead to decreasing the (S.B.S.) after thermocycling. These results were in agreement with [(25)].

B. Acrylic Teeth Bonded to Experimental Denture Bases: there was significant decrease in the (S.B.S.) **($p \leq 0.05$)** in acrylic teeth bonded to experimental denture bases in the control, acetone and thinner groups after thermocycling. This might be due to the differences between the coefficient of thermal expansion of P.V.P ($14\text{-}50 \times 10^{-6}$\C°) and the coefficient of thermal expansion of acrylic resin denture base which is nearly the same coefficient of thermal expansion of acrylic teeth (80-81×10ˉ6\Cº); therefore, this difference resulted in the creation of thermal stress, so the bond strength was affected by such thermal fluctuation.

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