Effect of plasma treatment of acrylic denture teeth and thermocycling on the bonding strength to heat cured acrylic denture base material

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ABSTRACT

Background: Acrylic resin polymer s used in prosthodontic treatment as a denture base material for several decades. Separation and debonding of artificial teeth from denture bases present a laboratory and clinical problem affect patient and dentist. The aim of this study is to evaluate the effect of oxygen plasma and argon plasma treatment of acrylic teeth and thermocycling on bonding strength to hot cured acrylic resin denture base material.

Materials and Methods: Sixty denture teeth (right maxillary central incisor) are selected. The denture teeth are waxed onto the beveled surface of rectangular wax block according to Japanese standard for artificial teeth. The control group consisted of 20 denture teeth specimen without any treatment. The oxygen plasma group consisted of 20 denture teeth specimen treated with oxygen plasma for two minutes exposure time at plasma apparatus. The argon plasma group consisted of 20 denture teeth treated with argon plasma for two minuets exposure time. All the specimens are undergone flasking and wax elimination procedure in the conventional way. All specimens stored in distilled water for 7 days at 37°C, then half of the specimens of all groups undergoes thermocycling between 5°C - 55°C in 60 seconds cycles for three days and tested for shear bond strength using universal testing machine the data was collected and analyzed statistically using analysis of variance and independent sample t-test.

Results: The plasma treated groups showed the higher mean force required to fracture the acrylic teeth from their heat cured acrylic resin denture bases, as compared to control group, and the oxygen plasma treatment group showed higher shear bond value than the argon plasma treatment. The thermocycling had a deleterious effect on bonding strength for control group while the plasma treated group showed an increase in bond strength following thermocycling.

Conclusion: Plasma treatment method was an effective approach for increasing the shear bond strength as a result of surface oxidation and chemical etching effect of oxygen plasma and micromechanical interlocking effect of argon plasma.

Key words: Plasma treatment, Shear bond strength, Thermocycling, Acrylic resin teeth. (J Bagh Coll Dentistry 2013; 25(Special Issue 1):6-11).

INTRODUCTION

Acrylic resin denture teeth had been widely used for removable prosthesis construction, principally due to these acrylic teeth ability to be bond chemically to the acrylic resin denture base material, owing to the similar chemical composition and formulation of the materials [1]. One of the main advantages of acrylic teeth are their ability to adhesively bonding to acrylic resin denture base material, in spite of that bonding which seems satisfactory, failures are still common and teeth detachment from denture base is one of the frequent complain and repair requirement for conversional prosthodontics, and this resin teeth detachment and fracture are considered to be a tragedy for the patient, whatever his or her age or social position status are being [2].

Acrylic teeth detachment from the denture, resin material could be attributed to several factors, from these factors is the direction of functional forces ridge lap area which prepared for teeth bonding to base material, contamination of acrylic resin teeth with separating medium or remnant of wax contaminate the bonding surface during wax elimination procedure [3].

On the other hand, attempt to improve artificial acrylic teeth bonding to acrylic denture base that influence on the bonding strength as ridge lap grinding, bonding agents, solvents or monomer / polymer solution application, microwave polymerization, polymerization temperature or cross linking agent concentration [4].

One of the most universal surface treatment techniques is the plasma treatment [5]. Plasma consisted from a partially ionized gas or gas mixture, the charged ions or electrons accelerated in electrical field to the energies that are comparable or exceed bond energies of the polymer surface plasma treatments had been found to improve the hydrophilicity of polymers surface without altering the bulk properties which directly impact their function [6].

Plasma surface treatments are using gases as oxygen, argon and nitrogen [7]. Oxygen plasma was reported to improve hydrophobicity and hydrophilicity and induce various functional groups which affect polymer bonding [8]. In addition oxygen plasma treatment increased surface energy of polymers [9], while argon plasma treatment of polymers reported to induce cross linking properties of polymers [10]. Recent studies have been indicated that plasma treatment

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could increase the bond strength between heat cured and self cured acrylic resins to levels exceeding that obtained with adhesive primer [12, 13], also studies indicated that plasma treatment increased tensile bond strength between soft liner and denture base resin [6,11]. From that this study was designated to evaluate the effect of oxygen plasma treatment and argon plasma treatment of acrylic resin artificial teeth and themocylcing on the shear bond strength (SBS) to hot cured acrylic resin denture base material.

MATERIALS AND METHODS

Sixty right maxillary central incisor acrylic artificial teeth (Florident, China) were selected, and had been waxed onto the beveled surface of rectangular wax block, the slope of the beveled surface aligned each artificial acrylic tooth so that the long axis of the tooth was at a 45° from the base of wax testing block, that would be in accordance to the Japanese standard for artificial teeth bonding test (JIST) (November 6506, 1989).

The conventional flasking technique had been followed for specimen preparation, the two halves of the flask were coated with separating medium (Vertx divosep Holland) and allowed to dry to be ready for pouring of the stone type III (Elite Model, Italy) in the lower half of the flask using vibrator to avoid air entrapment. Then waxed teeth were loaded in the stone mould before setting of stone in such a way that the waxed denture bases were embedded in the stone only. Following stone setting, a layer of separating medium had been used to coat the lower half of the flask; then the upper portion of the metal flask was positioned on top of the lower portion and filled with type III dental stone with vibration, then wax elimination was done by placing the flask in boiling water for 5 minutes. The flask was opened and washing of the two halves with water and detergent to remove any wax remnant. After dryness the two halves of the flask was coated with separating medium to be ready for packing with acrylic dough.

For plasma treatment, the artificial acrylic teeth were removed from the upper half of the flask, and each 10 artificial teeth were tied with upper silk as a ring surrounding the cervical portion of the teeth and the teeth were inserted in plasma apparatus chamber with base of the teeth is toward the plasma source to be exposed to the plasma gas. The exposure time was 2minutes, at 800 volt; 75MA powers of 60 watt, with plasma source were kept 4cm above the teeth specimens [6, 11].

According to type of plasma treatment 10 specimens of artificial acrylic teeth were treated with oxygen plasma other 10 specimens of artificial teeth were treated with argon plasma for the same exposure time and distances following plasma treatment. The artificial acrylic teeth were replaced in their position in the upper halves of the flask, a layer of separating medium was placed on the stone of both halves, heat cured acrylic resin(Vertex, Holland)was mixed according to manufacture recommendation using dry and clean jar using a clean wax knife for 30 second. Packing of acrylic dough by rolling the acrylic resin dough with the poly ethylene sheet, the two halves of the flask were assembled and placed under hydraulic press with gradual application of pressure to allow even flow of the dough throughout the mold space, then pressure was relived and the flask opened and the over flowed material surround the mould space were cut with sharp knife and removed. Final flask closure was performed by contacting the two flask halves till metal to metal contact had achieved and left under pressure for 5 minute with 20 bars, then flasks were immersed in water bath for 90 minutes at temperature of 73 C° then the temperature was raised to 100 C° and kept boiling for 30 minute then the flasks allowed to slow cooling in a water bath at room temperature before deflasking.

The sample were carefully deflasked and cleaned, all acrylic access were removed with an acrylic and then all samples were polished using bristle brush or rouge wheel with pumice and lathe polishing machine. After finishing and polishing, all of the specimens were stored in distilled water at 37 °C for seven days before SBS was tested. Half of the experimental specimens were thermocyled using thermocycling device, by subjecting the samples to 60-second cycle for three days at temperature ranging from 5 °C to 55 °C after finishing the thermocycling then all the experimental specimen that were thermocycled or non thermocycled were tested. SBS was measured at a cross head speed of 1.5 mm/min using universal testing machine (hack, Germany), with load being applied at 45° from the log axis of each acrylic resin tooth on palatal surface, till fracture was reached. The SBS were calculated based on the fracture force in Newton the adhesive surface area in millimeter and converted to megapaskal (Mpa). The data had been statistically analyzed.

RESULTS

Descriptive statistics include means and standard deviation of SBS in (Mpa) of the experimental group showed the higher SBS values in plasma treated groups as compared to the control group and the oxygen plasma treated group indicated the higher SBS than the argon plasma treated group. The analysis of variance (ANOVA) test showed a highly significant difference between plasma treated groups and control group, (Table 1, Figure1).

The least significant difference (LSD) test showed a highly significant difference in SBS values between oxygen plasma group and control group and between argon plasma group and control group, and between oxygen plasma group and argon plasma group, (Table 2).

Effect of thermocycling

With the thermocycling ANOVA and LSD showed a highly significant difference in SBS values among the control and the plasma treated groups, (Table 1 & 2).The SBS values are higher under thermocycling for both plasma treated groups and the higher value was detected in oxygen plasma group. For control group, thermocycling decrease the SBS values in comparison with the control group without thermocycling, (Figure 3).

The independent sample t-test used to compare the effect of thermocycling for each experimental group and showed a highly significant difference between each group before and after thermocycling, (Table 3).

In the statistical evaluation, the following levels of significance are used:

Non-significant	NS	$P > 0.05$
Significant	*	$0.05 \geq P > 0.01$
Highly significant	**	$0.01 \geq P > 0.001$
Highly significant	***	$P \leq 0.001$

Table 1: Descriptive statistic and ANOVA test of SBS in (Mpa) between control and plasma treatment groups with and without thermocycling.

State	Groups	Descriptive statistics		Group difference ANOVA test	
		Mean	S.D.	F-test	p-value
Without Thermocycling	Control	2.20	0.02	5101.08	0.000 ***
	Oxygen Plasma	9.07	0.06		
	Argon Plasma	8.59	0.29		
With thermocycling	Control	2.03	0.07	41304.46	0.000 ***
	Oxygen Plasma	9.48	0.06		
	Argon Plasma	8.94	0.07		

Table 2: The LSD test of SBS in (Mpa) between control and oxygen plasma and argon treated groups with and without thermocycling.

State	Groups		Mean Difference	p-value
Without thermocycling	Control	Oxygen Plasma	-6.88	0.000 ***
		Argon Plasma	-6.39	0.000 ***
	Oxygen Plasma	Argon Plasma	0.49	0.000 ***
With thermocycling	Control	Oxygen Plasma	-7.46	0.000 ***
		Argon Plasma	-6.92	0.000 ***
	Oxygen Plasma	Argon Plasma	0.54	0.000 ***

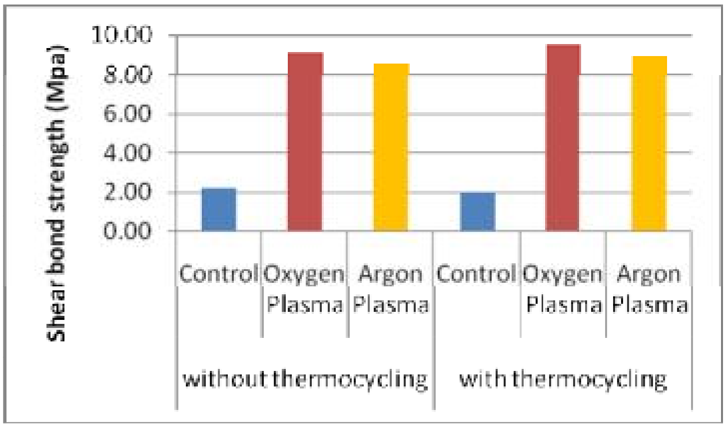

Figure 1: SBS in (Mpa) of all experimental groups with and without thermocycling.

Table 3: Differences in SBS in (Mpa) in each experimental group under the effect of thermocycling

Groups	State	Descriptive statistics		State difference	
		Mean	S.D.	t-test	p-value
Control	Without thermocycling	2.20	0.02	7.66	0.000 ***
	With thermocycling	2.03	0.07		
Oxygen Plasma	Without thermocycling	9.07	0.06	-15.75	0.000 ***
	With thermocycling	9.48	0.06		
Argon Plasma	Without thermocycling	8.59	0.29	-3.77	0.001 ***
	With thermocycling	8.94	0.07		

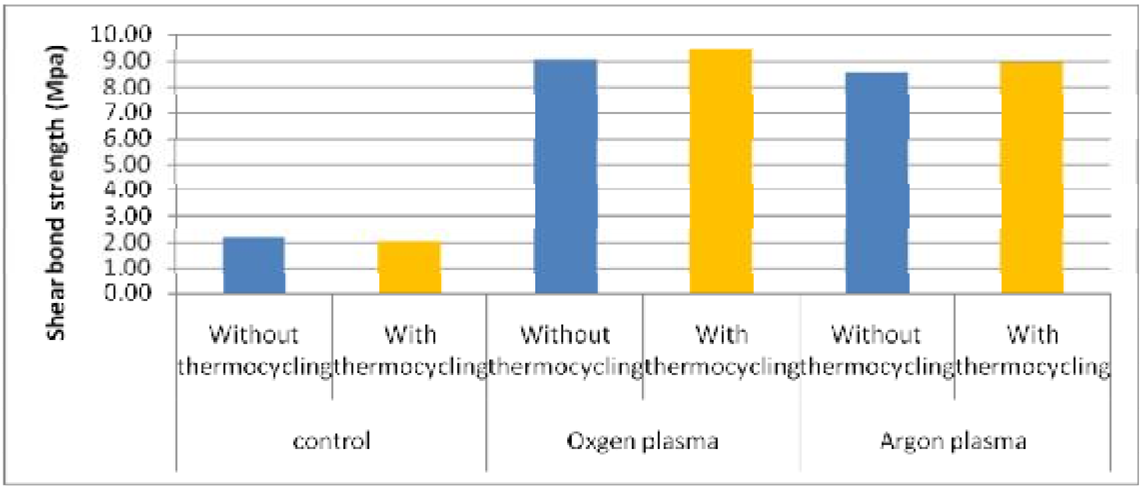

Figure 2: Comparison of the effect of thermocycling on SBS in (Mpa) in each experimental group.

DISCUSSION

In clinical practicing, the ability of artificial teeth to resist debonding from denture during masticatory stresses is of paramount importance for successful prosthodontic treatment and patient's confidence in removable prosthesis, since the bond failures between tooth and denture base represent a problem for rehabilitation success [16, 17]. In order to minimize these failures, several approach being used for enhancement of bonding strength between acrylic teeth and the resin base. It had been demonstrated that the type of acrylic resin teeth, method of polymerization, tooth surface treatments and conditioning and the thermal stress can influence the resin/tooth bond strength [3, 14, 15, 18].

One of the fast and efficient methods for improving bonding properties of artificial acrylic teeth to heat cured resin denture base material is the plasma surface treatment techniques.

According to the results of the present study, both types of oxygen and argon plasma showed an improvement in SBS and bonding ability of acrylic resin teeth to heat cured acrylic resin denture base materials, and the hypothesis of if oxygen and argon plasma could provide more retention against debonding of artificial teeth from heat cured denture base materials was accepted.

Effect of oxygen plasma treatment of acrylic teeth

The oxygen plasma treatment of artificial acrylic teeth showed a highly significant difference with control group in the values of SBS, (Table 1).

Effect of oxygen plasma treatment of artificial acrylic teeth on bonding strength to heat cured acrylic resin denture base material could be explained on the bases of oxygen plasma produce oxidation reactions on the basal surface of acrylic teeth, this oxidation reaction allowing the introduction of oxygen containing group of Carbon- Oxygen single bond (C-O) and Carbon-Oxygen double bond (C=O) on to the polymer of acrylic teeth surface, due to high reactive property of oxygen plasma [6]. As a result of oxygen containing groups the surface hydrophilicity of the plasma treated teeth will be improved [19], allowing the denture base resin to be penetrated into artificial teeth resin resulting in improvement in bonding strength. Inaddition, oxygen plasma treatment of artificial teeth producing an increase in surface area of polymer by removal of surface material and producing a rough surface, this rough surface will contribute in more intimate contact between teeth polymer and heat cured denture base polymer which in turn resulting in further bonding strengthening [6, 11]. These findings of present study come with Zhang *et al* [6] and Massod and Mohamed [11] findings in bond strength improvement with oxygen plasma treatment.

Effect of argon plasma treatment of acrylic teeth

The argon plasma treatment of artificial acrylic teeth showed a highly significant difference with control group in the values of SBS, (Table 1). This highly significant difference may be attributed to the effect of argon gas particles which specified by high molecular weight and as being hit the acrylic teeth polymer surface, physical removal of polymer surface material due to high energy and enhance micromechanical interlocking and inducing crosslinking properties of polymer with denture base polymer leading to highly significant bond strengthening with the denture base material, as compared to the control group. This result is in agreement with Chan *et al* [5] and Massod and Mohamed [11].

Difference in SBS between oxygen plasma and argon plasma acrylic teeth treatment

The findings of the present study indicating that oxygen plasma treatment of acrylic teeth is highly significant in SBS values in comparison with argon plasma (Table 1). This could be explained by the oxygen plasma had double effect on the surface of acrylic teeth; the first is the oxidation reaction and introduction of oxygen containing group and the second effect is the surface etching and roughing which in turn increase the surface area of polymer treated to bond to other polymer area. While the argon plasma had micromechanical interlocking and crosslinking properties which improve bonding strength of acrylic teeth to denture base material [5, 6, 11].

Effect of thermocycling

For control group, the SBS between the acrylic teeth and acrylic denture base was decreased after thermocycling, (Table 3). This could be explained on the bases of hydration of specimen leading to development of voids between the acrylic teeth and their denture bases, these voids will affect significantly on bonding strength resulting in decrease in SBS since the water absorbed by polymer material resulting in stress buildup at the interface area between teeth and denture base due to swelling of the voids with thermocycling procedure [20, 21, 23].

While the effect of thermocycling on plasma treated group is appositive effect leading to highly significant difference in SBS values compared with control group, (Table 2). This improvement in bonding ability explained by plasma treatment introduce element into the treated surfaces of acrylic resin teeth without thermodynamic constraints, radical are created in plasma zone play an important role in implantation process these facts are combined with ability of plasma to convert polymer from hydrophobic to hydrophilic which in turn improve the adhesion strength since the thermocycling process lead to hydration of the specimen [12, 13, 19, 22, 24].

The results also indicated that the oxygen plasma had higher bond strength after thermocycling than the argon plasma, (Table 3). This high significant difference in SBS values could be cleared by implantation of radical will be in combination with oxidation and surface roughing in oxygen plasma while the argon plasma will lead to micromechanical interlocking combined with implantation of radical after hydration in thermocycling procedure [19].

As conclusions

- Plasma treatment method was an effective approach for increasing the SBS as a result of surface oxidation and chemical etching effect of oxygen plasma and micromechanical interlocking effect of argon plasma.
- Oxygen plasma treatment showed greater effect on the SBS than the argon plasma treatment due to the double effect of oxidation and etching on the surface of acrylic teeth.
- Thermocycling showed an increase in bonding strength following plasma treatment.

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