The effect of plasma on transverse strength, surface roughness and Candida adherence of two types of acrylic denture base materials (Heat cure and light cure)

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ABSTRACT
Background: Dental polymers have a great use in dental applications such as denture, temporary crowns...etc; this is due to their superior physical and chemical characteristics. At the same time some of these properties impose a limitation on applications in several new and high technology areas. Plasma treatment is one of the most widely used surface treatment techniques in which the composition and structure of a few molecular layers at or near the surface of the polymer are modified. The aims of this study were to evaluate the effect of plasma treatment by argon gas on transverse strength; surface roughness and Candida adherence to heat cure and light cure acrylic denture base materials. Also compare the effect of plasma treatment on heat and light cure denture base materials.

Materials and methods: A total number of 180 specimens were prepared in this study; they were divided into two main groups according to the type of the material used (heat cure acrylic resin and light cure acrylic resin). Each main group was subdivided into three subdivisions according to the type of the test used (transverse strength, surface roughness and Candida adherence), for each test 30 samples were divided into three groups according to the time of plasma treatment that were applied (control, 5 and 10 minutes). Plasma treatment process was performed for all the studied groups in two different periods (5 and 10 minutes) except for control group no plasma treatment were performed.

Results: Plasma treatment of heat cured acrylic specimens revealed a decrease in the transverse strength of the studied groups for 5 and 10 minutes. Similar results were obtained for light cure denture base material after treatment with argon gas plasma for the same periods of time used for heat cure. Plasma treatment of heat cure and light cure acrylic specimens showed decrease in surface roughness and Candida adherence for (5min and 10min). The correlation between surface roughness and Candida adherence in the present study showed a weak correlation for all tested groups for both types of materials except for 5 minutes plasma treated heat cure acrylic specimens which were moderate. Statistically, there was no significant difference between surface roughness and Candida adherence for all groups of both types of materials except for 5min group of heat cure acrylic specimens.

Conclusion: Within the limitation of this study it can be concluded that argon plasma treatment to the surface of heat and light cure denture base materials can cause a decrease in transverse strength, surface roughness and Candida adherence for 5 and 10min treatment times.

Key words: Plasma, argon gas, candida albicans, heat and light cure acrylic. (J Bagh Coll Dentistry 2012; 24(Sp. Issue 2):10-17).

INTRODUCTION
Dental polymer introduced in 1937 and since that time it has a great use in dental applications such as denture, temporary crowns...etc; this is due to their superior physical and chemical characteristics such as high strength, and chemical inert nature. They are also relatively inexpensive and easy to process. At the same time some of these properties impose a limitation on applications. Thus it is required that their surface properties be modified to suit a particular application without affecting their bulk properties (1).

Plasma treatment is one of the most widely used surface treatment techniques. Plasma can be defined as a mixture of charged and neutral species, such as electrons, positive ions, negative ions, radicals, neutral atoms and molecules. During plasma treatment, the composition and structure of a few molecular layers at or near the surface (approximately 10nm) is modified due to the action of the energetic particles (2).

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Plasma used to alter surface properties of polymers such as wettability and adhesion to metals or to other types of polymers, without changing their bulk properties (3).

A wide variety of parameters can greatly affect the physical characteristics of plasma and subsequently affect the surface chemistry obtained by plasma modification. Processing parameters, such as gas types, treatment power, treatment time and operating pressure, can be varied by the user; however system parameters, such as electrode location, reactor design, gas inlets and vacuum are set by the design of the plasma equipment (4).

The present study designed to evaluate the effect of glow discharge plasma by argon gas on some properties of heat cure and light cure acrylic denture base materials.

Aims of this study are to:
1. Evaluate the effect of plasma treatment (argon) on heat cure and light cure acrylic denture base materials related to the following properties:
   A. Transverse strength.
   B. Surface roughness.
C. Adherence of Candida albicans to the surface of two types of acrylic denture base materials.

2. Evaluate the effect of exposure time to plasma argon gas for the same properties and materials mentioned above.

3. Compare the differences between heat and light cure acrylic denture base materials (in regarding to the same properties mentioned above) after plasma treatment with argon gas.

MATERIALS AND METHODS

A total No. of 180 specimens were prepared in this study, they were divided into two main groups according to the type of the material used (heat cure acrylic resin and light cure acrylic resin). Each main group was subdivided into three subdivisions according to the type of the test used (transverse strength, surface roughness and Candida adherence), for each test 30 samples were divided into three groups according to the time of plasma treatment that were applied (control, 5min and 10min). For transverse strength and surface roughness tests the metal patterns were constructed with the dimensions (65×10×2.5mm) length, width and depth respectively, while the dimensions for the circular metal pattern used for the adherence of Candida albicans test were (50mm diameter × 2.4mm depth). All those done according to ADA specification No.12 (5).

After the specimens being conditioned in distilled water for 48 hours, all the specimens were cleaned for five minutes using ultrasonic cleaning device in Methanol. Plasma treatment done using a device called Dc-gl ow discharge plasma which is a homemade manufactured system based on the following principle components: (1) the plasma chamber (a cylindrical stainless steel vacuumed chamber with (50×50 cm) length and diameter respectively (2) Vacuum pumps system (rotary and turbo pumps), (3) High voltage De- power supply (4 kV), (4) gas source. (5) Multimeters for discharging voltage and current measurements (6) penning and pirani heads and readers.

Plasma treatment process were performed for all studied groups in two different periods (5 min and 10 min) except for control group no plasma treatment were performed. After plasma treatment the specimens were tested for transverse strength using instron transverse testing machine (model 1195 with digital display unit and chart drive) and for surface roughness using profilometer device (surface roughness tester, Tylor Hobson).

RESULTS

The effect of plasma treatment (argon gas) on transverse strength of heat cure and light cure acrylic specimens.

The mean distribution, standard deviation, minimum and maximum values of the transverse strength of two tested materials (heat-cure and light cure) observed in table 1. In general the results of the transverse strength test revealed that the highest mean value (60.48 N/mm²) was for L.C.A. control group specimens, also the control group of H.C.A. specimens had the highest mean value (24.53N/mm²), in this table two way (ANOVA) test revealed a highly significant difference (P>0.05) between all groups of the same material while one way (ANOVA) showed a highly significant difference (P<0.01) between the two tested groups of H.C.A. and L.C.A. specimens.

<table>
<thead>
<tr>
<th>Studied groups</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>Two- way ANOVA test P value between groups of same material</th>
<th>One-way ANOVA test P value of all groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCA Control</td>
<td>10</td>
<td>24.53</td>
<td>4.15</td>
<td>21.1</td>
<td>30.7</td>
<td>0.0001*</td>
<td>0.0001*</td>
</tr>
<tr>
<td>5min P.T.</td>
<td>10</td>
<td>14.22</td>
<td>4.96</td>
<td>9.4</td>
<td>19.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10min P.T.</td>
<td>10</td>
<td>13.64</td>
<td>1.47</td>
<td>12.2</td>
<td>15.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCA Control</td>
<td>10</td>
<td>60.48</td>
<td>0.02</td>
<td>60.5</td>
<td>60.5</td>
<td>0.0001*</td>
<td>0.0001*</td>
</tr>
<tr>
<td>5min P.T.</td>
<td>10</td>
<td>42.48</td>
<td>2.56</td>
<td>40.3</td>
<td>46.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10min P.T.</td>
<td>10</td>
<td>34.27</td>
<td>1.07</td>
<td>33.1</td>
<td>35.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The effect of plasma treatment (argon gas) on surface roughness of heat cure and light cure acrylic specimens.

The mean distribution, standard deviation, minimum and maximum values of the surface roughness for the experimental and control groups of two tested materials (heat-cure and light cure) were shown in table 2. In general the results of the surface roughness test for H.C.A. specimens showed that control group specimens had the

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highest mean values (0.908 μm) while the samples exposed to argon gas for 10 min had the lowest mean values of surface roughness (0.350 μm), on the other hand for light cure specimens, control group had the highest mean values (5.845 μm) compared to 10min light cure group specimens which had the lowest mean values (4.636 μm).

Also from this table two way (ANOVA) revealed a highly significant difference (P>0.05) between all groups of the same material, and one way (ANOVA) showed a highly significant difference between two test groups (P<0.01) H.C.A. and L.C.A. specimens.

The effect of plasma treatment (argon gas) on Candida adherence of heat cure and light cure acrylic specimens.

The mean distribution, standard deviation, minimum and maximum values of the Candida adherence in experimental and control groups of two tested materials (heat-cure and light cure) were shown in table 3. Statistical analysis revealed that plasma treatment to H.C.A. and L.C.A. specimens have remarkable effect on the adhesion of Candida albicans to the surface of the samples. The highest mean values (0.259) was found for control samples while for H.C.A. specimens exposed for 10min to plasma argon gas had the lowest mean values of candida albicans adherence (0.124), on the other hand for light cure specimens, control group had the highest mean values (1.095). Also from this table two way (ANOVA) revealed a highly significant difference (P<0.01) between all groups of the same material, and one way (ANOVA) showed a highly significant difference between the test groups (P<0.01) for the H.C.A. and L.C.A. specimens.

Microscopical examination

The results of Candida adherence to acrylic surfaces (heat and light cure acrylic) were obtained from examining the sample surfaces through optical light microscope and enumerating the numbers of Candida that adhere to the surface of the acrylic samples.

The number of Candida albicans cells on the surfaces of heat cure acrylic control specimens was higher than that on the surfaces of plasma treated specimens (P<0.005). Also the number of Candida albicans cells significantly decrease with increasing the time of plasma treatment from 5min to 10 min as shown in the microscopical figures 1(A,B,C).

Also the number of Candida albicans cells on the surfaces of light cure acrylic control specimens was higher than that on the surfaces of plasma treated specimens (P<0.005). Also the number of Candida albicans cells significantly decrease with increasing the time of plasma treatment from 5min to 10 min as shown in the microscopical figures 2 (A,B,C).
While more *Candida albicans* cells were counted on the surface of light cure acrylic control specimens than that on the surfaces of heat cure acrylic control specimens (P<0.005).

![Figure 1: Optical microscopical picture for heat cure acrylic specimens ((A) control, (B) 5 min, (C) 10 min)](image)

**Figure 1: Optical microscopical picture for heat cure acrylic specimens ((A) control, (B) 5 min, (C) 10 min)**

![Figure 2: Optical microscopical picture for light cure acrylic specimens ((A) control, (B) 5 min, (C) 10 min)](image)

**Figure 2: Optical microscopical picture for light cure acrylic specimens ((A) control, (B) 5 min, (C) 10 min)**

Relation between surface roughness and *Candida* adherence

The result of this study showed that there was a correlation between surface roughness and *Candida* adherence in all studied groups, this correlation was either weak or moderate depending on the effect of surface roughness of the specimens on *Candida* adherence. Also this correlation was either direct or inverse depending on the amount of *Candida* adherence to the surfaces of the specimens. **Table 4** shows the correlation between surface roughness and *Candida* adherence in which there was a weak correlation between surface roughness and amount of *Candida* adherence for all tested groups for both types of materials except for 5 min plasma treated heat cure acrylic specimens which was moderate. Statistically there was no significant difference between surface roughness and *Candida* adhesion for all groups of both types of materials except for 5 min group of heat cure acrylic specimens.

**Table 4: Correlation between surface roughness and *Candida* adherence**

<table>
<thead>
<tr>
<th></th>
<th>surface roughness</th>
<th>Candida adherence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat cure acrylic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>R -0.336</td>
<td>P 0.342 (NS)</td>
</tr>
<tr>
<td></td>
<td>P 0.079</td>
<td>P 0.828 (NS)</td>
</tr>
<tr>
<td>5 minutes</td>
<td>R -0.673*</td>
<td>P 0.033 (S)</td>
</tr>
<tr>
<td>10 minutes</td>
<td>R 0.044</td>
<td>P 0.905 (NS)</td>
</tr>
<tr>
<td>Light cure acrylic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>R -0.079</td>
<td>P 0.831 (NS)</td>
</tr>
<tr>
<td>5 minutes</td>
<td>R -0.057</td>
<td>P 0.876 (NS)</td>
</tr>
<tr>
<td>10 minutes</td>
<td>R -0.078</td>
<td>P 0.831 (NS)</td>
</tr>
</tbody>
</table>

**DISCUSSION**

The effect of glow-discharge plasma on the transverse (flexural) strength of two types of denture base materials.

Transverse strength or modulus of rupture is obtained when a load is applied in the middle of a beam supported at each end. Transverse strength measurements are used to greater extent than
either tensile or compressive strength; because, this test more closely representing the type of loading applied to a denture in the mouth since it reflects the loading arrangement in clinical practice (6).

The results of transverse strength test in this study showed that heat cured acrylic control specimens had lower transverse strength values than light cure acrylic control specimens (highly significant difference) and this result was in agreement with (7,8) who attributed their results to the difference in their structural formula (chemical composition), since the light cure acrylic consist of micro fine amorphous silica filler particles, the filler content is about 15%, the presence of fillers are thought to increase mechanical properties of the material such as transverse strength. While the results of (9) showed that the transverse strength of light cure acrylic resin is lower than that of heat cure acrylic resin, the reason for this result might be due to the presence of the large number of porosities in this material which could not be kept under pressure during the polymerization process so common defects and internal voids often result. Several studies have been proposed that internal porosities concentrated stresses in the matrix and contributed to the formation of micro cracks under loading (10,11).

The results of the present study showed a decrease in the transverse strength value for both types of materials (H.C.A and L.C.A.) after plasma treatment i.e. there are significant differences between control and plasma treated specimens for 5 min. and 10 min., this decrease of the transverse strength of both materials since Ar gas might has a high etch rate and according to the study of Zhang (12) which showed that during the etching process by Ar gas, the plasma will generate volatile etch products at room temperature from the chemical reactions between the elements of the material etched and the reactive species generated by the plasma. Eventually the atoms of the shot element embed themselves at or just below the surface of the target, thus modifying the physical properties of the target.

The results of transverse strength test for heat cure acrylic specimens after 5 and 10 min treatment time to plasma appeared a non significant difference between 5 and 10 min groups of specimens, this might be due to that; at short exposure times Ar plasma seems to have little effect on transverse strength of heat cure acrylic specimens. While the results of transverse strength test for light cure acrylic specimens showed statistical significant differences between 5 and 10 min treatment times.

There were high significant differences between the specimens of two types of materials after plasma treatment; this is related to the main difference between the control groups of the two materials (heat cure and light cure).

The effect of glow-discharge plasma on the surface roughness of two types of denture base materials.

Achieving a smooth surface with extremely fine or no surface scratches has always been a prime objective for resin restoration. This is because of biological consequence of plaque accumulation on rough surfaces (13).

The digital profilometer is a suitable device for studying the surface roughness of restorative materials, it gives quantitative measurement in micron that can be evaluated and compared statistically.

The results revealed that there were highly significant differences between control specimens of heat cure acrylic and their contrast of light cure acrylic material, in which light cure specimens had higher values of surface roughness. This might be due to the chemical differences between the two materials since the light cure material chemically are more common with composite materials than with the denture base resins. From another point of view, when the fractured section of cured (VLC) material examined under scanning electron microscopy, spherical particles can be seen protruding in some area and in others spherical pits, which make it had rough surface as it compared with heat cure acrylic resin (14).

Regarding the results of the effects of plasma on the surface roughness of heat and light cure acrylic specimens, it appeared that there was decrease in the surface roughness of both materials after treatment with plasma, this might be due to, during the plasma treatment process; glow discharge plasma is created by evacuating a reaction chamber and then refilling it with a low-pressure gas. The gas is then energized; the energetic species in gas plasma include ions, electrons, radicals, metastables, and photons (15). Surfaces in contact with the gas plasma are bombarded by these energetic species and their energy is transferred from the plasma to the solid leading to remove the peak and valley on the surface of the specimens result in slight removing of the surface particles which might lead to a significant decrease in surface roughness. The results of this study were in agreement with previous studies who showed that these species (ions, electrons, radicals, metastables, and photon) are involved in the process of plasma treatment;
they interact with the exposed surfaces causing some chemical changes at the surface of the material. If the applied energies are higher than the characteristic bonding energies of the polymers, some parts of the surface can undergo scission reactions and form new bonding configurations(16,17).

Statistically the results showed a significant difference between 5 and 10 min plasma treated time for both types of materials (heat cure and light cure) denture base materials, this might be attributed to that, argon plasma treatment decreases surface roughness at short treatment times and this reduction in surface roughness increases continuously after longer time of treatment(18).

There were high significant differences between the same groups of different materials (heat cure and light cure) after plasma treatment process. This might be due to the main differences between the control groups of the two materials.

**The effect of glow-discharge plasma on Candida adherence.**

The initial attachment of Candida albicans on the mucosal surface of the denture is essential in the colonization and development of denture stomatitis (19). The development of methods that reduce the adherence of Candida to these surfaces could be a significant step toward treatment and prevention of denture stomatitis. Glow-discharge plasma, a type of cold plasma, has been often used as a method of surface modification; however, in dentistry it has received little attention. In this technique, gas temperature can remain as low as room temperature—preserving the integrity of polymer-based materials (20). This is of particular importance for denture base acrylic resins, in which increase temperature might cause dimensional changes and hence the fitness of the denture bases to the supporting tissues will be affected (21). Glow-discharge technique may affect the surfaces of acrylic resins in many ways, including cleaning of organic or inorganic debris, generating reactive and functional groups on the surface layers without affecting their bulk properties and making the surfaces more adherent to specific cells and proteins depending on the plasma atmosphere.

The results of this study revealed that there were significant differences between control specimens of heat cure acrylic and their contrast of light cure acrylic material, in which light cure specimens had a higher value of Candida adherence to the surface of the specimens, which might be due to their high value of surface roughness.

Adherence of Candida albicans to the surface of heat cure denture base materials decrease after plasma treatment, the same results obtained for light cure acrylic specimens in which there was a marked decrease in Candida adherence to the surface of light cure acrylic denture base material. Statistically high significant differences were found between different groups (control, 5 min, and 10 min) for both types of denture base materials.

The results of this study revealed that Ar plasma treatment significantly reduced the yeast adhesion. These results were in agreement with Zamperini (22) who found that Ar plasma treatment showed promising potential for reducing the adherence of Candida albicans to denture base resins (heat cure), this might be due to the movement of polar groups from the surface to the polymer bulk. It has been reported that surface-charged resins may alter the ionic interaction between the denture base and Candida spp. (23,24). Negatively charged resin surfaces showed significantly lower levels of Candida than the untreated ones (25).

While the results of this study were in disagreement with the data reported by Yildirim (26) who have found higher counts of Candida albicans in plasma treated surfaces than in the unmodified control group. One possible reason for this disagreement could be due to the difference in the methodology in which oxygen gas were used for plasma surface treatment at 50 or 100 W, for 15 min.

There were significant differences between the same groups of different materials (heat cure and light cure) after plasma treatment process, this might be due to the main differences between the control groups of the two materials.

**The correlation between surface roughness and Candida adherence.**

Roughness has been considered as a factor that affects the adhesion of Candida albicans to acrylic denture base materials (27). The results of the present study showed statistically there was no significant difference between surface roughness and Candida adherence however, there were various studies have found that an increase in surface roughness facilitated the yeast retention (27-30).

In this study the results appeared that there were a weak correlation between surface roughness and Candida adhesion in all groups but no significant influence of roughness on adherence of Candida albicans was verified, and these results were in accordance with other studies (31-34). This can be explained that specimens of acrylic denture base materials with more surface roughness
such as voids and micro cracks on surface were (Candida retention and inducing adhesion of microorganisms) irregularities providing increased microorganism roughness may serve as a reservoir, with surface irregularities providing increased microorganism retention and inducing adhesion of microorganism (Candida and bacteria). The superficial defect such as voids and micro cracks on surface were possible sites for Candida adhesion [8].

REFERENCES