Effect of plasma treatment on some surface properties of acrylic resin polymer

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ABSTRACT

Background: Polymer surfaces usually present problems in bonding and finishing due to their low hydrophilicity. The aim of this study is to investigate the effect of plasma treatment with the use of two types of gases (oxygen and argon) on surface roughness, and chemical surface properties of acrylic resin denture base polymer material.

Materials and Methods: Three heat cured acrylic resin specimens of (2*8*30 mm) dimensions were prepared for each test carried out in this study. Two tests were conducted, surface roughness test and chemical surface analysis test.

Results: Application of plasma treatment increased surface roughness for both oxygen and argon plasma treated acrylic resin specimen groups compared with control untreated group, with a highly significant difference ($P < 0.01$) among groups. FTIR chemical analysis for oxygen plasma treated acrylic resin specimen group showed a spectrum with a broad peak, which represents the hydroxyl group (-OH). This was an important chemical change that increased the hydrophilicity as compared with FTIR spectrums of control and argon plasma treated acrylic resin groups which exhibited relatively the same peaks with mild chemical changes.

Conclusion: Application of oxygen and argon plasma treatment represents an effective surface treatment method for increasing the surface roughness of acrylic resin denture base polymer material. Oxygen plasma treatment can activate the treated surface towards further chemical reactions, and increase the hydrophilicity of the acrylic resin denture base polymer material.

Key words: Acrylic resin polymer, plasma treatment, surface roughness, FTIR analysis. **(Received:18/12/2019; Accepted:20/1/2020)**

INTRODUCTION

Since the 1940s, Acrylic resins are the most polymer materials that are used to fabricate denture base in dentistry. Poly (methyl methacrylate) resin is the most common resin that is used in dentistry.[(1)] Polymer surfaces usually present problems in bonding and finishing due to their low hydrophilicity.[(2)] Schemes to modify PMMA surfaces fall in two basic categories: photophysical and photochemical methods, such as laser alteration or UV irradiation in air, and "wet" chemical modifications. Other chemical modification schemes involve plasma treatment of PMMA to activate the surface toward further reactions.[(3-5)] Many different types of gas-plasmas have been cited in the literature including air, oxygen, UV-ozone, H_2O, ammonia, and argon for modification of polymer surfaces. [(6-10)] Several studies were conducted regarding the use of plasma treatment for acrylic denture base materials.[(11-13)] The present study aims to investigate the effect of plasma treatment on some surface characteristics of acrylic resin polymer material.

MATERIALS AND METHODS

Three heat cured acrylic resin (PMMA) specimens were prepared for each test done in this study. The specimen dimensions were 2×8×30 mm. These specimens were prepared from SR Triplex hot, heat-cured acrylic denture base material (Ivoclar Vivadent, Germany). For each test done in this study, the specimens were grouped as control/plasma untreated, oxygen plasma treated and argon plasma treated acrylic resin specimens groups. In this study the application of the two types of gases (oxygen and argon gases) were done with the use of the plasma apparatus with parameters: 800 V, 75 mA, power 60 W, with 2 minutes exposure time.

Surface Roughness Test

Three specimens of heat-cured acrylic resin denture base material (Ivoclar Vivadent) were prepared according to the manufacturer's instructions. Immediately after preparation, the surface roughness for the control specimen group was measured. The other two specimens were measured after oxygen and argon plasma treatment. The surface roughness for each specimen was measured in 5 areas by the use of the surface roughness tester.

Chemical Surface Analysis (FTIR Analysis)

With a view to understanding the surface-chemical changes of acrylic denture base material (PMMA) after the application of oxygen and argon plasma treatment, the chemical changes which appeared on the surface of the untreated and plasma treated acrylic (PMMA) specimens were investigated using FTIR analyzer (Fourier Transform Infrared Spectrophotometer, SHIMADZU, FTIR-8400S).

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FTIR spectra of each control, oxygen plasma treated and argon plasma treated specimens were obtained by placing the disk to be analyzed on a specified position inside the FTIR analyzer.

RESULTS

Surface roughness test

Results about the effect of plasma treatment on surface roughness of acrylic resin polymer specimens for the three groups (control, oxygen and argon plasma treated specimens) revealed an increase in the mean values of average surface roughness (Ra) after the application of plasma treatment (oxygen and argon plasma treatments) compared with the control group (without plasma treatment) for the acrylic polymer specimens, as shown in figure 1 and tables 1and 2.

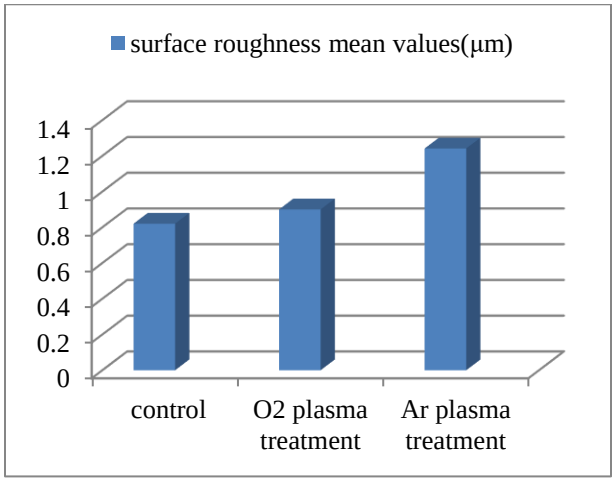

Figure 1: A Polygon illustrating the mean values of surface roughness (µm) for the control, oxygen and argon plasma treated acrylic resin polymer specimens.

Table 1: ANOVA test among acrylic polymer groups with different types of surface treatment.

Source	D.F	SS	MS	F	p-value
Factor	2	0.6019	0.3009	9.82	**0.002**
Error	15	0.4599	0.0307		
Total	17	1.0618			

P< 0.05 significant
P> 0.05 non-significant
P< 0.01 highly significant

Table 2: LSD between groups of acrylic polymer with different types of surface treatment.

Type of surface treatment	p-value	Sig.
Control vs. Oxygen plasma treatment	0.216	**NS**
Control vs. Argon plasma treatment	0.011	**S**
Oxygen plasma treatment vs. Argon plasma treatment	0.027	**S**

P< 0.05 significant
P> 0.05 non-significant

Chemical surface analysis (FTIR analysis)

Results of FTIR analysis for 3 groups (control, oxygen and argon plasma treated acrylic resin polymer specimens) are shown in figures 2, 3 and 4, respectively.

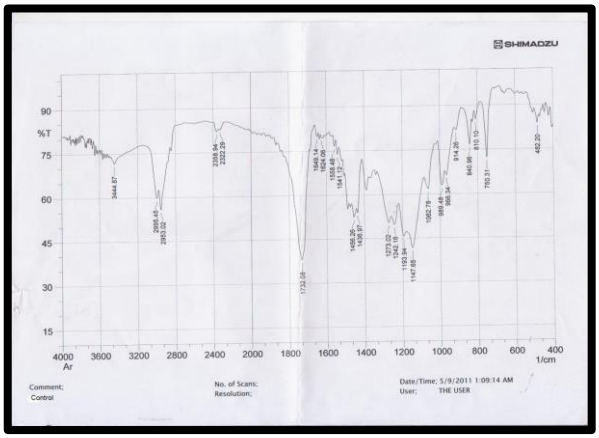

Figure 2: FTIR analysis of the control acrylic polymer specimen.

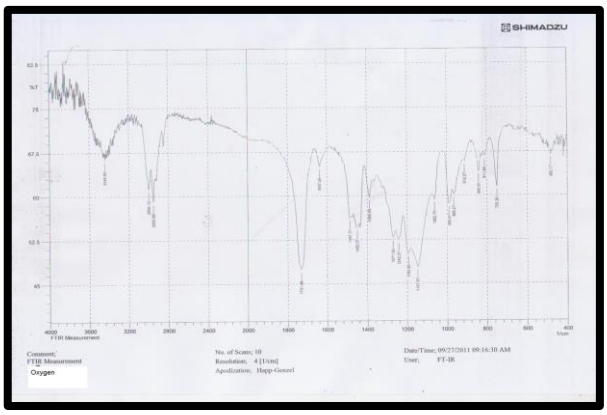

Figure 3: FTIR analysis of oxygen plasma treated acrylic polymer specimen.

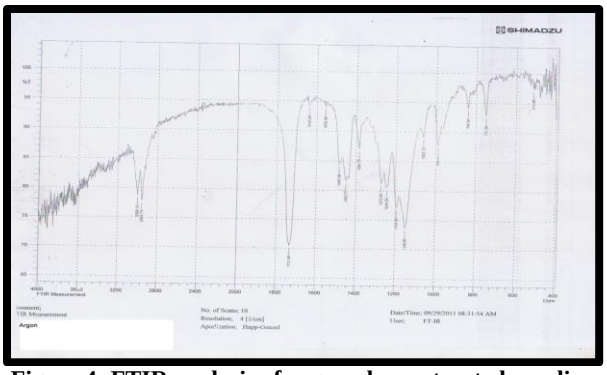

Figure 4: FTIR analysis of argon plasma treated acrylic polymer specimen.

DISCUSSION

Effect of application of the oxygen and argon plasma treatment on surface roughness.

The results obtained in this study regarding the effect of application of the oxygen and argon plasma treatment on surface roughness of acrylic polymer specimens for the three groups (control, oxygen and argon plasma treated specimens) revealed that there was an increase in the mean values of average surface roughness (Ra) after the oxygen and argon plasma treatment as compared with the control group. Treatments with oxygen and argon gases (plasma modification processes) generate new chemical species on the surface of PMMA due to the chemical reactions and physical sputtering (such as with Ar plasma) with active gas-phase species. Argon and oxygen plasmas have also been shown to participate in surface sputtering in addition to modification, resulting in the physical removal of material from the surface.[14] Oxygen plasma treatment usually creates microroughness on the treated surface due to an etching effect.[15]

Effect of application of oxygen and argon plasma treatment on chemical surface analysis (FTIR analysis)

In the present study, FTIR spectrum for oxygen plasma treated acrylic (PMMA) specimen exhibited a surface rich in oxygen-containing groups (C-O-C, -OH, C=O), in addition to carbon-containing groups (CH aliphatic group) and (C=C). The broad peak represents the hydroxyl group (-OH) which appeared in FTIR spectrum for the oxygen plasma treated group was an important chemical change which increased the hydrophilicity for the oxygen plasma treated acrylic (PMMA) specimen. The hydroxyl functional group (-OH) is an important species because of its high chemical reactivity with respect to surface esters and it also increases hydrophilicity.[16] Also the other functional groups such as oxygen-containing groups and carbon-containing groups have induced and activated the oxygen plasma treated surface toward further chemical reactions, so the surface might be oxidized (generating new chemical groups), and/or degraded as a result of an etching effect (chemical removal of surface material). FTIR spectrums for control and argon plasma treated groups exhibited relatively the same peaks with no appearance of the hydroxyl (-OH) group in FTIR spectrum for argon plasma treated group, which indicated that treatment with argon gas in the present study might induce little chemical changes on the surface of the argon plasma treated acrylic (PMMA) specimen.

CONCLUSION

Application of oxygen and argon plasma surface treatment is an effective treatment method for enhancing surface roughness of acrylic resin denture base polymer material. Oxygen plasma treatment can activate the treated surface towards further chemical reactions, and increase the hydrophilicity of the acrylic resin denture base polymer material.

Conflict of interest: None.

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الخلاصة

الخلفية: سطوح البوليمر عادة تظهر مشاكل في الربط والانهاءات بسبب انخفاض قابلية التبلل.كان الهدف من هذه الدراسةهو لتقييم تأثير المعالجة بالبلازما مع استخدام نوعين من الغازات (الاوكسجين والآركون)على خشونة السطح والتغييرات السطحية الكيميائية لبوليمر راتنج الاكريل.

المادة والطريقة: ثلاثة عينات من راتنج الاكريل المصلب حراريا وبابعاد(8*2*30) ملم كعرض, ارتفاع, وطول بالتتابع قد حضرت لكل فحص قد جرى في تلك الدراسة وقسمت ال مجموعة بدون معالجة بالبلازما ,مجموعة معالجة ببلازما الاوكسجين , ومجموعة معالجة ببلازما الآركون . اثنان فحوص جرت في الدرلسة, فحص خشونة السطح وفحص تحليل السطح الكيميائي.

النتائج: تطبيق المعالجة بالبلازما زادت خشونة السطح لكلا عينات راتنج الاكريل لمجموعتي المعالجة ببلازما الاوكسجين والعالجة ببلازما الآركون بالمقارنة مع مجموعة الغير معالجة بالبلازما مع فرق معنوي عالي بين المجاميع. التحليل الكيميائي (اف.تي.أي .أر) لمجموعة عينة راتنج الاكريل المعالجة ببلازما الاوكسجين اظهرت طيف مع قمة عريضة والتي تمثل مجموعة الهيدروكسيل والتي اعتبرت تغير كيميائي مهم ادى الى زيادة قابلية التبلل عند المقارنة مع اطياف ال (آف.تي.آي.آر) لمجاميع عينات راتنج الاكريل البدون معالجة بالبلازما والمعالجة ببلازما الآركون والتي اظهرت نسبيا نفس القمم مع تغيرات كيميائية قليلة .

الاستنتاجات: تطبيق المعالجة ببلازما الاوكسجين والآركون كانت طريقة معالجة سطحية فعالة لزيادة خشونة السطح لمادة بوليمر قاعدة طقم الأسنان الراتنجي الأكريلي . تحليل (أف . تي . آي . آر) الكيميائي اوجد ان المعالجة ببلازما الأوكسجين قد فعلت السطح المعالج باتجاه تفاعلات كيميائية اضافية وزادت قابلية التبلل لمادة بوليمر قاعدة طقم الأسنان الراتنجي الأكريلي**.**