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Non-polar micro-coating on acrylic denture material for reducing the incidence of dental biofilm formation

Dr. Lateef Essa Aljorani.*
Dr. Arshad F. Jassem Al-Kaabi.**

Abstract

Aim: Dental plaque formation is a major health risk associated with prolonged worn acrylic dentures. The dental biofilm usually develops when improper cleaning and sterilizing of dentures is achieved. The aim of this study was to improve the acrylic material surface properties for minimizing the incidence of dental plaque formation on acrylic dentures by lowering the surface energy.

Method: The acrylic (polymethylmethacryate) surface modification was achieved by applying a non-polar micro-coating on acrylic samples which was the dental baseplate wax. Two experimental groups used in this study, the control and the coated groups with 10 samples each. The surface analysis was conducted using the contact angle's technique. All samples soaked in salivary solution for 5 days. The methylene blue dye material used as an indicative for the dental plaque formation.

Results and conclusion: The surface analysis showed a significant decrease in the surface hydrophilicity of the coated group by increasing the water contact angle degree values (P-value<0.05). The microscopic analysis by visual inspection showed a reduced formation of the dental biofilm on the acrylic samples. Within the limitations of this study, the suggested coating material can possibly reduce the incidence of the dental biofilm formation on acrylic dentures.

Key words: Biofilm on dentures; denture coating; denture surface treatment

Introduction

Good dental health enables people to eat properly and get enough nutrition necessary for living. In order to maintain oral health, several means are available such as brushing, flossing, and using mouth wash. When losing natural teeth, wearing dentures assists the functionality of the mouth for mastication. However, it might increase the risk of losing oral hygiene with insufficient care by the patients [1]. One of the major threats to oral hygiene is the development of dental biofilm on teeth surfaces. Biofilm consists from a complex bacterial gathering and accumulations into a form of a 3 dimensional structure adhered to the solid surface of the teeth and surrounded by an extra cellular matrix for protection from the outside environment [2,3]. The biofilm could by single-layered or multiple-layered and could consist from homogenous bacteria or heterogeneous types of organisms [4]. Achieving oral hygiene is challenging especially for those who wear dentures. it was reported that wearing prostheses could significantly

*Assistant Professor, College of Health & Medical Technology / Baghdad Middle Technical University.
**Assistant Lecturer, College of Health & Medical Technology / Baghdad/ Middle Technical University

increase the risk of dental plaque formation and the poor oral hygiene [5]. Dentures are considered as a reservoir for microorganisms [6]. Several denture cleaning and disinfecting methods were used that showed their effectiveness [7]. However, some of them showed a diverse effects in terms of dimensional stability, chemical reactions and acting as a source of biological contamination of the denture material [8, 9]. Adding antimicrobial agent to the acrylic resin material can reduce biofilm formation on the surface but it might significantly change the water sorption ability, solubility, and monomer elution of the denture material [10, 11]. The aim of this study was to evaluate a new approach for surface modification of acrylic resin (polymethylemethacrylate) in an attempt to reduce the incidence of dental biofilm formation. This was achieved by applying a micro-coating of dental wax to the acrylic surface to reduce the acrylic critical surface tension which by itself should minimize the incidence of dental biofilm formation.

Materials and methods

Sample preparation

Hot cure acrylic resin samples (polymethylmethacrylate) Superacryl Plus (Iran) were prepared for the experiment with dimensions 20 x 20 x 2 mm. There were 2 groups of samples in this experiment each consist of 10 specimens. The tested group was coated by a handpiece-rotating brush (40,000 rpm) with dental baseplate wax (Zhengzhou Shengxin Medical Instrument Co., Ltd./China) .

Contact angle measurements

Water Contact angle measurements were taken for all samples using a digital microscope (Digimicro / China) with 200X magnification power. A drop of distilled water was placed on the acrylic surface by a stainless steel needle and then the contact angle was measured electronically by ImageJ software. The average time from drop placement to measurement was 5 seconds.

Biofilm development and methylene blue staining

A custom made rotary instrument was prepared for the purpose of this study (Figure 1). It consisted from 2 rotating discs on both sides of the machine where the samples were attached. The 2 discs were connected to a motor by rubber bands. The rotation speed of the discs was11 round/minute. The lower part of the disc was immersed in a salivary solution consist of 20% saliva and 80% water. The rotation cycle lasted for 3 days. Methylene blue stain (Sigma Aldrich CAS7220-79-3 / USA) was used to confirm biofilm formation on the acrylic samples. The samples were washed with a stream of distilled water at a shear stress of about 1 Pascal. Then, a 1 microliter of methylene blue stain is smeared over the acrylic surface and after 10 minutes the samples were washed again with distilled water thoroughly for 5 seconds. The samples then were observed visually and microscopically.

Result

Contact angle data:

In this step, 10 samples from each group were used for obtaining the contact angle measurements data, Table (1). A water droplet was carefully placed on the sample surface with maximum diameter of less than 2 mm. As shown in Tables (2,3), the independent sample T test (IBM SPSS V20) clearly confirm that there is a statistically significant difference in a

values of the contact angle data between the two groups (P-value <0.05). This was associated with higher mean value for the coated group and a lower value for the standard deviation for the coated group as well.

Microscopic analysis:

The pictures (3 and 4) are images for the representative samples of the control group and the coated group respectively with 200X magnification.

Discussion

Biofilm formation is a major issue associated with watery environment. It starts when a thin layer of glycoprotein deposits on the material surface after dehydration. Then, the bacterial or whatever cells available in that environment stick to the glycoprotein film to form the primary film which eventually leads to the biofilm formation when the cells multiply and release the extracellular substance. The degree to which the biofilm is formed is quite dependent on the material surface energy that could lead to glycoprotein denaturation and thus increase the susceptibility of cellular adhesion .

It was found in some literature that increasing surface-free energy led to robust candida albicans biofilm formation on denture material [12]. It was also found that using different acrylic resin types with slight difference in surface-free energy did not influence biofilm formation [13]. According to (Moura et al, 2006) different acrylic resin polymerization methods had no effect on biofilm formation [14].

Contact angle technique is used to indicate the surface free energy of a material that can be estimated by graphically determining the Critical Surface Tension. The different measurements of contact angles occur as functions of surface tensions of a series of liquids. This technique demonstrates the relationship between the properties and chemistry of the material surface which involves the outer most 3-4 Angstroms of the surface. The Critical Surface Tension of a material, which is a measure of the surface's wettability, and it is calculated from the contact angles of a liquid set according to the Young's equation (Figure 2) as cited by Zisman [15].

In this study, there was an attempt to minimize the incidence of biofilm or dental plaque formation on acrylic dentures by modifying the material surface properties. This was done by applying a non-polar coating that was the baseplate dental was to the acrylic surface. The contact angle's measurements was an indicative procedure for surface modification. The results showed that the wax coating had significantly decreased the critical surface tension of the acrylic samples and thus, decreasing the surface energy.

The microscopic analysis was slightly ambiguous. All samples from both groups differ in the degree of staining by methylene blue. However, there was a pattern observable between the two groups. As shown in Pictures (3 and 4), the biofilm formation trend differs in distribution with more rounded areas of colonization in the coated group than the control group. This can be considered as a confirmation for the lower incidence of dental plaque formation on acrylic surface when coating it with a non-polar wax material.

Conclusion

Within the limitations of this study which might have a significant impact on the experimental outcome, the surface analysis showed a remarkable

decrease in the surface hydrophilicity of the acrylic material and this was associated with a significant minimize in the incidence of dental plaque formation on the acrylic material for dentures.

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Tables

Table (1): Contact angle measurements

Coated group	Control group
65.28	43.38
68.18	53.95
73.03	53.45
66.40	45.68
69.88	45.42
71.33	43.11
67.91	46.38
68.01	54.92
70.66	48.46
68.09	50.73

Table (2): Mean and standard deviation for the contact angle data

	Grouping	N	Mean	Std. Deviation	Std. Error Mean
Contact angle	Control	10	48.5480	4.44188	1.40465
	Coated	10	68.8770	2.34084	0.74024

Table (3): Independent sample T test results

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Contact angle	Equal variances assumed	6.536	.020	-12.804	18	.000	-20.32900	1.58776	-23.66476	-16.9932
	Equal variances not assumed			-12.804	13.64	.000	-20.32900	1.58776	-23.74283	-16.9157

Figures

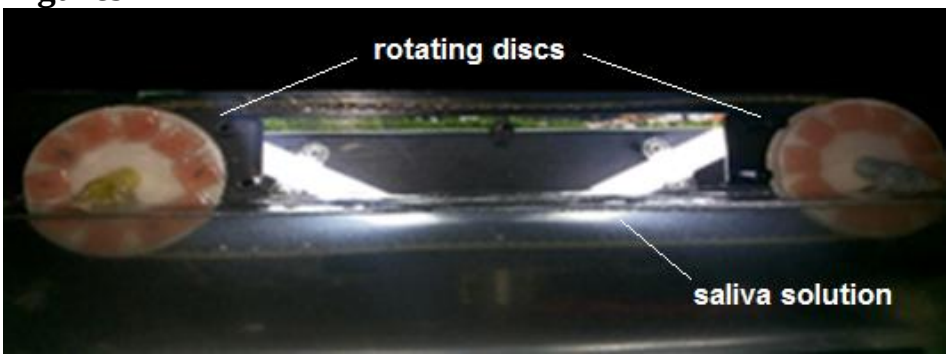


Figure (1): Rotary Instrument for dipping the samples in salivary solution

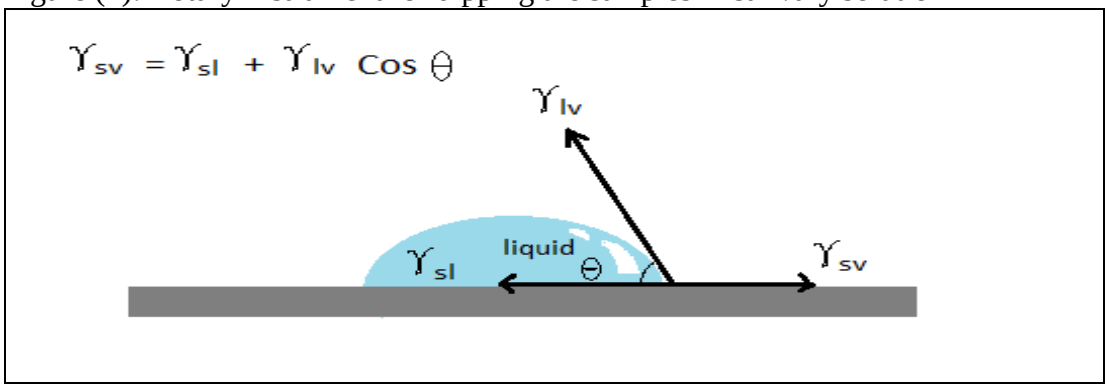
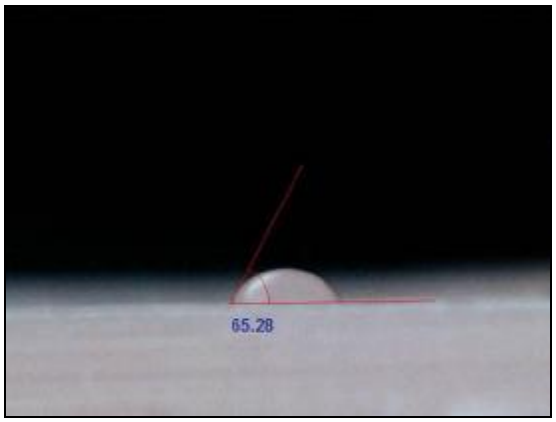


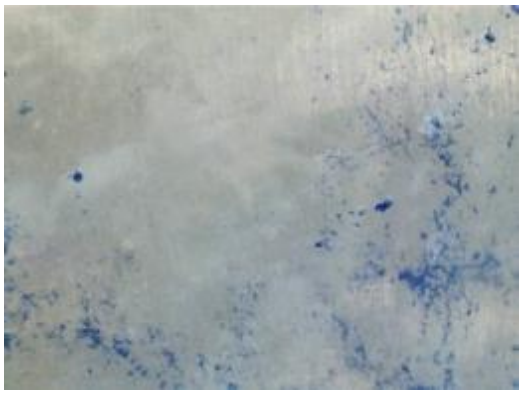
Figure (2): Young's equation for contact angle measurement

Pictures:

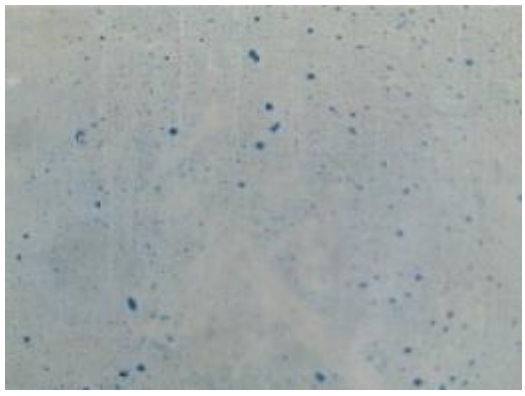
Picture (1): Digimicro microscope



Picture (2): Contact angle measurement



Picture (3): Control group sample



Picture (4): Coated group sample