Effect of Polyamide (Nylon 6) Micro-Particles Incorporation into RTV Maxillofacial Silicone Elastomer on Tear and Tensile Strength

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ABSTRACT

Background: The longevity of any prosthesis depends on the materials from which it was fabricated, that is why, defects in the material properties may reduce the service life of prosthesis and necessitate its replacement. The aim of this study was to evaluate the effect of adding different concentrations of Polyamide-6 (Nylon-6) on the tear and tensile strength of A-2186 RTV silicone elastomer.
Materials and Methods: 80 samples were fabricated by the addition of 0%, 1%, 3% and 5% by weight PA-6 micro-particles powder to A-2186 platinum RTV silicone elastomer. The study samples were divided into four (4) groups, each group containing 20 samples. One control group was prepared without PA-6 micro particles and three experimental groups were prepared with different percentage of PA-6 micro particles (1%, 3%, and 5%) by weight. Each group was further subdivided into 2 groups according to the conducted tests, i.e. tear and tensile strength tests (n=10). The data were analyzed with a descriptive statistical analysis, one-way ANOVA, post-hoc LSD test.
Results: The mean value of tear and tensile strength of 1% PA-6 reinforcement group increased significantly when compared to control group on the contrast to the same values of 3% and 5% PA-6 reinforcement groups which were decreased significantly.
Conclusion: the 1% PA-6 reinforcement improved tear as well as tensile strength among all other percentages (0%, 3% and 5%).

KEYWORDS: Polyamide, Room Temperature, Silicone Elastomer. **(J Bagh Coll Dentistry 2017; 29(4):7-12)**

INTRODUCTION

Patients with facial defects are preferred to be treated through surgical intervention whenever favorable circumstances are present. However; prosthetic restoration for patients suffering from facial deformities may also considered satisfactory; this type of treatment works as a psychological therapy allowing the individuals to integrate again into society after becoming embarrassed, constrained and diminished physically and psychologically. It helps people to reestablish their self-esteem and confidence [1,2]. In general, the goal of prosthodontic rehabilitation is not constrained by restoring function and esthetic; hence, different types of maxillofacial materials have become noticed [3,4]. Silicone elastomer may be considered as the material of choice when fabricating facial prostheses due to its biocompatibility, low chemical reactivity, ease of manipulation, and optical transparency [5]. However, its mechanical properties do not fulfill the ideal requirements, resulting in a reduction in the clinical longevity of the prosthesis. That is why; reinforcement of this material may become mandatory to overcome its deficiencies [6].

Gunay et al. in (2008)[7] reported improvement in the tear strength and other mechanical properties of A-2186 room temperature vulcanized (RTV) silicone elastomer after being incorporated with tulle (Nylon). Additionally, various researchers mentioned the use of different types of additives which incorporated within the silicone matrix and resulted in improvement in the mechanical and physical properties of the silicone base material [8,9,10].

The aim of the present study was to evaluate the effect of adding different weight percentage (1%, 3%, 5%) of Polyamide-6 (Nylon-6) on the tear and tensile strength, of A-2186 RTV silicone elastomer.

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MATERIALS AND METHODS

This study investigated the tear and tensile strength of A-2186 Platinum RTV silicone elastomer (Factor II Inc., Lakeside, AZ, USA) before and after the addition of polyamide-6 (Nylon-6) micro-particles powder (average particle size 15-20 micron) (Goodfellow, Cambridge Limited, England).

A specialized cutting of 4±0.05 mm and 2±0.05 mm thickness acrylic sheets (PT. Margacipta Wirasentosa, Indonesia) is performed by using a laser engraving cutting machine (JL-1612, Jinan Link Manufacture & Trading Co., Ltd., China) to prepare the mold parts. The depth of the mold cavity, 2±0.05 mm thickness sheets, corresponds to the thickness of the specimens to be fabricated for each conducted test while the 4±0.05 mm thickness sheets were used to make the bottom and cover parts [10]. A-2186 is a platinum RTV silicone elastomer consisting of 2 parts; part A representing the silicone base while part B representing the cross linker.

The PA-6 fillers were first weighed by electronic digital balance followed by the addition of accurate weight of silicone (part A) to prevent dispersion of the filler. The modified silicone was mixed by a vacuum mixer (Multivac 3, Degussa, Germany) for 10 minutes; the vacuum was turned off for the first three minutes to avoid suction of the filler and then turned on for the rest of the 7 minutes at 360 rpm speed and a vacuum value of -10 bar. The silicone cross linker (part B) was added to the silicone base (0% PA-6) or the modified silicone (part A and PA-6) and mixed again in the vacuum mixer for 5 minutes to get a homogenous and free bubble mixture [11].

The mold was brushed with separating medium and left to dry then the silicone mixture was poured and the mold was closed with the aid of screws and G-clamps [10]. According to manufacturer's instruction, the silicone should be set aside for 24 hours at 23± 2°C and a relative humidity of 50%±10 % for complete setting (Figure 1).

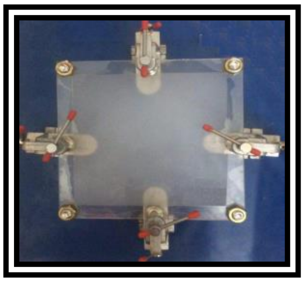

Figure 1: Silicone was poured inside the mold

After polymerization, the silicone sheet (15×15 cm) [12] was separated from the mold cavity and was cut (Figure 2) by suitable cutting dies with the help of a custom-made specimen cutting press. The press consists of hydraulic jack of (3) tons capacity (Lezaco, Syria) attached to metal plates; this type of cutting ensures smooth cut surfaces.

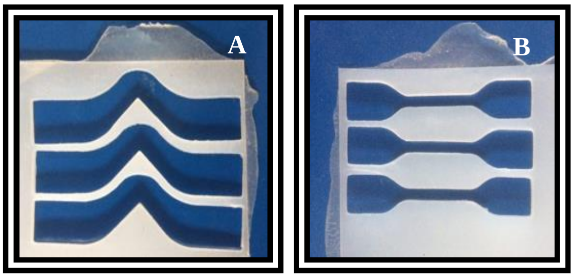

Figure (2): Specimen's preparation through cutting of the silicone sheet. A, tear specimens; B, tensile specimens

All specimens were visually inspected for surface irregularities, bubbles and internal defects [13] then, they were stored inside a vaccine storage box (polar bag, china) for, at least, 16 hours of favorable conditions before testing [2,14,15].

All test specimens were tested with a computerized universal testing machine (WDW-20, Laryee Technology Co. Ltd., China) at 500 mm/min cross-head speed [9]. According to ISO 37 [17], forty specimens of Type 2 dumb-bell shape were fabricated for tensile strength , 10 specimens were used as control group and the other 30 were silicone specimens after the addition of different concentrations of PA-6 fillers, (n=10). Specimens were mounted in a computerized universal testing machine 25±0.5 mm apart [9]. The Maximum load was calculated by the machine software then the tensile strength was calculated according to the following equation:

$$\text{Tensile strength}=F/A$$

Where:

F*:* The maximum force recorded at break (N).

A:The original cross-sectional area of the specimen (mm^2).

Forty specimens of Type C which is an un-nicked specimen with a 90° angle on one side and with tab end specimens, were fabricated according to ASTM D624[18] for tear strength test, 10 specimens were used as control group and the other 30 were silicone specimens after the addition of different concentrations of PA-6 fillers, (n=10). Specimens were mounted in a computerized universal testing machine with a 30±0.5 mm distance apart [19]. The maximum load was calculated by the machine software then the tear strength according to the following equation:

$$\text{Tear strength}=F/D$$

Where:

F: The maximum force required for specimen to break (KN).

D: The median thickness of each specimen (m).

Furthermore, SEM analysis was performed on 4 samples. One sample represents the silicone material before the addition of PA-6 fillers and the other 3 were after the addition of 1%, 3% and 5% of PA-6 fillers respectively.

RESULTS

3.1. Scanning Electron Microscope

SEM results of A-2186 platinum RTV silicone elastomer before and after the addition of 1%, 3% and 5% by weight PA-6 micro-particles powder are shown in (Figure 3).

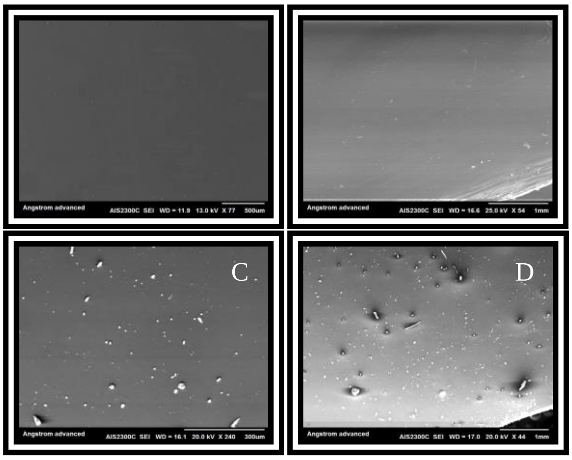

Figure (3): **SEM of A-2186 silicone elastomer. A, before the addition of PA-6 fillers; B, after the addition of 1% PA-6 fillers; C: after the addition of 3% PA-6 fillers and D: after the addition of 5% PA-6 fillers**

SEM images demonstrated that when the concentration was increased to 3%, the PA-6 micro particles began to agglomerated; this agglomeration was further increased when the fillers loading increased to 5% as well.

3.2. Tear and Tensile strength test.

Figure 4 represents the mean values of tear and tensile strength of A-2186 silicone elastomer before and after the addition of 1%, 3% and 5% PA-6 fillers. Highest mean value of tear and tensile strength were found in (1% by weight) PA-6 filler group while the lowest mean value of the both tests were found in (5% by weight) PA-6 filler group.

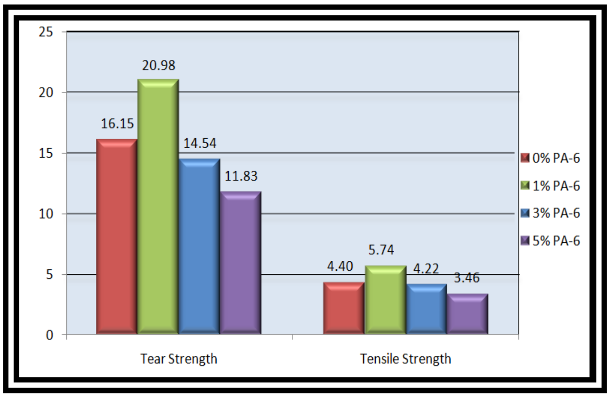

Figure (4): **Graphical representation of mean values by bar chart**

Descriptive statistics, One-way analysis of variance (ANOVA), Post-hoc LSD analysis, Pearson correlation, coefficient of determination and % of variation of the tear and tensile strength values are presented in tables 1- 4.

The results of tear strength test indicated highly significant difference ($p \leq 0.01$) between all tested groups (Table 1). The tear strength mean value of the group formed by the addition of 1% PA-6 micro particles fillers to the silicone elastomer was high significantly ($P \leq 0.01$) greater than that of all other study groups of (0%, 3% and 5%) PA-6 micro fillers (Table 2).

The results of tensile strength test indicated highly significant difference ($p \leq 0.01$) between all tested groups except for the group formed by the addition of 3% PA-6 micro fillers when compared to the control group, where a non-significant difference ($p \geq 0.05$) was reported (Table 3,4). The tensile strength mean value of the group formed by the addition of 1% PA-6 micro particles fillers to the silicone elastomer was high significantly ($p \leq 0.01$) greater than that of all other study groups of (0%, 3% and 5%) PA-6 micro fillers (Table 4).

Table (1): Descriptive statistics and ONE -way Analysis of variance (ANOVA) for tear strength test

% of PA-6 fillers	N	Mean	SD	SE	Min.	Max.	ANOVA F-test	P. value	Sig.
0%	10	16.15	0.64	0.20	15.2	17	195.58	0.000	HS
1%	10	20.98	1.21	0.38	19.2	22.79			
3%	10	14.54	0.82	0.26	13.72	15.88			
5%	10	11.83	0.67	0.21	10.8	12.8			

Table (2): Post-hoc LSD, Pearson correlation (R), Coefficient of determination (R^2) and % of variation for tear strength test

Compared groups		LSD							
		Mean difference (I-J)	P. value	Sig.	R	R^2	% of variation	P. value	Sig.
0%	1%	-4.83	0.000	HS	0.57	0.32	32.49	0.07	NS
	3%	1.60	0.000	HS	-0.46	0.21	21.16	0.90	NS
	5%	4.31	0.000	HS	-0.45	0.20	20.25	0.18	NS
1%	3%	6.44	0.000	HS	0.09	0.008	0.81	0.80	NS
	5%	9.14	0.000	HS	-0.13	0.016	1.69	0.70	NS
3%	5%	2.70	0.000	HS	-0.52	0.014	1.44	0.12	NS

Table (3): Descriptive statistics and ONE -way Analysis of variance (ANOVA) for tensile strength test

% of PA-6 fillers	N	Mean	SD	SE	Min.	Max.	ANOVA F-test	P. value	Sig.
0%	10	4.40	0.56	0.17	3.44	5.20	29.69	0.000	HS
1%	10	5.74	0.67	0.21	4.70	6.60			
3%	10	4.20	0.55	0.17	3.20	4.85			
5%	10	3.46	0.38	0.12	2.80	4.00			

Table (4): Post-hoc LSD, Pearson correlation (R), Coefficient of determination (R^2) and % of variation for tensile strength test

Compared groups		LSD							
		Mean difference (I-J)	P. value	Sig.	R	R^2	% of variation	P. value	Sig.
0%	1%	-1.33	0.000	HS	0.68	0.46	46.24	0.02	S
	3%	0.18	0.45	NS	-0.34	0.11	11.56	0.32	NS
	5%	0.94	0.000	HS	0.29	0.08	8.41	0.40	NS
1%	3%	1.52	0.000	HS	-0.39	0.15	15.21	0.26	NS
	5%	2.28	0.000	HS	0.39	0.15	15.21	0.26	NS
3%	5%	0.76	0.004	HS	-0.30	0.09	9.00	0.39	NS

DISCUSSION

Tear and tensile properties are the most important properties regarding facial prosthesis [20]. In view of the fact, testing the mechanical properties is an important step towards the modification of the current material or acceptance of a new one [9]. The aim of this study was to investigate the tear and tensile properties of the tested maxillofacial silicone material which can only be achieved by the addition of correct filler concentration which becomes somehow mandatory because the unfilled cross-linked polydimethylsiloxane has very low mechanical properties [5,21].

After the addition of 1% by weight PA-6 micro fillers, the mean value of the tear strength test demonstrated highly significant increase in comparison to the control group by. This may be due to the nature of the fillers; the amide (-CO-NH-) groups within the filler structure are highly polar, so, PA-6 forms multiple hydrogen bonds among adjacent strands [22], this property may result in forming a 3-D network of fillers within the polymer matrix that lead to a change in the overall density and increase overall tearing resistance of the polymer [23]. When the filler loading increased to 3%, the mean value of the tear strength test decreased in a highly significant manner in comparison to the control group. Moreover, the mean value of the tear strength test also decreased in a highly significant manner in comparison to the control group when the fillers percentage increased to 5%. These changes in the mechanical properties (reduction) can be explained by the SEM images (Figure 3), where the PA-6 micro particles fillers had agglomerated to a different extent when the fillers loading increased.

As depicted in the statistical analysis, the tensile strength test mean value was increased in a high significant manner after the addition of 1% by weight PA-6 micro fillers, in comparison to the control group. This may be due to increasing in the overall cross-linking density of the polymer, after the addition of the filler, by forming multifunctional cross-links making the polymer stronger and stiffer; in other words, prevent the polydimethylsiloxane chains from breaking under tensional forces [(24)]. Additionally, during testing, the input energy that is responsible of breaking the polymer network may be dissipated into heat by filler incorporation, hence; higher amounts of energy needed to be available to cause the deformation [(25)]. On the contrast to that, a non-significant reduction in the tensile strength means value in comparison to the control group was reported. Again, when the filler loading increased to 5%, the mean value of the tensile strength test decreased in a highly significant manner in comparison to the control group. This reduction is explained by the SEM images (Figure 3), where the PA-6 micro particles fillers had agglomerated to a different extent when the fillers loading increased resulting in reducing the mechanical properties of A-2186silicone elastomer.

CONCLUSIONS

The following conclusions were reached after taking into consideration the limitations of this study

1. The results of this study revealed significant improvement in the tear strength and tensile strength of A-2186 RTV silicone elastomer after the addition of 1% concentration of PA-6 micro particles powder.
2. As the PA-6 micro particles loading increased to 3% and 5%, impairment in the mechanical properties were noticed.

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الخلاصة

ان استمرار عمل اي تعويضات اصطناعية يعتمد على المادة المصنوعة منها تلك التعويضات لذلك فان اي خلل في نوع المادة سيؤدي الى خلل في استمرارية وديمومة تلك التعويضات ما يستوجب حينها استبدالها. ان الهدف من هذه الدراسه هو بيان تأثير اضافة تراكيز مختلفه من مادة البولي امايد-6 (نايلون-6) على قوتي الشد والتمزق لسيليكون الوجه والفكين نوع A-2186. تم تصنيع 80 عينة بأضافة 0%,1%,3% و 5% وزنا من مسحوق البولي امايد -6 المايكروي الى سيليكون الوجه والفكين المطاطي المفلكن بدرجة حرارة الغرفة نوع A-2186. قسمت عينة الدراسة الى اربع مجاميع, كل مجموعة تحوي 20 عينة. تم تحضير المجموعة الضابطه بدون اضافة مسحوق البولي امايد-6 المايكروي, كما تم تحضير المجاميع الثلاث الاخرى بأضافة تراكيز مختلفه من مادة البولي امايد-6 (1%,3% و 5% وزنا) ومن ثم قسمت كل مجموعة الى مجموعتين طبقا لنوع الفحص, حيث ان كل مجموعة تحوي 10 عينات. ان تدعيم السيليكون بنسبة 1% قد حسن من خاصيتي الشد والتمزق مقارنة بالمجموعة الضابطهةومجاميع الدراسة الاخرى.