European Scientific Journal August 2015 edition vol.11, No.24 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431

MECHANICAL DURABILITY OF 3D PRINTED FACIAL PROSTHESES COMPARED TO TRADITIONAL SILICONE POLYMER PROSTHESES

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Abstract

Purpose: To test the effect of natural and accelerated weathering conditions on the mechanical properties of 3D printed starch samples infiltrated with a maxillofacial silicone polymer.
Materials and Methods: A total of 72 samples (dumbbell-shaped, trouser-legs samples, and hardness blocks) were manufactured from silicone polymer (SP) and starch printed and infiltrated silicone polymer (SPIS) according to industry standards (ASTM). Thus, they were set out to evaluate the key mechanical properties of the SPIS (tensile strength, tear strength, percentage elongation, and hardness test). Specimens were exposed to different natural weathering (outdoor, ambient, and dark environment for 4 months) and artificial weathering conditions (2 weeks exposure and 6 weeks exposure) were compared to those of pure silicone polymer (SP). One way analysis of variance ANOVA was used to test the results statistically.
Results: Exposure to 4 month natural weathering conditions recorded a significant difference in tensile strength between the control group and the three test groups for SP samples *($p<0.05$)*. However, there was no significant differences between the three test groups *($p>0.05$)*.Tear strength statistical analysis showed a significant differences between the control group for the

SP samples and the other three test samples *($p<0.05$)*. Furthermore, SPIS samples demonstrated a significant increase in tear strength of the indoor samples compared to the control samples and the outdoor samples *($p<0.05$)*. However, there was no significant difference *($p>0.05$)* observed between the control values and the two other test groups. However, percentage elongation recorded no significant differences between the control group and the test groups for SP samples, or between the test samples in the same group *($p>0.05$)*. Percentage elongation for SPIS recorded non-significant differences *($p>0.05$)* between the control values and the dark samples. However, when compared to the outdoor samples, there was a significant difference *($p<0.05$)* between the control and the indoor samples. Hardness test also recorded significant differences *($p<0.05$)* statistically between the control data and the test data for both SP and SPIS samples. Furthermore, artificial weathering condition was more detrimental and showed significant deterioration of some of the mechanical properties of both SP and SPIS specimens when they were exposed for 2 weeks and 6 weeks. Deterioration was more significant at six weeks exposure than 2 weeks when compared to non weathered control group.

Conclusions
The general properties of facial prostheses were affected non-significantly by exposure to four months natural weathering for both pure silicone polymer SP and starch printed infiltrated polymers SPIS. However, accelerated weathering conditions were significantly deteriorated for the silicone polymer infiltrated starch models SPIS.

Keywords: Facial Prostheses, Mechanical durability, Silicone polymer, 3D Printed specimens

Introduction

Service life of facial prosthesis is considered too short as the prosthesis requires replacement every few weeks or months as a result of material degradation and changes in the physical properties of the materials used (Haug et al., 1999, Takamata et al., 1989). Properties change causes stiffness, tearing of the edges, and colour fade of the prostheses. Articles reported an average life span of these prostheses from 4-14 months (Jebreil, 1980, Chen et al., 1981, Haug et al., 1999) (Polyzois et al., 2011, Hooper et al., 2005, Lemon et al., 1995). However, service life of facial prostheses is dependent on the inherent properties of the material used and how the prosthesis is being used by the patient (Stathi et al., 2010).

However, longevity and overall integrity of the prosthesis is dependent on the ability of the prostheses to resist alteration in the mechanical and optical properties under natural weathering conditions (Craig et al., 1978). UV radiation from sunlight and other weathering conditions including temperature, moisture, and hand contact during removal and cleaning, affects the overall integrity of the prostheses (Chen et al., 1981, Hanson et al., 1983). Moreover, the use of adhesives for retention alters the elastic properties of the prosthesis, changes the colour, and leads to stiffness of the prosthesis. Thus, this can become problematic at the margin of the prosthesis as it can lead to tearing and lack of adaptation to the surrounding tissues.

Accelerated weathering and weathering chambers have been extensively applied to simulate normal life weathering conditions and to test the overall deterioration of materials (Sweeney et al., 1972, Gary et al., 2001, Kiat-Amnuay et al., 2002). In addition, accelerated weathering is used to simulate the long term effect of outdoor natural weathering conditions. This is achieved by utilizing the most aggressive components of weathering - ultraviolet radiation, moisture, and heat.

Q-Sun and QUV are two most commonly used accelerated weathering testers. Each produce light, temperature, and moisture in different ways. The major difference is the type of light used by both machines. Consequently, Q-Sun utilizes xenon light, which is similar to sunlight (295nm - 800nm). On the other hand, QUV uses the most harmful part of sunlight which is an UV light with a spectrum of electromagnetic wavelength from 300 nm- 400 nm (QUV&Q-Sun, 2012).

A recent project utilised 3D printing technology for the manufacturing of soft tissue prostheses. The project employed a 3D photogrammetry system for 3D data capture and data manipulation in a bespoke 3D CAD package for designing the prostheses with final manufacturing adopting a process of layered printing using a Z510-3D colour printer. During this printing process a water-based binder was added to corn starch powder and the printed models infiltrated with maxillofacial silicone polymer (Zardawi et al., 2015a). In a previous work, we evaluated the mechanical properties of the printed prostheses (Zardawi et al., 2015b). Today, this paper is aimed to test the effect of natural and accelerated weathering conditions on the mechanical properties of 3D printed starch samples infiltrated with a maxillofacial silicone polymer SPIS.

Materials and Methods

Exposure to Natural Weathering Conditions - Test Design and Measurements

The test specimens were designed according to industry standards (ASTM - 1981). Thus, they were set out to evaluate the key mechanical properties of the SPIS under different natural weathering conditions compared to SP. These conditions includes:

1- Outdoors Weathering: Specimens were exposed to natural weathering and UV light from sunlight. Thus, these specimens were placed in a plastic container in the garden for 4 months during the month of July, August, September, and October 2011.

2- Indoors 'Window' Weathering: Specimens were left on a window ledge in order to expose the samples to sun light at daytime, ambient room temperature, and humidity for 4 months.

3- Time Passing 'Dark' Group: Samples were stored in a sealed glass container in complete darkness at room temperature and humidity for 4 months (Polyzois et al., 2011).

Furthermore, test groups included pure SP and SPIS specimens (dumbbell-shaped, trouser-legs samples, and hardness blocks). Thus, the types and the total number of samples used in this study are demonstrated in Table 1. A total of 72 samples were used for testing the effect of natural weathering conditions. One set was produced from printed starch and infiltrated Sil-25 silicone polymer, while the other set was produced from pure SP 'Sil-25'. Power analysis test was performed to define the sample size using "nQuery" software. Finally, the results were compared to a previously tested control specimens - SP and SPIS at 'zero' time, 24 - 48 hours after complete setting was achieved.

Exposure to Artificial Weathering – Test Design and Measurements

The purpose of testing the effect of UV light and weathering on the mechanical properties of the printed specimens (SPIS) and pure SP specimens was to expose them to accelerated weathering conditions for 2 and 6 weeks. A Q-Sun Xenon test chamber (Xe-1-BC1/SC) was used and a window glass filter was added in order to produce a spectrum in the critical short wave UV region (295 nm - 400 nm) (Figure 1). However, test samples were exposed to cycles of UV light and moisture at 50-70° C, as shown in Table 2.

At the end of the experiment, the tensile strength, tear strength, Shore A durometer hardness test, and the percentage elongation were measured. Hence, the results were compared to that of the control group. The experiment was divided into 2 main groups.

Group 1 - Silicone polymer Specimens SP Exposed to Artificial Weathering for 2 Weeks and 6 Weeks

Ten dumb-belled shaped and 10 trouser-shaped samples were produced according to ASTM D412/ISO 037 (ASTM-D412, 1981) and ASTM D624-07/ISO34 (trouser leg) (ASTM-D624, 1981) respectively from pure SP (Sil-25). Hence, this is used for testing tensile strength, tear strength, and the percentage of elongation. Furthermore, 4 hardness test specimens ASTM D1415-06 ISO48 (solid blocks) for testing Shore A Durometer hardness were produced. Specimens were inserted into the Q-Sun weathering chamber. Therefore, at the end of 2 weeks, the specimens were removed from the simulators and their mechanical properties were tested. Another group of specimens (ten dumb-belled shaped, 10 trouser-shaped, and 4 hardness Sil-25 pure SP specimens) was exposed to UV Light and weathering conditions for 6 weeks. Then, specimens were tested for their mechanical properties.

Group 2 - Silicone Polymer Infiltrated Starch (SPIS) Specimens Exposed to Artificial Weathering for 2 Weeks and 6 Weeks

Ten Dumbbell-shaped, ten trouser-shaped, and four hardness test specimens were printed as documented before. Thus, they were infiltrated with Sil-25 maxillofacial SP to investigate the effect of UV light and weathering conditions on the mechanical properties of the printed test samples 'SPIS'. 24 specimens were produced and inserted into the Q-Sun for two weeks; and then, the mechanical tests were measured. Another group of specimens (ten dumb-belled shaped, 10 trouser-shaped, and 4 hardness of starch printed and infiltrated SP specimens) was exposed to UV Light and weathering conditions for 6 weeks. Then, specimens were tested for their mechanical properties.

Furthermore, statistical analysis was performed for the resultant data using PSAW statistics 18. In addition, one way analysis of variance ANOVA was employed in order to make comparisons between the control groups and each test group for the SP and the SPIS specimens. Thus, the aim is to determine the effect of different natural weathering conditions on the mechanical properties of the SP and SPIS specimens used in this study.

Table 1: Types and number of samples (SP & SPIS) used for each test group

Samples	**Dark Group**	**Indoor Group**	**Outdoor Group**	**No. of Samples**
	Number of samples (SP)			
Dumbbell-shaped	5	5	5	15
Trouser-legs	5	5	5	15
Hardness	2	2	2	6
	Number of samples (SPIS)			
Dumbbell-shaped	5	5	5	15
Trouser	5	5	5	15
Hardness	2	2	2	6
Total	24	24	24	72

Figure 1: Q-Sun Xe-1 Xenon test chamber
http://www.q-lab.com/products/q-sun-xenon-arc-test-chambers/q-sun-xe-

Table 2: The 24 hour cyclic exposure in Q-Sun test chamber

N.	Accelerated Weathering	Hrs Per Day
1	**UV**	6
2	**UV + Water**	2
3	**UV**	2
4	**UV + Water**	2
5	**Dark**	8
6	**UV**	2
7	**UV + Water**	2

Results

Exposure to Natural Weathering Conditions

Table 3 presents the data (average and standard deviation) for the mechanical properties obtained from specimens tested under different natural weathering conditions: samples left in complete dark ambient conditions, samples left on the window ledge, and samples exposed to outdoor natural weathering conditions for 4 months. The table also shows a comparison with the control data that has been obtained 24 to 48 hours after complete setting of the specimens.

1- Tensile Strength

Average tensile strength for the dark group, the indoor group, and the outdoor group was 3.1 MPa, 3.0 MPa, and 2.9 MPa respectively against 3.5 MPa for the control group. Tensile strength values of the printed samples left in dark, indoors, and outdoors were 1.3 MPa, 1.2 MPa, and 1.4 MPa respectively against 1.2 MPa for the control group (Figure 3). Statistically, one way analysis of variance ANOVA recorded a significant difference between the control group and the three test groups for SP samples *($p<0.05$)*. Thus, no significant differences was recorded between the three test groups *($p>0.05$)*. Furthermore, no significant differences for SPIS samples were detected between the control group and samples *(p>0.05)* or the 3 test groups *(p>0.05)*. The only significant difference in this group was between the indoor samples and the outdoor samples for SPIS test groups *(p=0.029)*.

Tear Strength

Statistical analysis showed a significant differences between the control group for the SP samples and the other three test samples *(p<0.05)*. Furthermore, SPIS samples demonstrated a significant increase in the tear strength of the indoor samples compared to the control samples and the outdoor samples *(p<0.05)*. Thus, no significant difference *(p>0.05)* was observed between the control values and the two other test groups (Table 3).

Percentage Elongation

Statistically, there was no significant differences between the control group and the test groups for SP samples, or between the test samples in the same group *(p>0.05)*. Percentage elongation for SPIS recorded non-significant differences *(p>0.05)* between the control values and the dark samples. However, when compared to the outdoor samples, there was a significant difference *(p<0.05)* between the control and the indoor samples. Results also showed a significant difference between the indoor samples and the dark samples *(p<0.05)* and between the indoor and outdoor samples *(p<0.05)*.

Hardness

Data showed a change in Shore A hardness values for all SP groups exposed to natural weathering. Consequently, the average shore A for the dark, indoor, and the outdoor specimens were 31.9, 31.7, and 30.8 respectively against 30.9 for the control group. A considerable reduction in Shore A values was recorded for the printed specimens - dark, indoor, and outdoor to be 45.3, 55.1, and 37.7 respectively against 62.8 Shore A value for the control group (Table 3). Significant differences *(p<0.05)* were observed statistically between the control data and the test data for both SP and SPIS samples. Thus, the only non-significant differences were observed between the control group of SPIS sample and the indoor samples *(p=0.17)*. Similarly, there was no significant differences in the hardness between the dark and the window samples for SP group (*p=0.96*).

Table 3: Mechanical behaviour of SP and SPIS specimens under natural weathering conditions

Test	Sample	Control	Natural Weathering Conditions		
			Dark	Indoor	Outdoor
Tensile-MPA	**Silicone**	3.5±0.3	3.1±0.2	3.0±0.1	2.9±0.1
	Printed	1.2±0.2	1.3±0.2	1.2±0.2	1.4±0.1
Tear-N/mm	**Silicone**	12.2±1.5	6.9±1.2	7.4±1.5	8±0.8
	Printed	8.5±1.1	8.6±1	10.5±2.2	8.3±0.9
Hardness-Shore A	**Silicone**	30.9±0.7	31.9±1.5	31.7±0,5	30,8±0.7
	Printed	62.8±2.8	45.3±5.2	55.1±2.7	37.7±3.8
Elongation-%	**Silicone**	511±57.5	474±37.9	487±59.6	437±22.6
	Printed	244±36.1	309±60.0	179.4±14.9	281±53.5

Part 2- Exposure to Artificial Weathering Conditions

Table 4 illustrates the tensile strength, tear strength, hardness, and percentage elongation values for each test group. Also, it shows the pure SP and the SPIS samples for 2 weeks and 6 weeks exposure to accelerated weathering conditions. Results were compared to the control data of the un-weathered samples.

Table 4: Mechanical behaviour of SP & SPIS specimens before & after 2 & 6 weeks exposure to artificial weathering

Test	Sample	Before Weathering (control)	2 Weeks Weathering	6 Weeks weathering
Tensile Strength MPa	Silicone	3.5±0.3	2.9±0.4	2.9±0.2
	Printed	1.2±0.2	1.1±0.2	0.9±0.1
Tear Strength N/mm	Silicone	12.2±1.5	10.7±1.6	6.4±1.5
	Printed	8.5±1.1	8.1±0.8	7.5±1.6
Hardness Shore A	Silicone	30.9±0.7	32.3±0.8	34.4±1.9
	Printed	62.8±2.7	58.1±2.2	29.1±4.7
Elongation %	Silicone	511±57.5	479±32.7	468±52.2
	Printed	244±36.1	204±55.6	158±30.6

Average values of tensile strength, tear strength, and percentage elongation for the pure SP specimens before and after weathering are shown in Table 4. Before weathering, they were 3.5 MPa, 12.2 N/mm, and 511% respectively as against 2.9 MPa, 10.7 N/mm, and 479% respectively after 2 weeks weathering. Furthermore, they were 2.9 MPa, 6.4 N/mm, and 468% respectively after 6 weeks exposure to UV Light and weathering conditions. The average values of tensile strength, tear strength, and percentage elongation for SPIS samples before exposure were 1.2 MPa, 8.5 N/mm, and 244% respectively as against 1.1, 8.1 N/mm and 204% respectively after 2 weeks weathering. Furthermore, they were 0.9 MPa, 7.5 N/mm and 158% respectively after 6 weeks weathering.

A significant overall difference *($p<0.05$)* was detected by ANOVA for tensile strength for both the SP and the SPIS test data after weathering when compared to the control data. No significant differences *($p>0.05$)* in tensile strength were recorded between 2 weeks and 6 weeks exposure for both SP and SPIS samples. Also, the tear strength for SP groups showed significant differences *($p<0.05$)* between the groups, whereas SPIS showed no significant differences *($p>0.05$)* between the test groups and the control group. Statistically, SP percentage elongation results showed no significant differences *($p>0.05$)* between the test samples and the control samples, but SPIS data showed a significant difference *($p<0.05$)* between the control data and the test data (2 weeks and 6 weeks).

However, hardness test results for SPIS samples showed a slight reduction in hardness from an average of 62.8 indentation shore A hardness for the SPIS test samples before weathering to 58.1 Shore A after 2 weeks. Thus, there was a significant reduction to 29.1 after 6 weeks exposure to UV light and weathering conditions. In contrast, the SP samples demonstrated a slight increase in the indentation Shore A value after weathering and exposure to UV light. Their Shore A values were 30.9 before weathering. Thus, this increased to 32.3 after 2 weeks and to 34.4 after 6 weeks exposure to weathering (Table 4). A significant overall difference *($p<0.05$)* was detected by ANOVA between the samples for both SP and SPSI samples for 2 and 6 weeks exposure to accelerated weathering compared to the control groups.

Discussion

Natural outdoor weathering and artificial accelerated weathering tests are usually undertaken to assess the durability of maxillofacial facial materials. These methods involve exposing the samples to different factors that induce chemical, physical, and mechanical degradation such as UV light, humidity, and temperature.

The outdoor weathering exposes the samples to natural weathering conditions, but it is an un-controlled subjective method of testing. There is no control over the amount of each factor causing the deterioration which include, geographic location, season, weathering condition, time of day, and length of exposure (Eleni et al., 2009a).

The accelerated weathering condition is a controlled method of testing the effect of the most deteriorating factors on the SP. Thus, they do condense the process in a shorter time frame. However, it does expose the samples to extreme and aggressive weathering condition. It is still not clear how effective the artificial weathering process simulates the natural process and it may well present an incorrect estimation about the service life of the materials used for the fabrication of these prostheses (Maxwell et al., 2003). Therefore, the use of accelerated weathering to replicate outdoor weathering was brought into question by different results presented by two different studies. In 1994, Dootz et al reported no difference in the hardness and percentage elongation of Silastic 4-4210 before and after exposure to accelerated weathering (Dootz et al., 1994). On the other hand, Haug et al (1999) showed a significant differences in the percentage elongation and hardness of the same maxillofacial silicone before and after exposure to accelerated weathering .

It has been suggested that 1000 hours of exposure to UV light and other weathering conditions using accelerated weathering chambers is equivalent to one year of natural outdoors exposure (Wolf et al., 1999, Philip et al., 2004). Thus, one hour exposure to artificial weathering corresponds to 8.76 hours of natural weathering conditions. Therefore, the 2 weeks time frame exposure to accelerated weathering that has been applied in this study should be equivalent to 4 months of natural weathering conditions. Furthermore, 6 weeks exposure to artificial weathering would represent longer time period which corresponds to one year natural weathering. Hence, a much bigger change in the mechanical properties of the specimens was expected to be found.

In this project, both methods of weathering have been applied. Therefore, it should be noted that neither of them represent true clinical use and the way prostheses are being used by the patients in “real life”. It can only be seen as an indication of the kind of problems that may arise. In real life, there are issues of hand contact, applying and removing the prostheses, bodily secretions, and of course, the use of make up or adhesive to help disguise and retain the prosthesis. Furthermore, the patient does not spend all the time outdoors to be exposed to the full period of natural weathering used in this study. Polyzois (1999) suggested that 4 months exposure to natural outdoors weathering is probably equivalent to 8-12 months actual clinical service time. Yet, a patient with facial prosthesis is unlikely to stay outdoors for 24 hours a day. A maximum of 8-12 hours daily outdoor time by the patient might be expected, and the time frame in this study could be equivalent to 8 -12 months clinical service life of the prosthesis (Polyzois, 1999). Nevertheless, it is not possible to apply the real life experiments at an early stage of the project as the clinical component of the project is still developing.

The specimens were exposed to three different methods of natural weathering conditions, the dark, the indoor, and the outdoor, which showed different effects on the mechanical properties of the SPIS used for producing soft tissue facial prostheses. Exposure of the SPIS to different natural weathering conditions for 4 months showed no significant effect on tensile strength and tear strength of the test specimens compared with the control specimens. However, there was a significant increase in the tear strength of the indoor specimens. In contrast, statistically, the pure SP control samples showed a significant difference in tensile strength and tear strength with the 3 test methods: the dark, the indoor, and the outdoor group. Furthermore, statistical analysis of percentage elongation did not show any significant changes when the control data are compared to the test data of the outdoor and the dark samples. Data showed a slight reduction in percentage elongation for the indoor samples. On the other hand, statistical analysis showed a significant reduction in Shore A hardness values for all test groups.

In this study, the effect of accelerated weathering was also tested on SP and SPIS specimens for 2 weeks and 6 weeks. The device used 'Q-Sun' for testing the effect of accelerated weathering which exposes the samples to extreme and aggressive weathering conditions. The results demonstrated a considerable reduction in the mechanical properties of the pure SP and the SPIS specimens.

Following exposure to accelerated weathering for 2 weeks, statistical analysis of the results showed a significant reduction in tensile strength of the printed samples. Consequently, the percentage of elongation was also reduced, and this is shown in Table 4. The 2 weeks exposure induced a significant effect on the tear strength of the pure SP. However, no significant effect was recorded on the tear strength for the SPIS samples.

Six weeks exposure induced more reduction in the mechanical properties of the SPIS values compared to SP group. The effect of weathering on SP samples was non-significant on tensile strength and the percentage elongation specimens when compared to the tear strength and hardness values which demonstrated significant changes statistically. Additionally, there was a significant reduction in tensile strength, percentage of elongation, and hardness values for SPIS samples after 6 weeks exposure to UV light and weathering conditions. Thus, this is shown in Table 4. One notable feature was the significant reduction of the Shore durometer A values for the printed samples after 6 weeks exposure to accelerated weathering, which was also accompanied by a considerable reduction in their percentage elongation. This shows the consequence of harsh and extreme nature of artificial weathering conditions and the length of time used for testing. Furthermore, the SPIS is a composite, and starch constitutes 40% of the whole component by weight (Zardawi et al., 2015a), starch is a soft hydrophilic material and the accelerated weathering condition is beyond the starch's ability to resist deterioration under these extreme artificial weathering conditions.

The results indicate that exposure to 2 weeks and 6 weeks accelerated weathering had a more severe effect on both SP and SPIS. In theory, the 2 weeks weathering should be equivalent to four month natural weathering. However, when the results were compared with each other, the two weeks weathering were found to show a much more severe effect than the 4 months natural weathering conditions. Thus, 2 weeks of accelerated weathering may be more representative to a year of natural weathering conditions. The 6 weeks exposure to accelerated weathering was found not to be comparable to the results of natural weathering in this study and may well be a representative of many years of clinical use.

The mechanical data obtained from the SP samples under artificial weathering condition are comparable with other reports that evaluated clear and coloured maxillofacial silicone polymers under accelerated ageing mechanisms (Andres et al., 1992, Dootz et al., 1994, Eleni et al., 2009a, Eleni et al., 2009b). However, it contradicts the results achieved by Yu et al (1981), who evaluated 4 types of silicone, polyvinyl chloride, and polyurethane polymers for their physical properties. They tested hardness, percentage of elongation, and tear strength, before and after exposure to 600-900 hours weathering. They concluded that the 4 types of silicone polymers reported no changes in physical properties on accelerated ageing. In addition, they attributed this important characteristic to the inert inorganic backbone of the molecular chain. The high percentage of silicone elongation was attributed to the nature of fillers and configurations of crosslinkages. In contrast, the polyurethane showed complete deterioration and failed entirely after 600 hours of testing (Yu et al., 1980). Moreover the results of natural weathering conditions of the SP samples is also found to be consistent with the results of Eleni et al, 2009 (Eleni et al., 2009a).

Although there are inherent differences in these values for each group before weathering, the SPIS appear to be able to resist extreme weathering conditions well. Therefore, as a result of this, the SPIS could potentially be used to replace facial defects without going through significant deterioration during the service life of the prostheses.

Therefore, it would appear that this method of producing the prostheses has no demonstrable detrimental effect on the mechanical properties when compared to the material already used today ‘SP’. However, it is acknowledged that the mechanical properties are different when compared to pure silicone. Also, extended period of exposure to extreme weathering conditions adversely affects the samples tested ‘SPIS’.

According to the mechanical data obtained from these studies, there is some loss in properties. Thus, it is hard to judge how that will be reflected in the day to day clinical use of these prostheses. The results obtained suggest that the SPIS formulation is adequate for the purpose when compared to SP alone and the prostheses will last between 6 – 12 months. Hence, one can overcome the degradation process by making multiple prostheses. Furthermore, when the prostheses are used as interim replacements for patients with defects during any post operative healing period, it is only required to last for a shorter time and it would be perfectly adequate.

Conclusion

1- The silicone polymer prostheses showed non significant degradation in both the natural and the accelerated weathering conditions.

2- For the printed prostheses, there was no significant effect for the natural weathering conditions. Also, accelerated weathering conditions had a significant effect on some mechanical properties of the printed samples.

Acknowledgement

This study was supported in part by a Wellcome Trust Translational Research Grant awarded to Professor J M Yates and Fripp Design Limited, UK. Faraedon Zardawi acknowledges the Iraqi Ministry of Higher Education and Scientific Researches, and the University of Sulaimani for their sponsorship of this Doctoral Scholarship which led to the completion of this report.

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