Study the Mechanical Properties of Polymeric Blends (SR/PMMA) Using for Maxillofacial Prosthesis Application

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Abstract. A number of prosthetic materials, it may be used to replace facial parts of maxillofacial that lost through disease or trauma. The silicone rubbers it is considered are the best materials in this area. So that, the aim of this research is to study the effect of addition of PMMA material on the mechanical properties of blends SR/PMMA at different loading level (5%, 10%, 15% and 20%) of PMMA to silicone rubber. FTIR test and some mechanical properties such as tensile strength, elastic modulus, elongation percentage, hardness, compression strength and roughness were done on the all prepared samples, which are used for maxillofacial prostheses applications. The results showed that the optimum percent of PMMA is 10% that has ideal characteristic. So, this sample may be a promising material to achieve the properties required for maxillofacial prosthetic applications.

Keywords: Blend, Mechanical properties, Silicone rubber, polymethyl methacrylate.

1. Introduction

Maxillofacial prostheses are used to transform congenital, developmental, and acquired defects of the head and neck into natural appearing reproductions of the missing parts, thus, providing an acceptable appearance and improved function. Increasing numbers of maxillofacial patients with cancer, trauma or congenital diseases are requesting more comprehensive and high-quality prosthetic services. Maxillofacial patients suffer from not only pains and dysfunctions but psychological problems associated with facial disfigurement, especially after surgery [1, 2]. The main purpose of maxillofacial materials is to restore the function and form of defective and missing parts of the face, maxilla and mandible so that the psychological defects that result can be restored as well [3].

 Historically, Auricular, nasal, and even ocular prosthesis fabricated with various materials, have been found in Egyptian Mummies. Chinese were known to fabricate nasal and auricular prosthesis using natural waxes, resins and metals usually gold or silver. The ultimate challenge to a maxillofacial prosthetic material is its clinical performance; Future research should concentrate on two major goals first: Improving the physical and mechanical properties of the material, so that it will behave more like human tissue and increase the service life of the prosthesis. Second: Finding color stable coloring agents for coloring the facial prostheses [4, 5]. Polymers and elastomers are the mainstay of modern maxillofacial prosthetic reconstruction. Maxillofacial silicone elastomers have been widely used to fabricate facial prostheses for restoring the normal appearance of patients with maxillofacial defects [6]. Polymethylmethacrylate, polydimethylsiloxane and polyetherurethanes have been tested and used in meeting the demand for materials that will be biocompatible, durable, colour stable and easily manipulated [7].
Silicone rubber which refers to polydimethylsiloxane it can be classified in to vulcanized at room temperature (RTV) and vulcanized by heat (HTV). Room temperature vulcanize silicone elastomer has been used to fabricate maxillofacial prosthesis, because these materials are processed easily, less time consuming, are flexible and durable [3]. The most common silicone elastomer is with a Tg of -127 °C [8]. There are many advantageous characteristics of silicone prosthetics that consecrate silicone as the most suitable material for facial prostheses such as good biocompatibility and bio-durability, wide service temperature range, non-adhesive properties, low toxicity, possible optical transparency, low chemical reactivity, and excellent resistance to attack by oxygen, ozone, and sunlight. Its physical properties of relevance include hardness, high tear resistance and reliable bonding to acrylic substructures which are frequently used along with them [9, 10].

Polymethyl methacrylate is still being used as base material or clip carrier material, but it is hard and heavy so that acrylic resins are used for fabrication of prosthetic eyes in ocular or orbital prostheses, and for frameworks. PMMA is an amorphous and transparent polymer. Its stiffness is retained until near its softening temperature (110 °C) [4, 11]. Many attempts have been made to evaluate the physical and mechanical properties of different silicone maxillofacial materials. Results of these studies have shown a wide range of variation among tensile and tear strength, percentage elongation and Shore A hardness tests, in addition to the variation between different studies examining the same silicone maxillofacial material [3]. In this research the improvement of mechanical properties of polymer blend material (SR PMMA) for applications of facial and maxillofacial prostheses was studied. The blends were characterization by the following Tensile, Compression, Hardness, Roughness, and FTIR.

2. Experimental work:

2.1 Materials Used:
In this research silicon rubber (SR); which supply from Shenzhen Hong Ye Jie Technology Co., LTD, type 630 RTV which is vulcanized at room temperature in condensation method. It is generally consisting as a two part, one is a flowable liquid, and another is the catalyst. Second material of the blend is polymethyl methacrylate (PMMA) cold curing as resin type (Castavaria) has been used, provided from (Spofa Dental) Company. Table 1 shows some of the mechanical and physical properties of cold cure PMMA according to the supplied Company.

Table 1. shows the properties of neat PMMA according to the supplied Company.

| Property                                    | Value                  |
|---------------------------------------------|------------------------|
| Brinell hardness                            | min. 120 Mpa.          |
| Bending strength                            | min. 65.5 Mpa.         |
| Setting time                                | Max. 7 min.            |
| Time of solubility                          | Max. 4 min.            |
| Time required to prepare nontacky plastic mixture | 4-6 min.              |
| Resistance to impact                        | min. 0.40 J/cm²        |
| Absorability                                | Max. 32 mg/mm³         |
| Solubility                                  | Max. 8 mg/mm³          |

2.2 Preparation Method:
Firstly, preparation of neat sample (matrix) by mixing two parts of the silicone rubber in a ratio of 10:1 according to manufacturer’s instructions, where part A as a base material and part B is catalyst material. Secondly, preparation the binary polymeric blends samples (SR/PMMA) by mixing silicone rubber with PMMA polymer according to loading level (5%, 10%, 15% and 20%) of PMMA. Initially, a part A of silicone rubber in a liquid state is mixing with acrylic powder (PMMA) in standard proportion, then silicone rubber catalyst (part B) mixed with liquid monomer (MMA), After that the two groups were mixed together well. Finally pouring the blend into the metallic mould and left them inside the mould at room temperature about (6 hrs.) according to the instructions of the supplier.
company. After the polymerization curing completed, the specimens as a plates were then removed from the metal mold, the testing samples were obtained by cutting the prepared plates according to the relevant ASTM standard for each test, and all properties were measured at room temperature (25-30 °C).

3. Characterization and testing:

3.1 Test Methods
Fourier transform infrared spectrometer (FTIR) test is performed according to (ASTM E1252), made by (Bruker Optics Company, Germany), type is (TENSOR-27). FTIR was used to characterize the neat silicone rubber, and (SR PMMA) polymer blends [12]. It is equipped with a room temperature DTGS detector, mid-IR source (4000 to 400) cm⁻¹ and a KBr beam splitter.

In order to evaluation of the tensile strength, compression strength and hardness properties for all the prepared samples, all tests were performed in according to (ADA Specification No.12, 1999), where all the test specimens after preparation and polishing processes must be stored in distilled water at (37± 1 °C) for 48 hr.

For tensile strength tests, the specimens for tensile strength evaluation were made according to ASTM 638 standards [13]. In this test the universal tensile instrument, type (LARYEE) devise was used. The load was applied gradually to the longitudinally fixed sample at velocity of (500mm/min), the load was Increasing continuously until the sample was failed.

The compression test of elastomer specimens was carried in the laboratory according to the standard of elastomer compression test, ASTM D 395-03 (method B) [14]. With standard dimensions of a specimen are thickness 12.5 ± 0.5 mm and diameter 29.0 ± 0.5 mm. The hardness test of the samples was carried according the ASTM D 2240 [15], by using a device (Shore A hardness) type (Th200). In this test the specimens used must have smooth surface with thickness at least more than (3mm) and must not be exposed to mechanical vibrations, so, the specimens were made in the shape of a circular disk with dimension (thickness 6 mm – diameter 25mm). The examination occurs by work of five strikes at different places of the sample and calculated the average value of hardness.

The surface roughness test was performed by using the surface roughness tester (TR 200) device supplied with a sensor which moves linearly along the measured length. Sample was stabilized on the flat surface of machine and applying the needle of the device perpendicular to the sample and moved on the surface. For this test, the dimensions of sample are (25mm × 25mm and 3mm thick). Surface roughness was recorded for three times on different places on the surface of sample, and then the average values were recorded.

4. Results and discussions

4.1 FTIR spectrum:
In order to full characterization for the bands of neat silicone rubber and the (SR/PMMA) polymer blends, Fourier Transform Infrared Spectrometer (FTIR) test was done. The FTIR a spectrum of neat silicone rubber in the range (400-4000 cm⁻¹) is shown in Figure (1), the spectrum is quite similar to the reported [16, 17]. In general, the absorption peak at 2962.65 cm⁻¹ is assigned to stretching vibration of CH₃. The absorption peak at 1410 cm⁻¹ is assigned to the rocking vibration of -CH₂-. The absorption peaks at 1258.52 cm⁻¹ and 864.27 cm⁻¹ are assigned to bending vibration and rocking vibration of Si-CH₃. The absorption peaks at 1080 cm⁻¹ and 1009.28 cm⁻¹ are assigned to the stretching vibration of Si-O-Si on backbone of silicone rubbers. The absorption peak at 787.39 cm⁻¹ is assigned to the coupling of stretching vibration of Si-C and rocking vibration of -CH₃.

The FTIR spectra of polymers blend (SR: X% PMMA) with different ratios of PMMA (0, 5, 10, 15 and 20%) are shown in figure 2. It can be seen from the infrared spectrum of these group of polymeric blend specimens; these spectra is quite similar to the FTIR spectrum of silicone rubbers which shown in figure (1), no other new peak or peak shifts were observed for the polymeric blends of SR/PMMA specimens with the addition of PMMA. This is due to the find physical bond and absence of any cross
linking and chemical reaction between constituents of polymeric blends, as well as there is no any new interaction in these specimens of polymeric blends.

![FTIR spectrum](image1)

**Figure 1.** Shows FTIR spectrum for neat silicone rubber material

![FTIR spectra comparison](image2)

**Figure 2.** Shows FTIR spectra of neat silicone rubber and (SR/PMMA) polymer blend as a function of PMMA content in blend.

4.2 **Tensile Property:**

The tensile strength and modulus of elasticity for polymeric blends (SR: X% PMMA) in different ratios (0, 5, 10, 15 and 20%) of PMMA are show in Figures 3 and 4 respectively. The polymeric blends of SR/PMMA specimens have the highest tensile strength and modulus of elasticity as compare with the neat silicone rubbers. This is due to the adding of PMMA to silicone rubbers. Generally SR matrix material is much weaker in strength than the PMMA, since the matrix alone is unable to resist the tensile force applied on it and fails with strength lower than specimens of SR/PMMA that withstand the tensile load, this result related to the natural of the molecular structure of SR chains, where the backbone chain is contain on alternating silicon and oxygen atoms with side-bonded of atoms groups (CH$_3$) [18], the repeat unit of silicone rubbers (polydimethylsiloxane) that used in this
work which mentioned earlier in Figure 1. According to the predecessor, the silicone elastomers possess a high degree of flexibility in particular at low temperatures [to -90°C] and yet are stable to temperatures as high as 250°C [18]. Whereas the PMMA is a hard, rigid and this related to the natural of chains structure which contain on the methyl and methacrylate groups on every other carbon atom of the main chain provide considerable steric hindrance and thus makes PMMA rigid and relatively strong [19]. So, based on the foregoing this makes silicone rubbers have highest tensile strength and modulus of elasticity when mixed with PMMA. As well as, it can be noted from these figures that the tensile strength and modulus of elasticity increases with increasing weight ratio of PMMA content in the blend, and reach to the highest value (6.4 MPa, 2.85 GPa respectively) at 10% ratio of PMMA, then start to decline with increasing the amount of PMMA, but their values remain higher than they are in the base material neat silicone rubber. The reasons behind such behavior is attributed to the strengthening mechanism of PMMA in which, the amount of this material plays an important role in impedes to increasing the slipping of SR/PMMA chains. the increased in blends properties may be related to high adhesive between constituents of polymeric blends, these materials it may be in good compatibility between them until to PMMA content reach up to 10% ratio, but when increased the PMMA ratio to larger than 10% this may be lead to the formation of heterogeneous polymer blend, and that may be lead to phases separation then disintegrations between two materials in blends and with bad connecting between them.

![Figure 3](image_url)

*Figure 3. Shows the tensile strength of SR/PMMA polymeric blends as a function of PMMA content in blend*
Whereas the elongation at break decreased with increased the PMMA content in blend as show in figure 5, this may be related to the natural of molecular structure of PMMA chains have the repeat unit contain two side group as mentioned earlier that give stiffness to SR.

**Figure 4.** Shows Modulus of elasticity of SR/PMMA polymeric blends as a function of PMMA content in blend.

**Figure 5.** Shows elongation percentage of SR/PMMA polymeric blends as a function of PMMA content in blend.

### 4.3 Hardness and compression property:

The hardness behaviors and compression strength for polymeric blends (SR: X% PMMA) at different ratios (0, 5, 10, 15 and 20%) of PMMA content is show in Figures 6 and 7 respectively. It was found that the hardness values and compression strength increased with adding of PMMA to silicone rubber and reach to highest values at 10% percent of PMMA content. This increase is due to the high strength of compatibility between the constituents of polymeric blend and a natural of chains structure for each of silicone rubber as a matrix material and PMMA as the second material. Above 10% PMMA percent both the hardness and compression strength decreased as result of weakness of coherence between materials which may be because the formation of some of free volume which led to decreased in these properties.
4.4 Surface roughness test:
From figure 7 which shown the relation between surface roughness as function of PMMA content in the blend, it was found that this property increased with increased PMMA percent due to the rigidity of PMMA material as compared with nature of a silicone elastomers material which possess a high degree of flexibility.
Figure 8. Shows surface roughness property of SR/PMMA polymeric blends as a function of PMMA content in blend

5. Conclusions
From the test results of the prepared polymeric blends (SR/PMMA), it was concluded the following:

1. That there is good correlation in FTIR spectrum for neat silicone rubber and (SR/PMMA) polymer blend, where there are no other new peaks or a deviation in the positions of peak were observed for the polymeric blends of SR/PMMA specimens with the addition of PMMA.
2. The tensile strength, modulus of elasticity, hardness and compression strength increased and reaches to the highest values at 10% of PMMA content, so, this sample may be a promising material to achieve the properties required for maxillofacial prosthetic applications.
3. The results show that the development of the mechanical properties of silicone rubber with the addition of PMMA to it, in the specific ratios, so, these polymeric blends (SR/PMMA) can be used in the applications of facial and maxillofacial prostheses.

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