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PHYSICAL PROPERTIES OF SILICONE ELASTOMERS. REVIEW ARTICLE

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INTRODUCTION

The materials that are used for fabrication of extra-oral prosthesis should have desirable physical properties. These properties involve hardness, wettability, non-water absorption, colour stability, high tensile, elongation percent and tear strengths (Aziz *et al.*, 2003; Thomas, 2006).

PHYSICAL PROPERTIES

1. Hardness

The hardness property expresses the flexibility of silicone material. This characteristic is an essential because it is very important to have a material with similar hardness to the missing facial defect (Aziz *et al.*, 2003).

Overall, the hardness of silicone elastomers can be measured by durometer shore A scale ranging from zero to 100, where the grade (zero) indicates the softness while the grade (100) means the hardest. The silicones which are used for facial and body prostheses range from 5 to 20 shore A. Table 1demonstrates the shore A scale for different types of silicone (Thomas, 2006).

Material	Durometer Shore A
MDX4-4210 Silicone Elastomer (Factor II)	27
Silicone MED 40072 (Rhodia Silicones Inc.)	25
A-2186 Silicone Elastomer (Factor II)	30
A-588 Variable Durometer (Factor II)	Variable 12,20, 29
VST-50 Versital (Factor II)	30
Techsil 3455ST (Techsil Ltd)	40
Elastosil RTV 625 (Wacker Chemic Gmbh)	25
Silbione RTV 4408 (Rhodia Silicones Inc)	8
Silopren LSR 2020 TP 3364(G.F. Bayer)	22
MED – 4940(Nusil)	48

To measure the hardness of silicone samples, the specimens are placed on a flat surface and the pressor foot of the durometer scale is applied on the samples with enough pressure in so that contact between the samples and the pressor foot occurs. When the contact occurs, the scale will determine the hardness of the specimen (Wolfaardt, *et al.*, 1975). Figure 1 demonstrates Application of durometer to specimens for hardness testing (Wolfaardt, *et al.*, 1985).

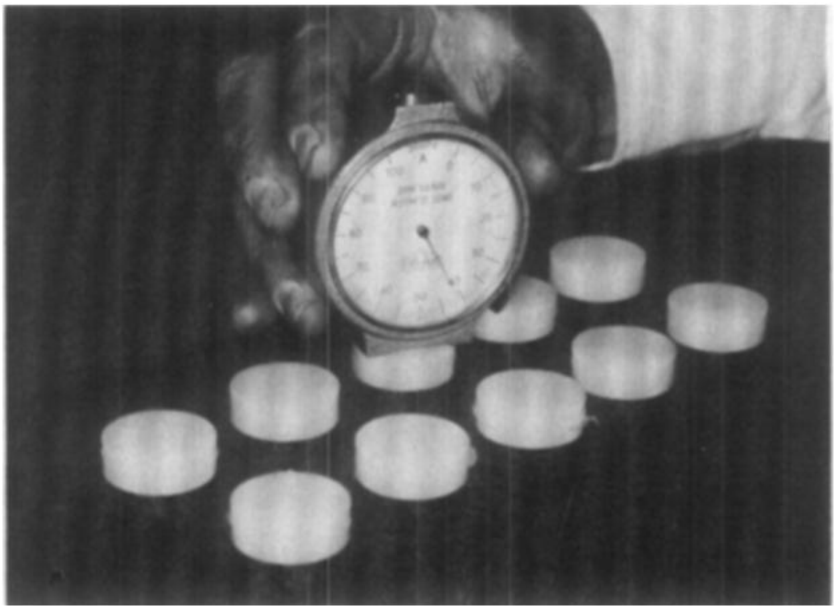

Figure 1: Application of durometer to specimens for hardness testing (Wolfaardt, *et al.*, 1985).

2. Tensile strength

The tensile strength of silicone elastomer is defined as the ability of a material to resist the stretch until it tears. Therefore, the material which is used for construction of extra-oral prostheses should have a high tensile strength (Aziz *et al.*, 2003).

In addition, the elongation percent of the samples at break is recorded where means the ability of material to be flexible before fracture. Thus, it is significant to have material with high percentage of elongation especially when peeling the prosthesis from the tissue. The tensile strength of material is measured in pounds per square inch (psi). To measure the tensile strength, the sample is placed in tensile machine where one end of the sample is clamped in one grip and the other end is clamped in other grip. Samples are then exposed to the load (such as 1 kilo Newton) until its breaks. For each sample, the tensile stress and the elongation percentage are calculated by computer software using the formula below (Aziz *et al.*, 2003).

Stress = Load / initial cross-sectional area

Percentage strain % = Extension / Original length x 100

According to these formulas, the tensile strength of a material depends upon the load which is applied on the sample and cross sectional area. As well as the elongation percentage depends upon extension of the sample after exposing to the load and sample's length. Table 2 demonstrates the tensile strength and elongation of different types of silicone elastomers (Thomas, 2006).

Table 2: Tensile strength and elongation percent of different types of silicone elastomers (Thomas, 2006).

Material	Tensile strength(Psi)	Elongation percent
MDX4-4210 Silicone Elastomer (Factor II)	650	500
Silicone MED 40072 (Rhodia Silicones Inc.)	700	400
A-2186 Silicone Elastomer (Factor II)	900	600
A-588 Variable Durometer (Factor II)	600-700	325-700
VST-50 Versital (Factor II)	750	480
MED – 4940(Nusil)	1037	452

3. High tear resistance

The material that used in the construction of extra-oral prostheses should have high resistance to tearing. The thin edge of extra-oral prosthesis (ear, eye, and nose) which is retained by medical adhesive is subjected to tearing due to the insertion and removal of prosthesis by the patient. Hence, the tearing of the edge causes the deterioration of the prosthesis over time (Aziz *et al.*, 2003).

The tear of silicone material is measured in pounds per square inch (ppi) or pounds per linear inch (pli). Table 3 shows the tear strength for different types of silicone materials (Thomas, 2006).

Table 3: Tear strength for different types of silicone materials (Thomas, 2006).

Material	Tear strength(PPi)
MDX4-4210 Silicone Elastomer (Factor II)	90
Silicone MED 40072 (Rhodia Silicones Inc.)	80
A-2186 Silicone Elastomer (Factor II)	90
A-588 Variable Durometer (Factor II)	45
VST-50 Versital (Factor II)	112
MED – 4940(Nusil)	252

4. Water absorption

Another physical property is water absorption, where the absorbed water may affect the physical properties and colour stability of silicone elastomer. The silicone consists of two main components polydimethylsiloxane chain and silica filler. The interaction between these components affects the physical properties of silicone. Hence, the material that used for extra-oral prosthesis should be hydrophobic nature (Waters *et al*., 1996; Aziz *et al*., 2003).

5. Wettability

It is important that the material used for fabrication of maxillofacial prosthesis should have high wettability, where the material that is easily wetted will form a superior lubrication between the tissues and reduce the abrasion between the tissue and prosthesis and patient discomfort (Polyzois *et al*., 1991; Waters *et al*., 1996, Aziz *et al*., 2003).

6. Viscosity

The material that used in the fabrication of extra-oral prosthesis should have a low viscosity to allow the material to enter into all parts of the mould easily and as the same time high to permit the settling of pigments inside the mould (Lewis and Castleberry, 1980). It is measured in centipoises (cps) or milli-pascals (mpas). Table 4 shows the viscosity of different types of silicone materials (Thomas, 2006).

Table 4: Viscosity of different types of silicone materials (Thomas, 2006).

Material	Viscosity(cps)
MDX4-4210 Silicone Elastomer (Factor II)	70,000
Silicone MED 40072 (Rhodia Silicones Inc.)	10,000
A-2186 Silicone Elastomer (Factor II)	90,000
A-588 Variable Durometer (Factor II)	85,000
VST-50 Versital (Factor II)	12,000
Techsil 3455ST (Techsil Ltd)	45,000
Elastosil RTV 625 (Wacker Chemic Gmbh)	45,000
Silbione RTV 4408 (Rhodia Silicones Inc)	1,900
Silopren LSR 2020 TP 3364(G.F. Bayer)	200
MED – 4940(Nusil)	Translucent paste

7. Colour stability

The material that is used for construction of facial prosthesis should be able to accept and retain intrinsic and extrinsic pigments. Tints must be soluble, and pigments and fibers must be dispersible. This property is measured by the solubility parameter. The ideal value for a prosthetic material is from 9 to 11 cals^{½} (Lewis and Castleberry, 1980).

Discolouration of silicone elastomer is one of the major factors which lead to remake of extra-oral prosthesis. This problem is caused because of colour instability of intrinsic and extrinsic pigments due to environmental factors (sun light, air pollution and body oil accumulation), ultraviolet light and cleaning agents (Polyzois, 1999).

Several studies were undertaken to assess the colour stability of different silicone elastomers after exposing to outdoor and artificial weathering. For example, Lemon *et al.*, 1995 assessed the colour stability of silicone elastomer in two conditions (natural and artificial weathering). The samples were measured before and after exposing to artificial and natural weathering using a spectrophotometer. They reported that artificial aging caused a change in the colour of silicone more than outdoor weathering.

Another study by Polyzois (1999) assessed the colour stability of three silicone elastomers: Ideal (Orthomax, Bradford, UK); Silskin 2000 (De Puy Healthcare, Leeds, UK), Elastosil M3500 (Wacker-Chemie GmbH, Munchen, Germany). He exposed the specimens to the sunlight and then he measured the colour stability using colourmeter. He found that the colour stability of Silskin 2000 was lower than the other two elastomers. He concluded that the type of silicone elastomer and time exposure to weathering were the main factors that affect the colour stability.

A similar study was undertaken by Eleni *et al* 2008 assessed the colour stability of silicone elastomers (Episil , Dreve- Dentamid GmbH, Unna, Germany) after exposing to ultraviolet in different time periods (8, 24, 48, 72, 96, 120, 144, 168 hours). The samples were measured before and after exposing to ultraviolet light using spectrophotometer. They reported that the change in the colour of silicone depended upon time exposure and type of the material.

8. Ideal properties

It is necessary that the material used for construction of an extra-oral prosthesis should be easy to use and process, easy to colour, translucent, non-toxic, biocompatible with the tissue, resistant to the light aging and long service life (Beumer *et al.*, 1979; Thomas, 2006).

Lewis and Castleberry, 1980 listed the ideal values for different properties and desirable physical and mechanical properties. (Table 5 & Table 6).

Table 5: Ideal values for different properties (Lewis and Castleberry, 1980).

Processing characteristics	Goal
Viscosity at ambient temperature	< 75,000 cps
Colour	Colorless
Solubility parameter	9 to 11 cal”
Pot life (working time)	15 to 60 min
Curing temperature	< 100^{o} c
Curing time	I to 2 hr

Table 6: Desirable physical and mechanical properties (Lewis and Castleberry, 1980).

Desirable performance characteristics	Goal
Tear strength	30 to 100 ppi
Tensile strength	1000 to 2000 psi
Modulus at 100% elongation	50 to 250 psi
Elongation at break	400% to 800%
Glass transition temperature	< 0°c
Heat distortion temperature	> 120° c
Critical surface tension	30 to 45 dynes/cm
Coefficient of friction	0.4 to 0.6
Hardness	25 to 35 Shore A scale
Water absorption	None

Overall, none of materials what are used in construction of facial prostheses has ideal properties. Table 7 indicates some advantages and disadvantages of silicone elastomers which are used in the construction of extra-oral prostheses (Thomas, 2006).

Table 7: Advantages and disadvantages of some silicone elastomers (Thomas, 2006).

Material	Advantages	disadvantages
MDX4-4210 Silicone Elastomer (Factor II)	Room temperature vulcanizing or heat cure at 95 for 1.5 hours	Less resistant to light aging
Silicone MED 40072 (Rhodia Silicones Inc.)	Room temperature vulcanizing or heat cure at 95 for 1.5 hours	---------------
A-2186 Silicone Elastomer (Factor II)	Room temperature vulcanizing or heat cure at 95 for 1.5 hours	Firm silicone, Mixed silicone stay nearly gel inside the moulds.
A-588 Variable Durometer (Factor II)	Room temperature vulcanizing or heat cure at 95 for 1.5 hours	Mixed silicone stay nearly gel inside the moulds.
VST-50 Versital (Factor II)	Room temperature vulcanizing or heat cure at 95 for 1.5 hours This material shows a reasonable working time (2 hours).Easy to use and manipulate.	This material requires de-gassing because of air voids
MED – 4940(Nusil)	This material shows a reasonable working time (2 hours). Provides very thin edges	Cure inhibition, this can be prevented by using 5% of platinum catalyst 50 solution

CONCLUSION

The materials that are used for fabrication of extra-oral prosthesis should have suitable physical properties. These properties are high tear resistance, high tensile strength, high modulus of elasticity, non water absorption, high wettability , colour stability and easy to use and manipulate by maxillofacial prosthetist. It is very important to consider all these properties when making a maxillofacial prosthesis.

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