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Properties of Maxillofacial Silicone Materials: A Literature Review

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I. Introduction

Restoration of facial defects is a difficult challenge for both the surgeon and the Prosthodontist. The Prosthodontist is limited by the inadequate materials available for facial restoration like movable tissue beds, difficulty in retaining large prosthesis and patient acceptance. Material design and properties are main problems faced by scientists in this field. The most common material used for the fabrication of maxillofacial prosthesis is polymeric in nature. These include vinyl chloride polymer and co-polymers, acrylic types, exemplified by polymethyl methacrylate, and silicone elastomer, both HTV and RTV[1,2]. Among these, silicone elastomers have gained considerable clinical importance, because of their heat and chemical inertness, strength, durability, ease of manipulation, esthetics and elasticity.

Till date, none of the facial prosthetic material, including silicone, fulfils all the requirement of a satisfactory prosthesis. The principal reason for replacement of facial prostheses is degradation in appearance because of changes in colour and physical properties. Frequent replacement of the prosthesis becomes less cost effective[3].

Ideal requirements of maxillofacial materials include:
Should be biocompatible/ non toxic/non allergic/nor cariogenic
Easily processed
Polymerization should occur at low temperature
Working time should be suffiecient
Materials should be adaptable to intrinsic and extrinsic coloration
Should be flexible without the addition of plasticizer
Should be chemically saturated
Be vulcanizable and thermosetting
Should have refractive index equivalent to base polymer
Should be dispersed in liquid form so that low pressure casting may be achieved[4].

This article gives a detail review of various properties of maxillofacial silicone materials like biocompatibility with the adjacent tissues, tensile strength, percentage elongation, hardness, tear strength, color stability and dimensional stability of the prosthesis.

II. Literature Review

According to Braley, RTV silicones are composed of short chain silicone polymers with hydroxyl ends. It also contains a crosslinking agent like tetraethyoxysilane(ethyl ortho silicate). Fillers are added for strength and stannous octoate acts as a catalyst.

Heat vulcanizing silicones contains a diorganopolysiloxane like poly di-methyl siloxane and benzoyl peroxide. Synthetic elastomers consists of a terpolymer of butyl acrylate(90%), methyl methacrylate(7.5%), and methacrylamide(2.5%).the terpolymer is composed of polyethyl methacrlate as reinforcing agent, formaldehyde as cross linking agent[2].

III. Properties

Biologic and chemical properties:

Biocompatibility:

Biocompatibility is the ability of material to elicit on appropriate biologic response in the body. It is evaluated using various methods like in-vitro cytotoxicity test on cell and tissue culture, subcutaneous connective tissue or bone implantation methods in experimental animals.

Mutaz B Habal in 1984 evaluated the biocompatibility of silicones and found no major immunologic or histologic rejection when implanted into the body. Some toxic effects that were reported were due to the method of sterilization. The silicones are usually sterilized using autoclave. Chemical or gas sterilization are not used because the chemicals might get adsorbed on the surface of the silicone and lead to toxic reaction in the body[5].

Schmalz and Hambrok in 1989 conducted a study to check the biocompatibility of Mollomed silicone(type of HTV silicone) by intramuscular implantation in rabbits. They found that there was no reaction to macroscopic examination of the implant site nor any inflammatory response of the fibrous tissue capsule around the specimen was noted.

Wolfaardt et al in 1992 evaluated the biocompatibility of Cosmesil maxillofacial silicone by subperiosteal, submucoasal and intramuscular implantation in baboons. They reported that Cosmesil has acceptable biocompatibility for its use in contact with the internal tissue spaces.

Gregory L Polyzois in 1994 assessed the biocompatibility of HTV and RTV silicones using cell culture method. They concluded that Mollomed(HTV), A-2186 and Silbione 71556(RTV) silicones showed no cytotoxic effects with Agarose overlay test[6].

Bige Turhan Bal et al in 2008 evaluated in vitro cytotoxicity of 3 maxillofacial elastomers(Cosmesil, Multisil and Episil) after accelerated aging. They found that none of the silicone elastomers were cytotoxic after 24, 48 and 72 hours of incubation[7].

Chemically inertness:

Sweeny et al in 1972 assessed the use of an accelerated aging chamber for evaluation of the color stability of maxillofacial silicone. When the elastomers are exposed to UV light, alteration in the color takes place due to inherent chemical alterations in silicone or due to discoloration of some pigments that are not UV resistant. Photo oxidation and hydrolysis of the silicone elastomer takes place after exposure to sunlight, humidity and temperature. These reactions results in alterations of the physical and chemical properties resulting in deterioration of the silicone[8].

Many authors like Lemon et al, Ishigami et al have investigated the effect of UV light on pigmented silicone elastomers and have showed that samples pigmented with red pigments discolor at a higher rate than the ones with yellow pigments. Yellow pigments are stable in the presence of sunlight, moisture and temperature below 177^0 C. This is mainly because of the chemical incompatibility between pigment and elastomer that permits migration of pigment during prolonged exposure to ultraviolet radiant energy[9].

The smaller the pigment particle, the higher its interaction with the polymeric chain of the silicone. Organic pigments are difficult to incorporate into silicone. Therefore, easy release of oxygen during disinfection or accelerated aging may occur, leading to more deterioration of the silicone. Furthermore, silicone has weak molecular interactions, which allows higher particles to be more easily separated. This leads to further chromatic alterations in the silicone. The organic pigment exhibits greater degradation with accelerated aging, since these pigments dissolve in contact with UV light.

Physical and mechanical properties:

The desirable physical and mechanical properties of a maxillofacial silicone elastomers are Tensile strength, Percentage elongation, Hardness, Tear strength and Dimensional stability. Many authors have evaluated the physical and mechanical properties of various maxillofacial elastomers and compared with each other.

Sanchez et al in 1992 conducted in vitro study to compare the physical properties of two maxillofacial silicones like MDX4-4210 and A-2186. According to the results obtained A-2186 had greater tensile strength, tear strength and larger percentage elongation[10].

Polyzois and Andreopaulos in 1993 evaluated some properties of clinical importance of a facial elastomer Cosmesil HC2 and compared it with Silskin II and Cosmesil SM4 after exposing to UV light. The results showed that Cosmesil HC2 is a resilient material and displays good tensile characteristics. The results also showed that weathering doesnot affect tear strength[11].

Li Xiao et al in 2007 evaluated the mechanical properties of Cosmesil M511 maxillofacial elastomer and compared it with A-2186 elastomer. The results showed that Cosmesil M511 had higher percentage elongation than A-2186. Tear strength and hardness was higher in A-2186. There was no significant difference in tensile strength and bond strength to acrylic resins between the two groups[12].

Han et al in 2008 studied the effect of increasing nanosized oxide concentration on tensile , tear strength and percentage elongation of A-2186 silicone. Results showed that nanosized oxide concentration of 2% and 2.5% showed significantly higher tear strength, tensile strength and percentage elongation as compared to 0.5%, 1%, 1.5% and 3% weight concentrations[13].

Hatamlen et al in 2010 investigated the mechanical properties of three elastomers namely Techsil S25, Cosmesil M511 and Cosmesil Z004. They also tested for their bond strength to acrylic resin substrate. They found that tensile strength of Techsil S25 was higher than Cosmesil M511 and Cosmesil Z004. Techsil S25 had higher percentage elongation than other silicones.Cosmesil Z004 and Techsil S25 was harder than Cosmesil M511. All materials had same tear strength and modulus of elasticity. Cosmesil Z004 had higher shear bond strength than Techsil S25[14].

All these authors concluded that no single material had all the desirable physical and mechanical properties to be used in the fabrication of maxillofacial prosthesis.

Esthetic properties:
Color stability

Daniela Nardi Mancuso in 2009 evaluated the color stability of silicones nonpigmented and pigmented, when employed for facial use after accelerated aging. In this Medical grade and industrial grade silicones were used. Pigments used were Cosmetic powder, iron oxide and ceramic powder. Reflectance spectrophotometer was used to check the color variation. The aging was done for 1000 hours at different intervals. It was concluded that during spectrophtometric analysis both industrial grade and medical grade silicones presented color instability during different periods of time analysis. The materials without the incorporation of pigments presented similar color alteration values and did not differ significantly. The cosmetic powder used altered the color of the test specimens than the other two pigments[15].

Panagiota N. Eleni in 2008 evaluated the color stability of 4 different pigmented silicone prosthetics after exposure to UV radiation. It was observed that significant differences were present in the color between the control (Un-irradiated samples) and irradiated samples as a result of the degradation caused by the UV radiation. Artificial weathering caused significant color changes detectable to the eye[16].

Marcelo Coelho Goiato in 2009 conducted a study to evaluate the color stability of two silicones subjected to chemical disinfection and storage time, used for facial prosthesis. Efferdent tablets and neutral soap were used for disinfection. Neutral soap was used to disinfect the control group specimens. It was found that the factors of storage time and disinfection with efferdent statistically influenced color stability. Disinfectants act as a bleaching agent in silicone materials[17].

Daniela Micheline dos Santos in 2011 evaluated the influence of two pigments (ceramic powder and oil paint) and one opacifier (barium sulphate) on the colour stability of MDX4-4210 facial silicone submitted for accelerated ageing. All groups exhibited chromatic alteration but the colour change was not perceptible through visual analysis of colour. It was concluded that opacifier protects facial silicone against colour degeneration and oil paint is a stable pigment even without adding opacifier[18].

Fabrication properties:

In 1996 Todd Lund[19] conducted a comparative study for various techniques used to reinforce dental stone moulds for construction of facial prosthesis. Though dental stone mould is convenient for fabricating facial prosthesis, they tend to break when repeated used for making duplicate prosthesis. In this study inexpensive plastic mesh, die hardener, and PVC pipe segment were added to reinforce stone mould. The samples reinforced with PVC pipe surpassed the load limit of Instron testing machine. The samples reinforced with die hardener and mesh were 13% more resistant to breakage than the control samples made of stone alone. Samples reinforced only with mesh were 3 % weaker than control group.

In 1999 Lai[20] et al conducted a study to evaluate and compare the physical properties of A-2186 cured in stainless steel moulds and stone moulds. The effects of additives and curing conditions on the physical properties were also studied. Maxillofacial prostheses are commonly fabricated using dental stone moulds. However, for evaluating physical properties, maxillofacial materials are most often cured in metal moulds. A-2186, a silicone-based maxillofacial prosthetic material was used.. Hardness, tensile strength, ultimate elongation, and tear strength of A-2186 cured in dental stone moulds, stainless steel moulds, and with and without additives were determined. It was found that Hardness, tensile strength and ultimate elongation of A-2186 cured in stainless steel moulds are significantly higher than those cured in stone moulds. Adding a small amount of a pigment, kaolin and a fiber reduces hardness, tensile strength, ultimate elongation and tear strength. Physical properties of A-2186 are affected by the additives commonly used in fabricating maxillofacial prostheses, and use of stone moulds for curing degrades A-2186's mechanical properties. In fabricating clinical prostheses, special attention should be exercised to avoid contamination of A-2186 with impurities that could inhibit curing and produce inferior prostheses.

IV. Conclusion

Materials that are currently available does not possess all the desirable properties for maxillofacial rehabilitation. There are certain advantages and disadvantages in each material. Lot of research needs to be done especially in improving physical and mechanical properties so that it resembles human tissue. Color stable pigments should be developed to match human skin and increase the life of the restoration. The fabrication procedure also plays an important role in producing clinically acceptable prosthesis.

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