
Evolution in Maxillo-Facial Prosthetic Materials-Review

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Abstract:

Maxillofacial prosthetic materials are used to replace the facial parts that are lost through disease or trauma. Acquired and congenital defects of the face create an unfortunate condition for an individual. For the individual to lead a comfortable life requires facial rehabilitation, thus a reassessment of materials used in the field of maxillofacial prosthesis seems desirable.

The materials have travelled a long way from wood, wax, primitive metal, leather, rubber, etc. to the latest biomedical material such as polymers. While the newer materials have exhibited some excellent properties they have also exhibited some frustrating deficiencies. We still are in search of a material comprising all the ideal properties so as to best restore a maxillofacial defect. The prosthodontist are limited by the inadequate material available for facial restorations, movable tissue below, difficulty in retaining large prostheses and the patient's capacity to accept the final result. Hence this review article discuss briefly about the evolutionary changes the maxilla-facial prosthetic material has undergone during these decades.

Key-words: maxillofacial prosthesis, retention aids, magnets, silicone.

Introduction:

Maxillofacial prosthetic materials are materials externally applied to correct facial defects resulting from cancer surgery, accidents, congenital deformities or the like. The term facial disfigurement is use to designate an abnormality of the face that is sufficiently marked to set the individual aside from other members of the society. The major requirements for the materials include high resiliency, high tear resistance and tensile strength, adequate softness, miscibility with the colorants, compatibility with adhesive material and facial tissues, and the materials must be non-toxic and non-irritating.

Maxillofacial prosthetics is defined as that branch of prosthodontics concerned with restoration and/or replacement of the stomatognathic and craniofacial structures with prosthesis that may or may not be removed on a regular or elective basis.¹ The objectives of these materials includes the restoration of aesthetic appearance and function of the patient, protection of tissues, therapeutic or healing effect and psychologic therapy.²⁻⁴ Although surgical procedures may be able to

fill or close off large defects, their results may be less optimal in providing acceptable levels of function or aesthetics.⁵⁻⁸

Maxillofacial prosthetic materials are classified into two main groups: extra oral and intraoral prosthetic materials. Among extra oral prosthetic materials vinyl chloride polymers, poly (methyl methacrylate), silicone, and polyurethane are discussed for use in facial prosthetics. At present silicones and polyurethane materials are considered most desirable for their strength, even though both are somewhat difficult to colour.

The criteria for ideal materials in maxillofacial prosthetics are as follows: extra oral prostheses should not irritate the surrounding tissues, yet it should be strong enough about the periphery to endure. It should be translucent, light weight, easy to process, and easy to manipulate prior to processing. It should be resistant to various chemicals such as ether, oil and to sunlight, heat, and cold. Implantable prosthetic materials must not be physically modified by

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the soft tissue; must not be capable of inciting inflammatory or foreign body reaction; must be chemically inert, non carcinogenic, capable of resisting strain, easy to construct, and easy to sterilize.

Several plastic materials, including acrylic polymers, silicones and polyurethanes, have been used for maxillofacial reconstruction. Among them, polysiloxanes, or the so-called silicones, have been used most widely. This is mainly due to several generally favourable qualities including ease of fabrication, high degree of chemical inertness, low degree of toxicity, and high degree of thermal and oxidative stability. The uniqueness of polysiloxanes is that siloxane bonds Si--O--Si in the main chains, as well as Si--C bonds where side groups are bonded to silicon, are extremely flexible and have a great freedom of motion. This is reflected in their lower viscosity, lower surface tension, lower melting point and glass transition temperatures, and is responsible for the elastomeric behaviours of many polysiloxanes.

Historical Background:

The origin of prosthetic reconstruction of facial defect has not been well documented by historians, archaeologists have found eyes noses, and ears constructed from waxes clay and wood in ancient Chinese culture. Artificial eyes have also been found in artificial mummies. **Prophet Mohammed (570-632)**⁹ had asked one of his companions who had lost his nose in a battle to get an artificial nose made of gold. **Ambrose Pare (1510-1590)**¹⁰ a famous French surgeon appears to have been the first to describe fabrication of nasal prosthesis using gold, silver, paper and linen cloth glued together. **Pierre Fauchard (1678-1761)** made great contributions to the prosthetic reconstruction of face. He made a silver mask to replace the lost portion of the mandible for a French soldier. **William Morton (1819-1868)**¹⁰ was credited with fabrication of nasal prosthesis using enamelled porcelain to match the complexion of patient. In 1880 **Kinsley**¹⁰ described a combination nasal palatal prosthesis in which the obturate portion was an integral part of nasal prosthesis. In 1889 **Claude Martin**¹¹ described using a ceramic material to fabricate a nasal prosthesis towards the end of nineteenth century; vulcanized rubber was widely used for facial prosthesis. **Upham** described the fabrication of nasal and auricular prosthesis made from *vulcanized*

rubber. In 1905 **Ottofy, Baird and Baker** reported using black vulcanized rubber as foundation for nasal prosthesis. In 1913, **gelatin-glycerin** Compounds were introduced for use in facial prosthesis in order to mimic the softness and flexibility of human skin. **Bercowitch** described the technique of fabrication and colouring of gelatin-glycerin facial prosthesis using water soluble dyes. **Kazanjian** described the use of celluloid paints for colouring vulcanized rubber facial prosthesis. In 1937, acrylic resin was introduced in the field of extra oral prosthesis. To overcome the rigidity problems of acrylic resin, **Tylman** introduced the use of **resilient vinyl copolymer acrylic resin** for facial prosthesis acrylic resin for facial prosthesis he used acrylic resin polymer stains for intrinsic colouring and water colour for extrinsic staining. In 1950, **Brasier** used acrylic resin polymer stains for intrinsic colouring and oil colours mixed with acrylic resin monomers for external tinting of facial prosthesis. In the early 1960's the introduction of **elastomers** resulted in major changes in fabrication of facial prosthesis. **Barnhart** was the first to use silicone rubber for construction and colouring facial prosthesis by combining a silicone rubber base with acrylic resin polymer stains. **Tashma** used dry earth pigments dispersed in colourless acrylic resin polymer powder for intrinsic colouring of silicone facial prosthesis. **Quellette** mixed dry mineral earth pigments in a silicone base material for external spray colouring of silicone prosthesis. In 1965 **Firtell and Bartlett** used dry mineral earth pigments and silicone base materials to produce stock colours from which base shade and surface colors could be formulated. **Schaff** reported the use of artists oil paint tattooed into the surface of silicone facial prosthesis to simulate freckles, blood vessels and general shading. **Fine** described the use of colored nylon flocking as a major colorant for both internal and external coloring of facial prosthesis. During 1970 different types of elastomers were used **Lantz** used modified **polysiloxane** elastomers. **Lewiz and Castleberry** described the use of **siphenylones** for facial prosthesis. In 1980 **Udagama and Drane**¹² introduced the use of silastic medical adhesive silicone type A for fabrication of facial prosthesis he also reported using prefabricated polyurethane film as a lining for facial prosthesis. In 1990 to the present, new generation acrylic resins have been introduced by **Antonucci and Stansbury**. Silicone block

copolymer and polyphosphazenes were evaluated in the market during this period.

Materials Used In Fabrication Of Maxillofacial Prosthesis:

1. Acrylic
2. Acrylic copolymers
3. Polyvinyl chloride and co polymers
4. Chlorinated polyethylene
5. Polyurethane elastomers
6. Silicone elastomers.

Acrylics:

These are chemically *polymethyl methacrylate* which can be compression or injection moulded and been used successfully for both intra and extra oral prosthesis. The material is readily available and the processing techniques are familiar and are compatible with most of the adhesive system and can be stained both intrinsically and extrinsically. Rigidity is the primary disadvantage of acrylic resin and its usefulness is compromised in highly movable tissue beds. Its relatively high thermal conductivity when compared to silicones can cause discomfort in cold climate and duplication of the prosthesis is not possible. Facial prosthesis made of these materials remains serviceable for upto 2 years and may require occasional surface repainting.

Acrylic Copolymers

Acrylic Copolymers are soft and elastic but have not received wide acceptance because of its number of objectionable properties like poor edge strength, durability and degradation when exposed to sunlight. These are nothing but elasticated methyl methacrylates (Palamed). **Palamed** can bond chemically to hard acrylic but attraction of dirt is a major problem and has a unique resilience. Incorporation of high molecular weight *acrylic polymers* with molecular blocks of polymer likes *polyether urethane; - hydrocarbon, - fluorocarbon or silicone* can eliminate the short comings of traditional acrylic copolymers and contain camphoroquinone as a photo-initiator.^[13]

Polyvinyl Chloride And Copolymer

At one time vinyl polymers and copolymers were popular and were widely used for facial restorations. The earliest form consisted of a combination of polyvinylchloride and plasticizers. These additives however extended processing time and predisposed to undesirable

shrinkage. Recently a copolymer of 5% to 20% vinyl acetate, with the remaining percentage being vinyl chloride has been introduced. The copolymer is more flexible, but less chemically resistant than poly vinyl chloride. The disadvantages include undesirable shrinkage, poor dimensional stability and poor edge strength. They lack life like translucency and tend to absorb sebaceous secretions and soil easily. Polymer degradation and darkening of the material secondary to ultraviolet exposure are very common.

Chlorinated Poly Ethylene

Lewis and castlebury^[14] made experiments on chlorinated poly ethylene a material similar to poly vinyl chloride in both chemical composition and physical properties. The processing procedure is complicated and requires the use of metal moulds and high heat curing of the thermoplastic polymer. Later on a potential material with processing techniques using gypsum moulds and steam autoclaves was developed with a laminated colouring technique but the processing procedures were relatively cumbersome.

Polyurethane Elastomers

Ephane -3 is available for use in facial restorations. These elastomers are denoted as polyurethane because they contain urethane linkages. They arise from 2 major reactions, in the presence of a catalyst; a polymer terminating with an isocyanate is combined with one terminating with a hydroxyl group. They are quite elastic with good edge strength and flexibility thus suited to defects with movable tissue beds and can be coloured both intrinsically and extrinsically.

Isocyanates^[15] are moisture sensitive causing local irritation and contamination. Cleansing the adhesive from the prosthesis is difficult and can be toxic. Hence care must be taken when using isocyanates. Processing procedure is complicated and requires metal, epoxy or urethane molds. **Turner & castlebury**^[16] reported the development the development of an aliphatic **polyurethane prepolymer – isophorone** and evaluated the mechanical properties of polyurethane elastomers reporting that the material did not disintegrate and demonstrated many desirable characteristics for use as a maxillofacial elastomer.

Silicone Polymers

Silicones were introduced around 1946, but came into use as in the fabrication of maxillofacial prosthesis only by around 1970's. Silicones consist of chain of alternate silicon and oxygen atoms, which can be modified by attaching various organic side chains to the silicon atoms or by cross linking the molecular chains. They are chemically termed *polydimethylsiloxane*. Silicones range in properties from rigid plastics through elastomers to fluids. As a maxillofacial material silicones exhibit weathering properties and maintain good physical properties over a wide temperature range.

Silicones are Classified:

a) According to applications:

1. **Implant grade:** used for implants but recently has been under a lot of controversy due to its adverse reactions as in the case of breast implants.
2. **Medical grade:** approved for external use only, this group involves the one used for fabrication of maxillofacial prosthesis.
3. **Clear grade and**
4. **Industrial grade**

b) According to vulcanisation procedure:

1. **HTV (High temperature vulcanisation) silicones**
2. **RTV (Room temperature vulcanisation) silicones**

High Temperature Vulcanizing [Htv] Silicones

HTV silicone is a white, opaque material with a high viscous consistency. The vulcanizing agent of HTV silicones is *dichloro benzoyl peroxide or platinum salt*. Filler used are finely divided *silica* with a particle size of **30µ**. Processing of heat cures silicones require sophisticated instrumentation and high temperature. These silicones exhibit excellent colour stability when exposed to ultraviolet light and are biologically inert. Some examples are **Silastic 370, Silastic 372, Silastic 373, Silastic 4-45145**.

Polydimethylsiloxane oligomers are added to reduce the stiffness and hardness of the prosthesis. The important objections are its *opacity* and lifeless appearance. They do not readily accept *extrinsic coloration* and extremely high temperatures are required for vulcanizing. **Bell¹⁷** evaluated the new generation of HTV silicones, [**Q7-4635, Q7-**

4650, Q7-4735, QE-4524U] and said they have improved physical and mechanical properties than MDX4- 4210 and MDX 4-4514. **Lontz and schweiget¹⁸** reported a new type of HTV silicone [**PDX siloxane**] saying that they are relatively acceptable materials. In **general** HTV silicones have better physical and mechanical properties than **RTV** silicones. The drawback of the materials is its opacity, difficulty in coloration, high superficial surface hardness and difficulty in processing.

Room Temperature Vulcanizing [Rtv] Silicones

These silicones are based first on *dimethylsiloxane oligomers* with terminal hydroxyl groups polymerised by condensation reaction, with a *tin* compound (catalyst) and a cross linker with the formation of ethanol byproduct and an unsaturated *vinyl terminated* dimethylsiloxane with a *silane terminated* dimethylsiloxane. These silicones have become the most common material as far as maxillofacial prosthesis is concerned due to its ease of processing.

Medical Grade Elastomer [A-103 - MDX4-4210] is a pourable, clear to translucent, platinum-cured, high strength medical grade silicone rubber which cures at room temperature. It has no shrinkage when cured at room temperature but have high elongation and improved tear strength.

Silastic medical adhesive silicone Type A is a one-component, low-slump, translucent silicone material for bonding silicone elastomers to one another, as well as to some synthetics and metals. Contains no solvents and cures at room temperature on exposure to air and moisture. While curing, the silicone adhesive gives off an acetic acid vapour. Following curing it is of the same chemical composition as other medical grade silicone elastomers. **Medical Grade Dispersion [A-4159 - MDX4-4159]** is a liquid RTV solution containing 50 percent active silicone ingredients in mixed aliphatic and isopropanol solvents. The active silicone used is an amino functional dimethylsiloxane copolymer. It has an excellent lubricity, high adhesion to metal, easy application, and room-temperature curing property.

Platinum Silicones

A-2000 is the latest in the development of elastomers specifically formulated for

prosthetics. This is the first generation of 1:1 mixture RTV silicone reacting well with thixotropic agents. The clinicians can control the viscosity of this silicone while working with the uncured material. **A-2002 Platinum Silicone Elastomer** is a new, low durometer, 10:1 by weight platinum, optically clear silicone elastomer. This low viscosity silicone is pourable and reacts with thixotropic agents. **A-2186 Silicone Elastomer** is a mixture of 10:1 Platinum Cure System. A-2186 Silicone Elastomer is a two-part, clear to translucent pourable silicone system which will cure at room temperature. Cure time can be reduced with elevated temperature. When properly cured, A-2186 offers high tear strength along with other good physical properties. **A-220 PSE-05 Soft Silicone Elastomer, A-222 PSE-30 Medium Silicone Elastomer, A-224 PSE-65 Hard Silicone Elastomer, VST-50, VST-50HD** are the latest silicones available and can be heat accelerated, with curing time of about 8-12 hrs at room temperature.

Condensation Silicones

TnSil Silicone Elastomer [FX-108T, FX-308T] are the new condensation cure, RTV, low viscosity, translucent, low durometer, tin silicone elastomer, which has proven to be a very economical and versatile material with enhanced properties and physical characteristics. Works well with the addition of A-300-8 thixotropic agent. The addition of FX-109 Accelerator to the elastomer, will accelerate the curing rate it and also decrease the library life of the elastomer. **Prosthetic Silicone Elastomer [A-101 6382]** has two-part RTV Elastomer and are prepigmented to an off-white color. Base is polydimethylsiloxane. Working time and curing time can be adjusted to the needs of the clinician from 4 minutes to one hour. Material is pourable and will vulcanize in the presence of moisture with no effect on the rate or thoroughness of the cure. Curing agent is Stannous Octoate. **Low Density Silicone Elastomer Kit [A-106 2370]** is a two component prosthetic Silicone Foam system supplied as a silicone base and catalyst. The system cures to rubbery foam at room temperature with minimal heat evolution. **Silastic 382, 399** is a viscous silicone polymer includes a filler, catalyst stannous Octoate, Orthosilicate cross-linking agent. These elastomers are color stable, biologically inert and retain their physical and chemical properties over a wide range of temperatures. **Silastic 891 - Udagama and Drane**^[19] first

reported the use of this material. It is a translucent flowing paste which polymerised at room temperature and requires no catalyst. In **1987 Udagama**²⁰ reported about improving the edge strength by bonding the prosthesis to a prefabricated polyurethane film with a primer. **Silastic 386** is a form of RTV silicone that belongs to the foam forming variety. Gas bubbles are released when the catalyst is added within the vulcanizing silicone. After the silicone is processed the gas is eventually released leaving a spongy material thereby reducing the weight of the prosthesis. **Cosmesil** was introduced in the year 1982. It is also a condensation type of RTV silicone which has very good flexibility, and tear strength. They are available as **cosmesil SM4** and **cosmesil HC2** (high compliance) and can be processed to varying degree of hardness.^[21]

NEWER MATERIALS:

SIPHYNELONES - These materials are silicone copolymers that contain methyl and phenyl groups. They exhibit improved edge-strength, low modulus of elasticity and improved colour stability when compared with the conventional polydimethyl siloxane.

POLYPHOSPHENES - Novas developed these materials for use as a resilient denture liner and have the potential to be used as a facial prosthesis.

SILICONE BLOCK POLYMERS - These materials are under development to improve some of the weakness of silicone, such as low tear strength, low percentage elongation, and the potentiality to support fungal growth.

OTHER RELATED MATERIALS:

1. PRIMERS:

Primers are available to bring effective bonding between silicones and acrylic and also to polyurethane sheets they are available individually for the platinum and condensation silicones.

Primers for platinum silicones: A330, A304, A305

Primers for condensation Silicones: A 320, A303-1, A330

2. COLOURS AND COLORATION:

Coloration of the prosthesis varies with the materials used. Basic skin tone should be developed into a shade guide for the materials that are used. The base shade is selected for the patient should be slightly lighter than the lightest skin tones of the patient. Surface details and characters can be added by either

intrinsic or extrinsic coloration. Intrinsic coloration is long lasting but is difficult to accomplish.

Colorants documented for maxillofacial prosthesis in the literature are:

- **Enamel porcelain and Ceramics**
- **Artists paint, Water soluble dyes & Celluloid paints**
- **Photographic stains, Acrylic resin stains**
- **Food colouring and Oil colouring**
- **Dry earth pigments and Nylon flocking**

Colouring silicones can be a difficult task. Many years been spent in the laboratory in developing colouring systems that are easy to use and provide excellent custom colour matching capabilities. The human visual system responds to the very small part of the electromagnetic spectrum that lies between 380 and 760 nanometers. It however does not respond uniformly. Given the same amount of output of power at each wavelength, the visual system will sense the yellow-green region as being the brightest and the red or blue regions as the darkest.

Colour research in maxillofacial prosthesis

The value and success of a well fitting prosthesis are compromised if the colour doesn't match properly with the adjoining tissue. A prosthesis that is given a solid flat colour is unrealistic and will appear artificial. It is by intrinsic coloration that a base shade is best produced. Colorants are pigments or dyes pigments are insoluble particles that most frequently produce light by scattering layers. Dyes are molecularly dispersed substances that most frequently produce transparent layers. Inorganic pigments often absorb the light characteristics

Many approaches and techniques existing for shade matching are trial and error mixing, Shade guide, Pigment dispersion, Colour measurements using a colorimeter or spectrophotometer, computerized colour formulations. At present most of the colour matching are done by trial and error basis, and no standardization for future reference is possible. **IKA-1 - Four Colour Intrinsic Shaker** creates consistent colours. This is an electric mixing device used for the uniform mixing of the intrinsic silicone pigments. This unit will shake up to 4 bottles at one time. It contains an electronic rheostat and creates a very consistent homogeneous mixture in less

than one minute. **Cantor** was the first to report using a reflectable **spectrophotometer** to evaluate the colour of human skin. It was found that discoloration of maxillofacial prosthesis may be largely due to environmental factors. **Kazangian** and others called for an extrinsic application of colorant to achieve a desirable tone. **Barnhart** used coloured methyl methacrylate powder and intrinsically to silicone rubber. **Tashima** added inorganic pigments powder to clear methyl methacrylate powder and applied intrinsically to a medical grade silicone. **Schaaj** used tattooing machine to apply pigments. **Bartlett** choose a silicone medical adhesive as a vehicle for extrinsic coloration.

3. ADHESIVES

The adhesives are classified according by the method they are dispensed [pastes, liquid emulsions, spray on and double sided tapes]. Among these **Double sided tapes** are the most commonly used because of the ease of application and removal.

Solvent Based Medical Adhesives:

These are pressure sensitive medical silicone adhesive which are dispersed in **pentafluoropropane**. It retains adhesive qualities in the presence of moisture or perspiration. Also adhesive qualities are unaffected by normal temperature variations

Water Based Medical Adhesives:

This adhesive in water emulsion [**B-400 and B- 401 - Secure Medical Adhesive**] has proven to be an excellent adhesive. There are no solvents present and for the past 20 years it has shown extremely good patient acceptance.

SILASTIC MEDICAL ADHESIVE SILICONE TYPE A is a one-component, low-slump, translucent silicone material for bonding silicone elastomers to one another as well as to some synthetics and metals. **SKIN – PREP** protective dressings are available which are made up of isopropyl alcohol, butyl ester of polyvinyl methacrylate and acetyl tributyl citrate.

Magnets

The magnets [**IM1, IM2 and IM3- Prosthesis Magnet**] are split-pole design with an airtight corrosion resistant seal and protected shim. A color coded magnet can be used to make a pick-up impression. **Multi Purpose Magnet [IMOB2]** are extremely powerful attachment used for multi-component assemblies of

prosthesis such as denture/obturator combinations. This attachment comprises of two paired magnets (one single and one lipped) and each magnet has a flange for retention within the prosthesis.

Conclusion:

Materials used for maxilla-facial prosthetics should emphasis the full range of chemical structures, physical properties ranging from hard stiff alloys, ceramics and polymers to

soft, flexible polymers. Still no material has gained favourable concern from the clinicians.²² The prosthodontist are limited by the inadequate materials available and no material in use exhibits all the desirable properties. These all state that the materials currently available do not meet the need. Hence selection of material for facial properties is more often dependent on the individual experiences and preferences of clinician.

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