



ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2021; 7(2): 255-259
© 2021 IJADS
www.oraljournal.com
Received: 09-02-2021
Accepted: 25-03-2021

Dr. Rajat Lanzara
Graded Specialist,
Prosthodontics, Military Dental
Centre, Bareilly, Uttar Pradesh,
India

Dr. M Viswambaran
Commandant, Air Force
Institute of Dental Sciences,
Bangalore, Karnataka, India

Dr. Dinesh Kumar
HOD, Department of
Prosthodontics and Crown &
Bridge, Army Dental Centre,
Research & Referral, Delhi,
India

Corresponding Author:
Dr. Rajat Lanzara
Graded Specialist,
Prosthodontics, Military Dental
Centre, Bareilly, Uttar Pradesh,
India

Maxillofacial prosthetic materials: current status and recent advances: A comprehensive review

Dr. Rajat Lanzara, Dr. M Viswambaran and Dr. Dinesh Kumar

DOI: <https://doi.org/10.22271/oral.2021.v7.i2d.1219>

Abstract

Body abnormalities or defects that compromise form, function and esthetics are sufficient to render an individual incapable of leading a normal life. Maxillofacial disfigurement can be the result of a congenital anomaly, trauma or tumour surgery. Multiple times due to size, location of the defect or because of patient's medical condition surgical reconstruction may not be possible so prosthetic rehabilitation is indicated in these cases. But the success of prosthetic rehabilitation is largely determined by the physical and mechanical properties of the material used. Materials commonly used these days for fabrication of facial prostheses are acrylic resins, acrylic copolymers, vinyl polymers, polyurethane elastomers and silicone elastomers. There has always been a quest for a maxillofacial prosthetic material that closely matches the defect tissues in appearance and properties. This article focuses on historical background, changing trends and future aspects of various materials used in rehabilitation of maxillofacial defects with their limitations and modifications.

Keywords: Maxillofacial defect, prosthetic materials, rehabilitation, silicone

1. Introduction

A healthy body, a beautiful face and a pleasing appearance forms an integral component for personal and professional success. Occurrence of any defect in the body particularly in the head and neck region adversely affects the appearance, function, social acceptance and psychological confidence of the patient. Facial disfigurement can be the result of a congenital anomaly, trauma or tumour surgery^[1]. Among the defects, head and neck cancers contribute a major factor as the etiology of the defect^[2].

Most of the cases undergo surgery with or without radiotherapy and or/ chemotherapy. Rehabilitation of these patients is the most essential and challenging phase of the treatment. The aim of any rehabilitation procedure is to return the patient to the society in a near normal status. Rehabilitation can be done either surgically or prosthetic^[3]. A facial prosthesis restores normal anatomy and appearance, protects the tissues of a defect, and provides great psychological benefit to the patient.

Prosthodontic results are largely determined by the materials used in the construction. Success of maxillofacial prostheses depends mainly on the physical and mechanical properties of the material used. An ideal maxillofacial prosthetic material should have optimum physical and mechanical properties. These include high tear strength, tensile strength, biocompatibility, possibility of coloration and adequate hardness level similar to the tissues of defect site^[4]. Materials commonly used for fabrication of maxillofacial prostheses are acrylic resins, acrylic copolymers, vinyl polymers, polyurethane elastomers and silicone elastomers^[5].

2. Historical Background

Early records indicate that artificial eyes, ears, nose were found on Egyptian mummies. They were made from ivory, rock, silver, gold, bronze and were often overlaid with organically – pigmented porcelain^[6]. Ambrose Pare in 1541 began keeping accurate records that benefited deformed human subjects from facial prosthesis. He described the use of facial prosthesis as an alternative to surgical reconstruction and was first to use an obturator to close palatal perforations^[7].

Tycho Brahe in 1576 lost his nose in a sword duel and replaced it with an artificial nose made of silver and gold. He apparently made a wax pattern to fill the defect and cast it [7]. In 1728, Pierre Fauchard designed a prostheses supported with wings that were positioned by patient from the oral side of obturator and made use of floor of nose for retention. In 1832 a young French soldier named Alphonse Louis was injured and rehabilitated with prosthesis of silver which had mandibular teeth, a hinged front replacing the facial structures, and an internal collecting reservoir for the secreted saliva. Louis was known as "Gunner with the silver mask" [8]. In 1880, Kingsley described fabrication of nasal prosthesis and obturator. Upham in 1900 described the fabrication of nasal and auricular prostheses made from vulcanite rubber. In 1913, gelatine-glycerine compounds were introduced for fabrication of maxillofacial prosthesis. Acrylic resin was introduced to the dental profession in 1940, and it replaced the older vulcanite rubber. Tylman introduced the use of a resilient vinyl copolymer acrylic resin for facial prostheses [7]. In 1960, Barnhart was the first to use silicone rubber for constructing and coloring facial prostheses by combining a silicone rubber base material with acrylic resin polymer stains [9]. Gonzalez described the use of Polyurethane Elastomers [10]. Lewis and Castleberry described the potential use of Siphenylenes for facial prostheses [6]. Turner documented the use of Isophorone Polyurethane [11]. Udagama and Drane introduced the use of Silastic Medical Adhesive Silicone Type A for fabrication of facial prostheses [12]. Udagama reported using prefabricated Polyurethane films as a lining for facial prostheses fabricated using Medical Adhesive Type A [13]. Advances in polymer chemistry have renewed interest in developing new materials for facial prostheses.

3. Currently Available Materials

Selection of the material used for fabricating a maxillofacial prosthesis depends on the objectives of the rehabilitation procedure. The following important objectives must be fulfilled - Restoration of esthetics, function, protection of tissue, therapeutics or psychological effect.

3.1 Acrylic Resin

Acrylic resin has been successfully employed for specific types of facial defects, particularly those in which little movement occurs in the tissue bed during function [14]. The major advantage of using acrylic resin is that material is readily available, chemical properties and processing techniques are familiar to dentists. Extrinsic and intrinsic coloration can be utilized with acrylic resin. Goiato *et al.* reported that microhardness of the resin was not influenced by the method of disinfection or the time of storage. Main drawback of the material is its rigidity so can't be used in highly movable tissue beds leading to local discomfort and exposure of margin [15].

3.2 Acrylic Co-Polymers (Palamed)

They are soft and elastic. The molds are underfilled (by 10%) to permit expansion of the material and formation of the foam like center. Cantor and Hildestad explained the complete procedure for fabrication of prosthesis [6]. Material however didn't receive wide acceptance because of objectionable properties like - poor edge strength, poor durability, degradation when exposed to sunlight, processing and coloration is difficult and the completed restoration becomes tacky, predisposing to dust collection and staining. Development of a new generation of acrylic monomers,

oligomers, and macromers was reported by Antonucci and Stansbury [8]. Their approach is to incorporate high-molecular weight acrylic polymers with molecular block of other types of polymers, for example - Poly - ether urethane, Poly - hydrocarbon, Poly - fluoro carbon, Poly - siloxane that can eliminate the short coming of traditional acrylic co-polymers and meet the requirements of a maxillofacial elastomer.

3.3 Polyvinyl Chloride & Copolymers

Chalian VA, Phillips RW introduced use of this material for fabrication of facial restorations [5]. The earliest form-consisted of a combination of a polyvinylchloride (a hard, clear resin that is tasteless & odorless) and plasticizer (which allows for processing at low temperature) [16]. Later copolymer of 5% to 20% vinyl acetate with vinyl chloride was introduced. The polymer was a thermoplastic material which was supplied as a solid suspension in a solvent. The material was more flexible and adaptable to both intrinsic & extrinsic coloration. The main drawback was that metal mould had to be used for curing and material exhibited poor tear strength and color stability.

3.4 Polyurethane Elastomers

Juan B. Gonzalez, Edmund Y.S. Chao, Kai Nan-An described the use of polyurethanes [17]. It is produced in presence of a catalyst, a polymer terminating with an isocyanate is combined with one terminating with a hydroxyl group. Polyurethanes possess excellent properties like flexibility, good edge strength, can be colored both intrinsically & extrinsically and good cosmetic results [18]. An important drawback is that curing requires precision as Isocyanate is moisture sensitive. When mold is contaminated with water - gas bubbles cause defects & poor curing of material results. Processing requires thorough dehydration before processing if stone molds are used.

3.5 Silicone Elastomers

The silicones were introduced in 1946, but only past few years they have been used in fabrication of maxillofacial prosthesis [19]. Silicone is made up of alternate chains of silicone and oxygen which can be modified by attaching various organic side groups to the silicon atoms or by cross linking the molecular chains.

Silicones have range of properties from rigid plastics through elastomers to fluids. They exhibit good physical properties over a range of temperature. Silicon is a combination of organic and inorganic compounds. Mohammad SA in their study reported that silicon resist absorbing organic materials that lead to bacterial growth; so, with simple cleaning, these materials are relatively safe and of adequate sanitary quality as compared to other materials [20]. Vulcanization makes the silicone resistant to ultraviolet (UV) light [21]. Depending whether the vulcanizing process uses heat or not, silicones are available as heat vulcanized (HTV) or room temperature vulcanized (RTV), and both exhibit advantages and disadvantages [22].

A. High Temperature Vulcanized Silicone

HTV silicone is usually a white, opaque, viscous material having a putty like consistency. They are available as 1-component or 2-component systems. The catalyst / vulcanizing agent of HTV is Dichlorobenzyl peroxide/platinum salt [23]. Various amounts of fillers are added depending on degree of hardness, strength and elongation. Polydimethyl siloxane may be added to reduce the stiffness or

hardness of the prosthesis. Lontz reported use of modified polysiloxane elastomers [24].

The process of vulcanization requires greater milling of the solid HTV stock elastomer for mixing the catalyst for cross-linking and pigmenting [24]. Vulcanization or cross-linking occurs by free radical addition. The processing temperature ranges from 180 to 220 °C for about 30 minutes under pressure using metal molds. Abdelnabbi *et al.* reported favourable results for mechanical and physical properties [9]. They have excellent tear strength and highest tensile strength, high percent elongation, excellent thermal, color and chemical stability rendering it more biologically inert.

B. Room Temperature Vulcanizing Silicones (RTVS)

Room temperature vulcanizing silicones (RTVS) are of two types – based on the type of reaction

1. Cross-linkage occurs by condensation reaction [25]: They have reactive groups, such as silanols (hydroxyl terminated polysiloxanes), cross-linking agent, e.g. tetraethyl silicate, and a catalyst, such as triacetoxysilane is used as the cross-linking agent. Their use has been limited to that of an extrinsic colorant carrier applied to the surface of the prosthesis eg Silastic 382 and 399.

2. Cross-linking of polysiloxanes by addition reactions [26]: These involve the addition of silyl hydride groups (-SiH) to vinyl groups (CH₂=CH-) attached to the silicone in presence of platinum as catalyst. These silicones are not truly room vulcanized silicones as curing of these silicones require heating the material at 150°C for an hour. Prostheses are polymerized by bulk multiple packing. Recently, epoxy resins and stainless steel molds are being used examples are silastic 382, 399, 891, MDX4-4210, Cosmesil, A-2186 and A-2186F. RTV silicone is blended with suitable earth pigment to produce the patient basic skin color.

Dooz ER, Koran A, Craig RG in 1994 evaluated the effect of accelerated aging on the physical properties of three maxillo-facial materials i.e. MDX 4-4210, A-2186, Cosmesil. They concluded that cosmesil substance showed maximum effect, and MDX 4-4210 the least change in their properties, of aging [27]. Aziz T, Waters M, Jagger R in 2003 conducted a study to analyze properties of five commonly used maxillofacial silicone materials Factor II, Cosmesil HC, Cosmesil St, Nusil and Prestige. They concluded that none of the commercially available silicone rubber materials possessed ideal properties for use as a maxillofacial prosthetic material [28].

4. Recent Advances

4.1 Silicone Block Co Polymers

Silicone block copolymers are new materials under development to improve some of the weaknesses of silicone elastomers, such as low tear strength, low – percent elongation, and the potential to support bacterial or fungal growth [29]. It has been found that silicone block copolymers are more tear-resistant than are conventional cross – linked silicone polymers. This is achieved by a surface modification consisting of the incorporation of block copolymers containing a PDMS block and a poly [2-(dimethylamino) ethyl methacrylate] (PDMAEMA) block in a PDMS matrix [30]. The improvement of the bioadhesive properties of elastomeric polydimethylsiloxane (PDMS) coatings is reported. Observations highlight the significant role of hydrophilic groups in the surface modification of silicone coatings.

4.2 Polyphosphazenes

Gettleman was first to introduce use of polyphosphazenes for fabrication of maxillofacial prostheses [31]. Polyphosphazenes fluoro elastomer has been developed for use as a resilient denture liner and has the potential to be used as a maxillofacial prosthetic material. Modifications of physical and mechanical properties of this commercially available elastomer may be needed to satisfy the requirements for fabrication of maxillofacial. Researchers in New Orleans dealt with maxillofacial prosthesis, have found that compounding polyphosphazenes with little or no fillers and decreasing the ratio of acrylic to rubber yields a softer rubber, with a HDA of 25, similar to human skin [11].

4.3 Foaming Silicones

Firtell *et al.* introduced foaming silicone for fabrication of light weight prosthesis [32]. When silicon is mixed with stannous octoate catalyst, releases a gas in the vulcanization process as bubbles are released with the resulting silicone mass being increased and density being decreased, which presents a much lighter material [33]. This process requires special flasks to deal with expansion problems while the gas is forming during processing. The mold also requires venting for gas release and reduction of expansion of the prosthesis. The purpose of the foam forming silicones is to reduce the weight of the prosthesis.

4.4 Siphenylenes

Lewis and Castleberry described the potential use of Siphenylenes for facial prostheses [34]. Siphenylenes are siloxane copolymers that contain methyl and phenyl groups. They are formulated as a pourable, viscous, room-temperature vulcanizing liquid. In tactile response, silphenylene elastomers feel more like skin. These polymers are transparent even when reinforced with silica fillers. These polymers possess many desirable properties of RTV silicones, including biocompatibility and resistance to degradation on exposure to ultraviolet light and heat. In addition, they exhibit improved edge strength, low modulus of elasticity and colourability. They also exhibit improved edge strength and low modulus of elasticity over the more conventional polydimethylsiloxane [34].

5. Future

With the advancement in medical sciences and incorporation of engineering concepts have resulted in development of prosthesis capable of perceiving sensory stimulus similar to natural sense organs. These organs have been termed as Bionic organs. The term 'BIONIC' means - having or denoting an artificial, typically electromechanical, body part or parts [35]. A Bionic organ is an engineered device or tissue that is implanted or integrated into a human interfacing with living tissues to replace a natural organ, to duplicate or augment a specific function or functions so the patient may return to a normal life as soon as possible [36]. Research in the maxillofacial region have led to the development of Bionic eye, nose and ear which consist of microchips, transducers, polymers, semiconductors, electronic arrays and radio transmitters. Various models and systems are already available and further research and development is under process.

Also the advancement in digital technology particularly Rapid prototyping and CAD/CAM has opened new avenues for time efficient, life like prosthesis. Multiple studies are focussed on

production of 3D printed silicone for fabrication of prosthesis. The CAD/CAM or 3D Printing can be joined with E-Skin spectromatch spectrometer uses a digital library of nearly 20,000 skin tones to match to patient skin for prosthetic applications. All entries in the digital library have a matching colorant recipe. The E-Skin instrument measures skin color and instantly retrieves and displays on its screen a matching colorant recipe from its database.

6. Conclusion

The most common materials currently in use for the fabrication of intraoral and extraoral prostheses are polymeric nature and they exhibit almost all desirable physical, biologic and clinical properties. The completed facial prostheses should be unnoticeable in public, faithfully reproducing lost structures in the finest detail. Its color, texture, form and translucence must duplicate that of missing structures and adjacent skin. To date, none of the commercially available materials satisfy all the requirements of the ideal material. Each of the material has strengths and weakness. Future research should concentrate on several major goals.

1. Improvement of the physical and mechanical properties of existing materials available or development of new alternative materials so that it will behave more like human tissue and increase the service life of the prosthesis
2. Identification of Color-stable coloring agents that are compatible with different types of elastomers.
3. Development of scientific method of color matching to human skin.
4. Development of a scientific color formulation system that conforms to the color matching tool to allow objective replication of human skin shades.
5. Development of 3D printed maxillofacial silicone prosthetic material.

7. References

1. Worthington P, Branemark PI. Advanced Osseo integration surgery: applications in the maxillofacial region. *BJOM* 1992;4(6):23-27.
2. Mortaon RP, Izzard ME. Quality of life outcomes in head and neck cancer patients. *World J Surg* 2003;27(3):884-889
3. Bou C, Pomar P, Miquel JL, Poisson P. Maxillo-facial prostheses: an issue in public health. *Odontostomatol Trop* 2006;29(113):34-40.
4. Eleni PN, Krokida M, Polyzois Gettleman L, Bisharat GI. Effect of outdoor weathering on facial prosthetic elastomers. *Odontology*. 2011;99(1):68-76.
5. Chalian VA, Philips RW. Materials in maxillofacial prosthetics. *Journal of Biomedical Materials Research Symposium* 1974;5(2):349-63.
6. Ring ME. The history of maxillofacial prosthetics. *Journal of Plast Reconstr Surg* 1991;87(1):174-184.
7. Maller US, Karthik KS, Maller SV. Maxillofacial prosthetic materials past and present trends. *J Indian Acad Dent Spec* 2010;1:25-30.
8. Beumer J III, Curtis TA, Marunick M. Maxillofacial Rehabilitation – Prosthodontic and surgical considerations, Ishiyaku Euro America, Inc 1996;378-453.
9. Khindria SK, Bansal S, Kansal M. Maxillofacial prosthetic materials- Review Article. *J Indian Prosthodont Soc* 2009;9(1):2-5.
10. Taylor TD. *Clinical Maxillofacial Prosthetics*. Berlin: Quintessence Publishing Company 2000, 352-356.
11. Turner GE, Fischer TE, Castleberry DJ, Lemmons JE. Intrinsic color of isophorone polyurethane for maxillofacial prosthetics, part I: Physical properties. *J Prosthet Dent* 1984;51(4):519-22.
12. Udagama A, Drane JB. Use of medical grade methyl urethane silane cross linked silicone for facial prosthesis. *J Prosthet Dent* 1982;48(3):86-88.
13. Udagama A. Urethane-linked silicone facial prosthetics. *J prosthet Dent* 1987;58:351-354.
14. Moore DJ, Glaser ZR, Tabacco MJ, Linebaugh MG. Evaluation of polymeric materials for maxillofacial prosthetics. *J Prosthet Dent* 1977;38:319-26.
15. Coelolho Goiato M, Alues Pesqueria A, Micheline Dos Santos D, Fiuza de Carvalho Dekon S. Influence of investment, disinfection and storage on the microhardness of ocular resins. *Journal of Prosthodontics* 2008;2(18): 32-35
16. Dorsey J, Zorach J, Glazer, Tabacco MJ, Linebaugh MG. Evaluation of polymeric material for maxillofacial prosthetics. *J Prosthet Dent* 1977;38(3):319-26.
17. Gonzalez JB, Edmund YS, Kai NA. Physical and mechanical properties of polyurethane elastomer formulations used for facial prosthesis. *J Prosthet Dent* 1978;39(3):307-318.
18. Gonzalez JB. Polyurethane elastomers for facial prosthesis. *J Prosthet Dent* 1978;39(1):212-218.
19. Polyzois GL. Evaluation of a new silicone elastomer for maxillofacial prostheses. *J Prosthodont* 1995;4(9):38-41.
20. Mohammad SA, Wee AG, Rumsey DJ, Schricker SR. Maxillofacial materials reinforced with various concentrations of polyhedral silsesquioxanes. *J Dent Biomech* 2010;1(1):821-832
21. Deba K, Yunus N, Kumar V, Ahmad N. Oral and maxillofacial prosthesis-II materialistic approach. *Heal Talk* 2012;4(6):18-20.
22. Mitra A, Choudhary S, Garg H, Jagadeesh HG. Maxillofacial prosthetic materials-an inclination towards silicones. *J Clin Diag Res* 2014;8(12):8-13.
23. Bellamy K, Limbert G, Waters MG, Middleton J. An elastomeric material for facial prostheses: synthesis, experimental and numerical testing aspects. *J Biomaterials* 2003;24:506-16.
24. Lontz JF. State-of-the-art materials used for maxillofacial prosthetic reconstruction. *Dent Clin North Am* 1990;34(2):307-325.
25. Anusavice, Kenneth J, Shen C, Rawls, Ralph H. Phillips' *Science of Dental Materials*. 11th ed. St. Louis: Elsevier; 2012, 755-756.
26. Huber H, Studer SP. Materials and techniques in maxillofacial prosthodontic rehabilitation. *Oral Maxillofacial Surg Clin N Am* 2002;14(1):73-93.
27. Doozot ER, Koran A, Craig RG. Effect of accelerated aging on the physical properties of three maxillo-facial materials. *J Prosthet Dent* 1994;71(4):379-4.
28. Aziz T, Waters M, Jagger R. Analysis of the properties of silicone rubber maxillofacial prosthetic materials. *J Dent*, 2003;31(3):67-74.
29. Polyzois GL, Winter RW, Stafford GD. Boundary lubrication and maxillofacial prosthetic polydimethylsiloxanes. *Biomaterials* 1991;12(1):79-82.
30. Tsai FH. Synthesis of silicone blocks copolymers for use as maxillofacial materials. *Proceedings of Conference on Materials Research in Maxillofacial Prosthetics*. Transactions of the Academy of Dental Materials

- 1992;5:126-9.
31. Gettleman L, Ross BL, Gebert PH, Guerra LR. Novel elastomers for denture and maxillofacial prostheses. In: Biomedical Engineering IV: Recent Developments 141-144
 32. Firtell DN, Donnan ML, Anderson CR. Light weight RTV silicone for maxillofacial prostheses. J Prosthet Dent 1990;63:466-68.
 33. Khindria SK, Bansal S, Kansal M. Maxillofacial prosthetic materials. J Indian Prosthodont Soc 2009;9:2-.
 34. Mahajan H, Gupta K. Maxillofacial prosthetic materials: A literature review. J Orofac Res 2012;2(2):87-90.
 35. Catapano G, Verkerke GJ. Handbook of Research on Biomedical Engineering Education and Advanced Bioengineering Learning: Interdisciplinary Concepts. 2012;(2):53-55.
 36. Allin S, Eckel E, Markham H, Brewer BR. Recent trends in the development and evaluation of assistive robotic manipulation devices. Phys Med Rehabil Clin N Am. 2010;21:59-77.