Review Article

A review of materials used in maxillofacial prosthesis - Part 1

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ABSTRACT

The rehabilitation of patients requiring not only the replacement of missing body part but also a loss of psychological confidence is a challenging task. Since maxillofacial defects lie on the face, the materials used for fabricating the prosthesis should fulfill a variety of requirements. At present, there is no ideal material which can be universally used. This article discusses materials available for the fabrication of maxillofacial prosthesis.

KEY WORDS: Dental materials, Facial defects, Maxillofacial prosthesis, Rehabilitation

INTRODUCTION

A number of materials are available and have been used for facial prosthesis. These include wood, wax, metals, and in recent times, polymers. While the new materials have exhibited some excellent properties, they also have exhibited some frustrating deficiencies. As yet, a material has not emerged which does not possess distinct and important undesirable characteristics. Much effort has been expended recently in studying existing materials in the hope of ameliorating them. A discussion follows of desirable physical, biologic, and clinical properties, emphasizing those properties that are most important for achieving clinical success and patient acceptance.

CLASSIFICATION OF MAXILLOFACIAL PROSTHESIS MATERIALS

Beumer[1] classified materials used for fabricating maxillofacial prosthesis as under:

1. Acrylic resins.
2. Acrylic copolymers.
3. Polyvinyl chloride and copolymers.
4. Chlorinated polyethylene (CPE).
5. Polyurethane elastomers.
6. Silicone elastomers - HTV, RTV, and foaming silicones.
7. New materials - silicone block copolymers and polyphosphazenes.

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IDEAL PROPERTIES OF MAXILLOFACIAL PROSTHETIC MATERIALS[2]

Esthetics

The completed facial prosthesis 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. A conspicuous prosthesis will increase, not decrease, patient anxiety, compromising social readjustments. The final esthetic result is the most important factor relative to clinical success or failure.

Fabrication

Materials that are easily processed with readily available instrumentation offer distinct advantages. Polymerization or conversion from liquid to solid occurring at temperature low enough to permit reusability of molds (epoxy dental stone, etc.,) is desirable. Blending of individual components should be easy, allowing some margin for error. Suitable working time is likewise beneficial. The material

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should be adaptable to intrinsic as well as to extrinsic coloration.

Physical Properties

Ideally, the prosthesis should possess sufficiently flexibility for use on movable tissue beds. The materials should be dimensionally stable, be light in weight, and possess suitable edge strength to permit thinning or feathering of margins. Variations in temperature should not affect physical properties and thermal conductivity should be sufficiently low to permit comfortable use in cold environments.

Biological and Chemical properties

The material should remain stable when exposed to environmental assaults such as ultraviolet rays, oxygen, secretions such as sebaceous, perspiration, nasal, and salivary, and adhesives and solvents. The material should not be toxic, allergenic, or carcinogenic and must be biocompatible. Resistance to stains is a distinct advantage for it and allows the use of cosmetics to camouflage margins. Finally, it is highly desirable than the prosthesis be durable and have the capability of being used for at least 6 months without significant compromise of esthetics and physical properties.

ACRYLIC RESINS

On occasion, acrylic resins can be successfully employed for specific types of facial defects, particularly those in which little movement occurs in the tissue bed during function (e.g., fabrication of orbital prostheses). The materials are readily available, and most dentists are familiar with its physical and chemical properties, as well as processing techniques. Both intrinsic and extrinsic colorations can be utilized. Extrinsic coloration is easily accomplished with acrylic base paints, using chloroform or monomer as a solvent. The strength of this material enables the clinicians to feather exposed margins. When needed, alterations are easily cleansed of adhesive or debris. Heat polymerizing methyl methacrylate is preferred over the autopolymerizing form because of the presence of free toxic tertiary amines in the later. Furthermore, the color stability, when exposed to ultraviolet light, is better in heat polymerizing methyl methacrylate. Facial prostheses made of this material remain serviceable for up to 2 years, but they require occasional surface repainting. With age, however, the prosthesis becomes shiny and crazing is occasionally noted. If the processed prosthesis has a well-stippled surface, its useful life can be prolonged. Surface color applications are more easily applied to such a surface and last for longer periods.

Rigidity is the primary disadvantages of acrylic resin. Its usefulness is compromised in highly movable tissue beds, leading to local discomfort and exposure of margins. Its relatively high thermal conductivity may precipitate discomfort in cold climates. Duplicate prostheses are not possible because of the destruction of the mold during removal from the flasking apparatus.[3]

Molds must be prepared in dental flasks to permit processing under pressure. Acrylic resin is particularly well suited to temporary facial restorations. Some clinicians still favor it as a permanent material because it is durable, color stable, and cosmetic. Furthermore, it is easily repaired or relined with either a tissue conditioner or temporary denture reliner, and it can be quickly and easily processed. Yet, a recent survey has indicated that a small percentage of clinicians (6%) are still using the material. Excellent cosmetic results can be achieved with acrylic resin.

ACRYLIC COPOLYMER

Acrylic copolymers are soft and elastic but have not received wide acceptance because of a number of objectionable properties. They possess poor edge strength and poor durability and are subject to degradation when exposed to sunlight; processing and coloration are difficult.[4] The completed restorations often become tacky, predisposing to dust collection and staining. A well-documented discussion of the properties and fabrication of prostheses with Palamed (a plasticized methyl methacrylate) is provided by Cantor and Hildestad. Data on mechanical and reflective spectrophotometric properties of Palamed were reported by Cantor.

Development of a new generation of acrylic monomers, oligomers, and macromeres was reported by Antonucci and Stansbury. They reported that these materials can be polymerized easily using different polymerization methods: Thermal, chemical, photoinitiated, or even dual cure initiators. Their approach is to incorporate high molecular weight acrylic polymers with molecular blocks of other types of polymers (e.g., poly-etherurethan,-hydrocarbon, -fluorocarbon, or -siloxane) that can eliminate the shortcomings of traditional acrylic copolymers and meet the requirements of a maxillofacial elastomer. A wide spectrum of physical and mechanical properties which may satisfy the requirements in maxillofacial application can be obtained by varying modes of polymerization. However, the results of laboratory and clinical tests of potential polymers have not yet been published.

POLYVINYL CHLORIDE AND COPOLYMERS - REALISTIC, MEDIPLAST, PROTOTYPE III

At one time, vinyl polymers and copolymers were popular and widely used for facial restorations. The earliest form consisted of a combination of

polyvinyl chloride (a hard, clear resin that is tasteless and odorless) and plasticizers. These additives, however, extended processing time and predisposed to undesirable shrinkage. These materials are cured at high temperatures in metal molds. Recently, a copolymer of 5–20% vinyl acetate, with the remaining percentage being vinyl chloride, has been introduced. This copolymer is more flexible but apparently less chemically resistant than polyvinyl chloride itself.

This family of polymers exhibits a number of desirable properties. They are somewhat flexible and adaptable to both initial appearances when properly manipulated. The primary deficiency arises from plasticizer migration and loss, resulting in discoloration and hardening of the prosthesis, particularly at the margins. Edges tear easily if thin and may require reinforcement with nylon fabric. These compounds are easily stained and degrade when exposed to ultraviolet light, peroxides, and ozone. They lack life like translucence and tend to absorb sebaceous secretions, cosmetics, and solvents that further compromise their physical properties. They soil easily because of surface tackiness. The polymer is a thermoplastic material which is supplied as a solid suspension in a solvent. Metal molds are required, as curing is accomplished at high temperatures. Their clinical usefulness may extend anywhere from 1 to 6 months.

Efforts have been made to improve polyvinyl chlorides by limiting the amount of plasticizer, hoping to minimize migration and loss at the margin of the prostheses. With these alterations, the lifespan of polyvinyl chloride prostheses has been extended to 9–11 months.[5] However, serious problems remain relative to polymer degradation and darkening of the material secondary to ultraviolet exposure. The poor dimensional stability of polyvinyl chlorides is another disadvantage.

CPE

Lewis and Castleberry[6] reported testing of CPE, a material which is similar to polyvinylchloride in both chemical composition and physical properties. The processing procedure involves high heat curing of pigmented sheets of the thermoplastic polymer in metal molds. Coloration, using oil-soluble dyes and repeated molding, is possible. However, the use of metal molds is a disadvantage of the system.

Gettleman also reported the evaluation of thermoplastic CPE 726/19–15 as a potential maxillofacial material. Processing technique using steam autoclaves with gypsum molds was developed, and a laminated technique of coloring was also described. CPE deteriorates in a service environment primarily due to the exposition to various environmental factors, including sebaceous oils (sebum) and perspiration. Specimens aged for a period, which simulates 1.5 years of clinical service, showed significant deformations in their physical properties.[7]

POLYURETHANE ELASTOMERS

As a class of biomaterials, polyether urethanes are widely used in blood-contacting devices, a notable prominence being that of the mechanical heart, the so-called Jarvik 7, and a number of cardiac replacement and assist devices derived from various commercial types. The term polyether urethanes refer to an extensive series of block copolymers chemically comprising hard segment of an extended diisocyanate and soft segment of polyols, the chemical variant compositions of which are specifically designed molecularly to a broad range of consumer and engineering materials from spandex fibers, paints, and rigid polymers to soft, rubbery elastomers.

The latter elastomer modifications have been attempted, especially for fabricating maxillofacial devices, curing at room temperature, employing a proprietary mixture of three components, ternary mixture, and room temperature curing to polyurethane form. Custom-making prosthesis involves precise, stoichiometric admixing of the polyurethane components, one of which is a hazardous, toxic diisocyanate, with accurate temperature control and scrupulous avoidance of moisture contamination. In addition, a special prefabricated metal mold is needed for polymerization to attain tensile strength for expected prosthetic performance. Exposure to model environmental types of metabolites, notably lactic acid and glycerides, under accelerated testing conditions tends to degrade and ultimately soften the polyurethane configurations attempted for maxillofacial prosthetics that the ternary composition published for maxillofacial prosthesis "is toxic to human excised donor orofacial tissue cells." As was the case with low viscosity admixture of components, notably ternary acrylic latex and RTV silicone ready for at-bench pourable mold forming, there is yet to be developed with block polymers of polyurethane such ideality of processibility for maxillofacial prosthesis.

More extensive, systematic chemical research of the block polyurethane configurations is needed to qualify the polyether urethanes with uncompromised stability to moisture and reactions with physiologic metabolites. The block polyether urethane polymers as laboratory bench admixtures adaptable to dental stone molding as practiced with dental acrylates will need a more extensive list of quality specifications of component ingredients, with preclinical exposure tests for stability and long-term effectiveness, hygienic maintenance, and quality control with a standard test for nontoxicity to orofacial tissue cells.

Polyurethane elastomers serve a variety of commercial and medical uses, but only one is available for use in facial restorations. They can be synthesized with a wide range of physical properties by varying the reactants and their amounts. These elastomers are denoted as polyurethanes because they contain urethane linkages. They arise from two major reactants. In the presence of a catalyst, a polymer terminating with an isocyanate is combined with one terminating with an isocyanate is combined with one terminating with a hydroxyl group. Varying the amount of isocyanates will change the physical properties of the final product.

The polyurethanes possess a number of excellent properties. They can be made quite elastic without compromising edge strength, thus permitting thinning and feathering of exposed tissue margins. Their flexibility is, especially, well suited to defects with movable tissue beds. They can be colored both intrinsically and extrinsically. Superior cosmetic results can be obtained, surpassing the other materials currently available.

However, serious deficiencies remain. These materials are difficult to process consistently. Little margin for error is possible when measuring the constituents. In addition, the isocyanates are moisture sensitive, and when water contamination occurs, gas bubbles cause defects and poor curing of the material results. Water contamination is particularly difficult to control in humid environments. If stone molds are employed, they must be thoroughly dehydrated before processing. Unfortunately, the polyurethane currently available for facial restoration is not color stable, presumably because of the effects of ultraviolet light and surface oxidation.[8] In addition, coloration applied extrinsically tends to wear off rapidly. In our experience, the clinical usefulness of this material is generally <6 months and more often approaches 3 months. The details of casting this material are discussed by Gonzalez.

Another discouraging property is the poor compatibility of this material with exiting adhesive systems. Cleansing the adhesive from the prosthesis is difficult and frustrating for many patients. Often, extrinsic coloration is removed during this procedure. Care must be taken when handling the isocyanates as these compounds are toxic. Free isocyanates have been found in cured restorations indicating the potential for local irritation. No irritation, however, has been reported by any of the major users. Stone, epoxy, urethane, or metal molds can be employed for processing. If stone molds are used, sculpting the contours of the prosthesis should be completed in wax, as clay residues will contaminate the molds and result in staining of the prosthesis and poor adhesions of the extrinsic coloration.

Several centers have investigated the family of polyurethanes in attempts to find an elastomer that exhibits more durability and color stability and better processing characteristics. Additives improving light stability are employed in commercial polyurethanes, but some of these are toxic or mutagenic. Hence, extensive testing will be required to evaluate individual agents. The structural integrity of the urethane chains is not sufficient to avoid breakage of chemical bonds when exposed to ultraviolet light. Therefore, degradation is not preventable without these light stabilizers. Lewis and Castleberry reported the development of an aliphatic polyurethane prepolymer, isophorone, and preliminary data on its physical and mechanical properties. Turner, having evaluated mechanical properties of polyurethane elastomers before and after 900 h of accelerated aging, reported that the material did not disintegrate and that is demonstrated many desireable characteristics for use as a maxillofacial elastomer. However, further evaluation on biocompatibility and clinical trials of the material are still needed.

CONCLUSION

As there is an increasing demand for rehabilitation of maxillofacial defects due to the rise in the incidence of cancer each year, it should be noted that it is a psychological issue that impacts the social and functional life of people worldwide. Almost none of the commercially available materials satisfy all the requirements of an ideal maxillofacial material. Each has its own advantages and disadvantages. In the next part of this two-part series, we will be elaborating on the use of silicones and newer materials for maxillofacial rehabilitation.

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