ADVANCEMENTS IN MAXILLOFACIAL PROSTHETIC MATERIALS

Abstract

Maxillofacial prosthetics is a subspecialty of Prosthodontics that involves rehabilitating patients with defects or disabilities that are congenital or acquired due to trauma, violence, and gunshot injuries in the head and neck region. Such prostheses replace soft and/or hard tissues and restore aesthetics as well as oral functions. The prostheses can be made from a variety of materials. This chapter elucidates the past, present and future in the scope of materials in maxillofacial prosthetics. From acrylic resins, silicones and its modifications to bioprinting and functional maxillofacial prosthetics, this chapter discusses the current state of the art in this field.

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I. INTRODUCTION

Maxillofacial Prosthetics is a subspecialty of Prosthodontics that involves rehabilitation of patients with defects or disabilities that are congenital or acquired due to disease or trauma. Prostheses replace soft and/or hard tissues and restore oral functions like mastication, deglutition and speech. Apart from this, such prostheses may be indicated for aesthetic and psychosocial reasons.[1] The United Nations predicts that the geriatric population will be about 2.1 billion worldwide by 2050. Aging is a natural biological phenomenon that is linked to more health concerns and an increased rate of cancer incidence.[2]Hence, head and neck cancers will cause an increased demand for maxillofacial prosthetics.[2,3]Not just for post cancer rehabilitation, maxillofacial prosthetics will play a vital role in rehabilitating patients with trauma, violence and gunshot injuries in the military.[2–4]

The jaw, nose, ears, and other facial structures that have suffered damage can be prosthetically replaced. The location of the prosthesis, biocompatibility, patient comfort, prosthesis durability and longevity, aesthetics and characterization, type of retention, prosthesis weight, and cost-effectiveness are a few of the variables that influence the material choice. The following materials can be used for maxillofacial prosthetics:

1. **Medical-Grade Silicone:** One of the most often used materials in maxillofacial prostheses is silicone, which has only been recently introduced.[2–5] It is transparent for improved aesthetics, biocompatible, soft, flexible, conforms to the patient's face shapes, is lightweight, and can be colored to match the patient's skin tone both intrinsically and extrinsically. Silicone prostheses give a natural appearance and are lightweight and pleasant to wear.[2–6] They can be:

   - Heat Temperature Vulcanised
   - Room Temperature Vulcanised

   A lot of research is being done in the field of silicones for usage in maxillofacial prosthesis.

   - **Reinforced Silicones:** Some maxillofacial prosthesis need extra support and strength. In order to improve the mechanical characteristics of the prosthesis and make them more resilient to deformation and durable, reinforced silicones that contain silica fibers or mesh have been produced.[7]

   - **Thermochromic Silicones:** The color of thermochromic silicones varies according to temperature. The application of this technology in maxillofacial prosthesis to identify possible issues with blood flow or variations in temperature in that area. Thermochromic pigments, as reported by Kantola et. al.[8] exhibited a greater change in color upon exposure to UV radiation, thereby rendering them unsuitable for use in maxillofacial prosthesis.

   - **Foaming silicones:** Foaming silicones were developed by Firtell et al. to provide a lightweight maxillofacial prosthesis.[9]As bubbles are generated during the vulcanization process when silicone and stannous octate catalyst are mixed together, gas created lowers the density of the silicone resulting in a lighter prosthesis[10] However, the main drawback of foamed material is that it has poor mechanical properties and is more susceptible to straining, therefore weakens the material. By covering foam with silicone, it improves strength but increases stiffness, this weakness can be partially remedied.[11]

- **Acrylic Resin:** a material that is frequently used for maxillofacial prosthetics when there is little movement of the underlying tissue bed.[12] It is sturdy, lightweight, and may be colored according to the patient's natural face features. However, it is very rigid, leading to marginal exposure and localized irritation.[13]

- **Polyurethane:** Due to its outstanding characteristics, including superior edge strength, flexibility, and aesthetics, polyurethane materials are used for a variety of maxillofacial prosthesis.[14] They are frequently used in nose and auricular prosthetics. However, because the material is moisture-sensitive, it is technique-sensitive.[15]

- **Polyvinyl Chloride:** This material, which is composed of polyvinyl chloride and plasticizers, was originally developed by Chalian and Phillips in 1974 [16]for application in facial prostheses.[12,16]It is a non rigid thermoplastic substance that allows both intrinsic and extrinsic staining, however it has low tear strength and unstable color.

- **Composite Materials:** maxillofacial prostheses often use composite materials, which are made up of a mixture of multiple materials. They are able to combine desired qualities like strength, flexibility, and aesthetics.

- **Polyphosphazenes:** For maxillofacial prosthetics, Gettleman developed polyphosphazenes.[17] For it to be used as a material for maxillofacial prosthetics, it might require modifications from its previous use as a resilient denture liner. A softer rubber can be produced by combining polyphosphazenes with minimal fillers and lowering the acrylic to rubber ratio, according to researchers in New Orleans working in the field of maxillofacial prosthesis. In order to properly match the rubber to the patients' skin, colors are incorporated to the rubber composition. [11,18]

Maxillofacial prostheses are always being improved as a result of advancements in materials and technological research, providing patients with more aesthetically pleasing, comfortable, and functional alternatives. The material aspect of maxillofacial prosthetics encompasses a number of subject matters, namely biocompatibility, cleaning techniques, colour and shade matching, and the effectiveness of material bonding, according to recent studies.[19–22] With the help of tissue engineering, computer-aided design and manufacturing (CAD/CAM), and surgical guides, Ferreira indicated the emergence of newer maxillofacial prostheses that are substitutes for hard tissue in the absence of bone grafts, thereby lowering morbidity and duration of recovery.[23]

Recent developments in maxillofacial prosthetic materials include:

- **3D printing technology:** Maxillofacial prosthesis have undergone a revolution because of 3D printing technology. It enables the production of highly individualized and exact prosthetic devices. The entire process has become more rapid, less expensive, and ensures that the prosthesis precisely adapts to the patient's anatomic facial form with the use of 3D scanning and printing technology.[24]

- **Biocompatible Materials:** The recent development of biocompatible materials has increased the tissue integration and compatibility of prosthetic devices. Hydrogels, medical-grade silicone, and other polymers have been enhanced to provide patients greater durability as well as comfort.

- **Nanotechnology:** New possibilities in maxillofacial prostheses have been made possible by the inclusion of nanotechnology. Nanomaterials can facilitate tissue integration while also enhancing the mechanical strength, flexibility, and aesthetics of prosthetic devices. Recently, using nano silica powder, that has a larger surface area than micron-sized silica powder, researchers discovered even stronger mechanical properties.[25]

- **Computer Aided Design and Computer Aided Manufacturing (CAD/CAM):** The production of maxillofacial prosthesis is increasingly using computer-aided design and fabrication technologies. These improvements in technology enable accurate digital design and effective production methods, resulting in better-fitting and more realistic-looking prostheses.

- **Techniques for Color Matching:** In maxillofacial prostheses, aesthetic results are vital. Digital imaging and spectrophotometry, the latest advances in color-matching approaches have improved prosthetic device personalization and natural blending with the patient's skin tone and facial characteristics.

- **Drug-Eluting Implants:** For particular implant maxillofacial prosthesis, researchers have been studying local drug delivery materials. These substances function as local drug delivery agents that release medications locally to promote wound healing and lower infection risks.[26]

- **Augmented Reality:** Maxillofacial prostheses have begun to use augmented reality due to breakthroughs in technology. Google developed Google Glass, which overlays virtual features like sounds, two-dimensional visuals, three-dimensional images, or films on top of reality using real-time calculations. A device called MindRDR uses an electroencephalopathy neurosensor placed on the patient’s forehead to recognise and decipher brain waves. Google also introduced electronic contact lenses that display augmented reality. The bionic eye was the original thought of Benjamin Franklin in the 19th Century and was formulated by Professor Wyatt and Dr. Rizzo called the Boston Retinal Implant Project. It aims to assist patients who are partially or completely blind restore their vision. [27,28]

Similar to that, an artificial nose called NeOse Pro built by Aryballe Technologie can recognize and analyze smells. It is a modern technology device that can recognize up to fifty odors rather than only being a prosthesis. [29]For patients with cardiovascular disorders who are on salt-free diets, an artificial fork developed by the Rekimoto Lab, Tokyo, stimulates the taste buds to simulate a salty flavor.[30]

- **Maxillofacial Tissues Printed using Biotechnology:** This relatively new technique in regenerative medicine and tissue engineering has the capability of reduced morbidity of the donor sites than autologous grafts. Bioprinting completely depends on CAD/CAM to design and produce bio-inks that are organic compounds that may or may not contain synthetic compounds at the tissue levels in three dimensions. [31,32]The major benefit of this method is the designing of the internal surface to facilitate tissue integration.

Hydroxyapatite, polyetherketoneketone (PEKK) and polycaprolactone (PCL) have been utilized as bioinks for cranioplasty procedures.[33] In maxillofacial prosthetics, a printed acrylonitrile/butadiene/styrene(ABS) scaffold coated with fibronectin or PCL coated with hydrogel and chondrocytes replaced cartilage in auricular and nasal defects. Five children having microtia participated in a clinical trial in China involving the transplantation of polylactic acid (PLA), polyglycolic acid (PGA), expanded microtia chondrocytes, and PCL biodegradable scaffold to tissue engineer patient-specific ear-shaped cartilage in vitro. The only 3D-printed items were a set of 3D ear molds and a 2D PCL mesh. The follow-up intervals ranged from six months to two and a half years. During the course of the study, they reported to have accomplished acceptable aesthetic results with mature cartilage production in the kids. They predicted good long-term stability.[34] Another study included the printing of an ear with a chondrocyte-seeded alginate hydrogel and incorporating it with a conductive electronic antenna that would be able to recognize sound waves that even a human anatomic ear would not be able to.[35]

Because the main goal of this hard tissue composite scaffold is currently to serve as an in vitro representation for investigations, diagnosis, and therapy, there is an enormous amount of potential for bioprinting, however the road to success in vivo is long, expensive, and requires extensive clinical research.

II. CONCLUSION

In order to improve patient outcomes and quality of life, bear in mind that the scope of maxillofacial prosthetics is continually expanding. Researchers and doctors are constantly investigating cutting-edge techniques and materials to do so. To keep up with the most recent developments in this sector, it is crucial to turn to the latest scientific publications and updates.

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