Biomaterials in Maxillofacial Surgery: A Literature Review.

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Abstract. Biomaterials are described as materials that are constantly in contact with biological systems and aim to rehabilitate, reconstruct, or aid bone formation. Biomaterials can originate from different sources, whether natural or synthetic, each with distinct applications and characteristics. Their use should be determined based on the individual clinical applicability of each. This article aims to review the different characteristics of various types of biomaterials and their clinical applications in maxillofacial surgeries. In conclusion, both synthetic and natural biomaterials possess properties that indicate their use. Therefore, it is up to the maxillofacial surgeon to determine which biomaterial will have the best longevity and biocompatibility for each case.

Keywords. Biocompatible Materials, Maxillofacial Surgery, Bone Remodeling, Bone Substitutes, Risks.

1. Introduction

A material can be classified as a biomaterial when its primary objective is to rehabilitate or restore the function of a specific biological structure. [1] It is imperative that such materials exhibit attributes to be designated as biomaterials, several defining characteristics contribute to their practical use, including bioactivity, osteoconductive, osteoinductive, bioresorbable, structurally similar to bone, easy to use, and cost-effectiveness. [2]

The use of biomaterials dates to as early as 2000 B.C., when the Egyptians used linen, gold, and leather-like materials for suturing techniques. [3] In contemporary times, science and technology have led to the development of new kinds of biocompatible materials aiming for longevity and success in each case. Scientific progress has also been dedicated to refining the existing materials within this category.

Following the discussion on the characteristics of biomaterials, it is important to highlight that there are two primary categories of bone-substitute materials: those of natural origin and those of synthetic origin. Materials of natural origin can originate from allogenic, xenogeneic, or autogenic sources, whereas synthetic materials may be referred to as alloplastic materials.

2. Natural materials

2.1 Autologous bone scaffold

Autogenous bone grafts are regarded as the gold standard for bone reconstruction, due to their attributes of high biocompatibility, osteogenic, and osteoconductive qualities. One reinforcing factor for the use of these materials is the low immunological response they provoke. Conversely, a drawback associated with this graft is the necessity for a secondary surgical site, which elevates the potential risks for the patient. [4]

2.2 Allograft materials

Allograft materials are substances recovered from donors of the same species but from different individuals. These materials can be classified into fresh frozen allograft, freeze-dried allograft (FDBA), and demineralized freeze-dried allograft (DFDBA). Some associated risks related to these materials include limitations on their use due to the potential for disease transmission, alterations in their biological and mechanical properties, as well as restrictions arising from religious convictions and cost-effectiveness considerations. [2]

To render these grafts suitable for use, they must undergo several stages, such as lyophilization and demineralization, or solely demineralization. (DFDBA) grafts are commonly employed when the primary objective is to fill a cavity and promote bone regeneration, due to their high osteoinductivity. Conversely, (FDBA) materials possess osteoconductive properties, meaning they provide a scaffold for new bone growth. [5, 6]

2.3 Xenografts

Xenogeneic grafts are materials of animal origin, typically from bovine (Fig. 1) or porcine sources. This category of grafts exhibits favorable physical and biological properties, which justifies its use. Like allografts, xenogeneic bone grafts must undergo a series of processing stages to render them suitable for clinical application, such as freeze-drying, demineralization, deproteinization, or decellularization. Even though strict quality control measures are applied to donor animals, it is imperative that xenogeneic bone tissue undergoes these processes to minimize the likelihood of graft rejection upon implantation. Despite the complex process, it is crucial to acknowledge the inherent risks associated with this type of graft, as it may potentially harbor zoonotic diseases, such as BSE (bovine spongiform encephalopathy) or PERV (Porcine endogenous retrovirus). [2, 7, 8]

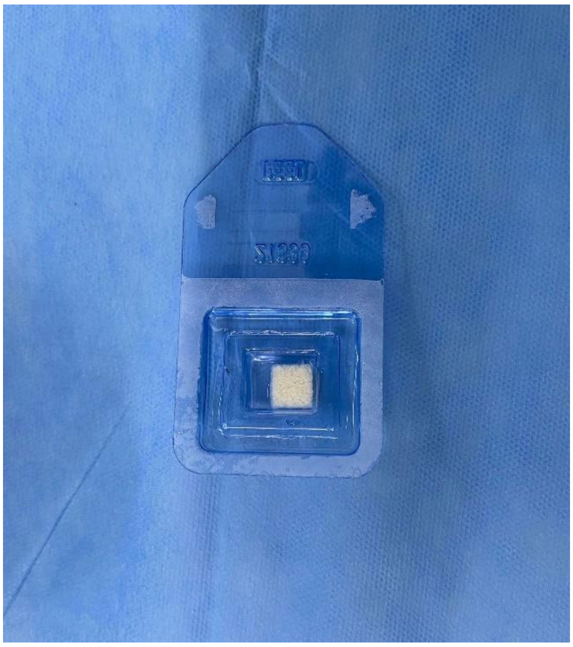

Fig. 1- Geistlich Bio-Oss® Collagen

3. Synthetic bone graft substitute

3.1 Selection of alloplastic materials

This category of biomaterial possesses several noteworthy properties that warrant their use. Among these properties, one can emphasize the ability to choose between absorbable and non-absorbable materials. Furthermore, these materials offer customization options to suit each specific case and need, allowing for the selection of materials with varying levels of hardness, porosity, and density. Additionally, these materials exhibit biocompatibility, with some even exhibiting osteoinductive and osteoconductive properties. The selection of the ideal material not only impacts its performance but also directly influences the immunological response triggered by the host.

3.2 Metals

Metallic materials offer several advantages when compared to the natural bone substitutes mentioned previously (autogenic, allogenic, and xenogeneic grafts). This type of material does not rely on bone banks or a secondary surgical site, thereby reducing the risk of surgical complications. Its use is not limited in quantity, making it the primary choice for extensive maxillofacial reconstruction surgeries. Its applications can vary between plates and screws, which are indispensable for osteosynthesis. [1]

Some of their favorable properties include surgical applicability, biocompatibility, ease of sterilization, low rates of postoperative complications, and high availability [9]

On the contrary, they are associated with inherent risks, such as inflammation, allergic reactions, and the potential for cancer due to the release of toxic metal ions and particles [2]

Among the materials most employed up to the present moment, we can cite stainless steels, titanium alloys, pure titanium, and cobalt-chromium alloys [3]

It is also worth emphasizing that the use of metals such as titanium is not confined solely to plates and screws (Fig. 2); this material can also be fashioned into metal meshes, which are extensively utilized in "blow-out" orbital fractures [10] or in maxillofacial fractures characterized by significant bone loss.

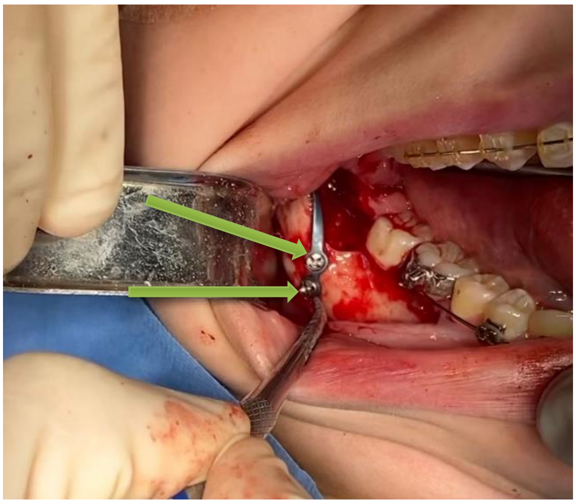

Fig. 2. 2.0 titanium mini plate and screws

3.3 Polymers

Polymers exhibit favorable elasticity and can be molded according to the patient's needs. They are widely employed in facial implants, particularly when there is a requirement for filling in deficient areas, thereby serving as valuable assets in specific cases of orthognathic surgeries. Polymers can be categorized into two classes: non-degradable and degradable polymer materials. [11]

Among non-degradable polymers, several stand out, including High-density Porous Polyethylene (HDPE). The use of this material has gained popularity due to its biocompatibility, ease of manipulation, and cost-effectiveness in achieving aesthetic results in a shorter timeframe compared to other types of grafts. Porous polyethylene possesses antigenic and antiallergic characteristics and is available in a wide array of shapes and sizes, making it suitable for reconstructions of the malar, mentum, mandible, and nasal areas. Notably, its high porosity facilitates soft tissue growth in the surrounding implant region. [9]

Another material worth mentioning is Polymethylmethacrylate (PMMA). Although widely used in cranioplasties, caution must be exercised when applying it in other contexts. Some drawbacks of this material include its lack of adherence to organic tissue and the release of residual monomers upon degradation, which can potentially lead to decidual damage. The popularity of PMMA stems from its affordability compared to titanium prostheses [12]

Furthermore, contraindications for PMMA use are related to patients with known allergies to PMMA or any of its components, inflammatory processes in proximity to the surgical site, pregnant or lactating individuals, those with autoimmune diseases, and coagulation disorders [13]

3.4 Bioceramics

These materials can be divided into bioactive ceramics, which provoke a response from the surrounding tissue, and bioinert ceramics, which do not prompt a response from the organism [3]. This type of material possesses excellent biological properties. However, when comparing them to the physical characteristics of other materials available in the market, it becomes apparent that not all ceramics are suitable for areas subject to significant physical stress due to their low resistance. Nonetheless, certain ceramics can be combined to obtain the best characteristic presented by each one [2].

Hydroxyapatite is part of the bioactive ceramics class and is a mineral found in bones, making it highly biocompatible. It adheres to the organism through a bioactive fixation, resulting in chemical adhesion [1].

Among the bioresorbable ceramics is β-tricalcium phosphate, a material that possesses properties conducive to bone repair and regeneration. Its absorption is replaced by bone tissue as the bone remodeling process occurs [2].

Bioactive glasses are biomaterials primarily composed of silica (SiO_2), calcium (CaO), sodium (Na_2O), and phosphorus (P_2O_5). This bioceramic exhibits remarkable biological properties, given that it can interact with connective tissue and stimulate osteoblastic cells and angiogenesis [3]. Its applications include bone regeneration and coatings for dental implants.

4. Conclusion

Considering the array of biomaterials available in the market, it is imperative to carefully evaluate the distinct characteristics of each. Up to the present moment, a biomaterial possessing all the ideal characteristics has not yet been developed. Hence, it is the responsibility of the surgeon to determine which material will yield the greatest benefits for the patient, ensuring both longevity and success in the treatment.

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