METALS USED IN MAXILLOFACIAL SURGERY

L. PACIFICI[1], F. DE ANGELIS[1], A. OREFICI[2], A. CIELO[2]

[1] *Department of Oral and Maxillofacial Science, "Sapienza" University of Rome, Rome, Italy*
[2] *Private Practice, Rome, Italy*

SUMMARY
The goal of maxillofacial surgery is to restore the shape and functionality of maxillofacial region. In the past years, there has been a tremendous progress in this field because of significant advances in biotechnology that provided innovative biomaterials to efficiently reconstruct the maxillofacial injured region. By using appropriate selection of the implant biomaterial, it is possible to reconstruct the native tissue, both in form and function. The ideal biomaterial should mimic native tissues regarding density, strength, and modulus of elasticity. Autografts are currently the gold standard for replacement of missing tissues, but synthetic biomaterials have been widely used because they eliminate the discomfort to take the replacement tissue from the donor site. Among synthetic biomaterials, different metals may be utilized to efficiently reconstruct the maxillofacial injured region. This article makes an effort to summarize the most important metals in use in maxillofacial surgery, and point out advantages and disadvantage of each type.

Key words: metals, vitallium, gold, stainless steel, titanium, maxillofacial surgery.

Introduction

Trauma or injuries of the maxillofacial region represent a major problem for surgeons. The goal of maxillofacial surgery is to restore the shape and functionality of maxillofacial region. In the past years, there has been a tremendous progress in this field because of significant advances in biotechnology that provided innovative biomaterials to efficiently reconstruct the maxillofacial injured region. Among them, there is a distinction between naturally occurring or synthetic biomaterials. Naturally occurring materials include autogenous grafts, allografts, and xenografts. Alloplasts are generally synthetic materials. It should be evidenced that there is no evidence for an ideal material (either synthetic or naturally occurring) for maxillofacial surgery. On the opposite, the choice of the selected material depends on many factors including the type of fractures, the necessity to be biocompatible, stable and not deformable over time, or resorbable. In this article, we review the metals commonly used in maxillofacial surgery, highlighting their advantages and disadvantage.

Metals in use for maxillofacial surgery

Metals for maxillofacial surgery may require specific characteristics and mechanical properties (1). These include tensile strength, shear stress, elasticity, and yield strength (Table 1).
The first introduced metals were vitallium (an alloy of cobalt, chromium, and molybdenum) gold, and stainless steel (2). However, these metals were proved to be problematic because of corrosion and poor handling properties. Thus, in 1967 the use of titanium was introduced and revolutioned the field of maxillofacial reconstruction (3).
In the following sections, we will examine the use of each of these metals in maxillofacial surgery (Table 2).

Vitallium

Vitallium is a base metal alloy that has been used in dentistry and medicine since 1929 (4). Vitallium (or CoCrMo) has been widely used in orthopedic and

Table 1 - Required characteristics of metals used for maxillofacial surgery.

Characteristic	Definition
Tensile strength	*Measurement of force required to break a material*
Shear stress	*Measurement of force required to break a material in a sliding type vector*
Modulus of elasticity	*Measurement of force required to deform the material in a reversible manner*
Yield strength	*Measurement of force required to deform the material in an irreversible manner*

Table 2 - Metals used for maxillofacial surgery and their biological response when implanted.

Metal	Biodynamic activity
Vitallium	*Biotolerant*
Shear stress	*Biotolerant*
Stainless steel	*Biotolerant*
Titanium	*Bio inert*

maxillofacial surgery and is well tolerated. Its use for reconstruction of midface bone defects has been reported in single case reports without significant evidence for morbidity or complications during the 1990s (5). At the beginning its use was particularly encouraged in cases of orbital fractures where reconstruction of the bony orbit is essential to maintain normal appearance and function of the eye (6). In large follow-up, no postoperative orbital infections were observed with no requirement of vitallium implant removal (5). Nonetheless, its use is not recommended in absence of rigid fixation and, in successive studies with animal models, this alloy was found to be less biocompatible than titanium, with decrease in the biomechanical fixation and increase in intra- and extracellular accumulation of metal ions in the immediate implant surrounding area (7). In addition, evidence for difficult to shape radiographic scatter has been evidenced (8). Despite these data, the choice between titanium alloy and CoCrMo should eventually be done by a comprehensive review of all factors influencing clinical implant survival.

Stainless steel (Iron-Chromium-Nickel Based Alloys)

Stainless steel has adequate strength, flexibility, ductility, and bio-compatibility for most maxillofacial implant applications. In addition, it is relatively cheap and easy to manufacture (9). Stainless steel alloys are used for orthopedic and implant devices. Their use for management of mandibular angle fractures has recently been proposed by Kanubaddy et al. (10).

Disadvantages are represented by corrosion (11, 12), late-onset implant failure, and presence of radiographic scatter at MRI (13). In addition, iron based alloys are subjected to allergic reactions in susceptible patients, due to the presence of nickel into the alloy. They have high galvanic potentials and corrosion resistance (2). This can result in galvanic coupling and biocorrosion, if titanium, cobalt, zirconium or carbon implant biomaterials are used with it (14).

Gold

Gold implants are used in reconstructive surgery, especially for middle ear and upper lid closure in facial nerve paresis-induced lagophthalmos (15). However, in order to achieve better therapeutic benefits, clinical reports have documented that the surface of gold implants should be modified or encased in biocompatible alloplastic materials.

Gold is also applied to a long list of dental prostheses, including inlays, onlays, crowns, bridges, periodontal splints, and post and cores (16). Within this range of

use, gold has sufficient strength and corrosion resistance, and it is relatively biocompatible. In addition, gold dental prostheses have a long-life cycle.
Reported complications may include, among others, migration, extrusion, and allergy (17-20). In most recent years aesthetic concerns and cost made gold a less popular prosthesis than in the past and thus these types of implants have been replaced by cheaper and more biocompatible materials.

Titanium

Titanium exhibits mechanical properties desirable for internal rigid fixation, and, when combined with its degree of biocompatibility (21), makes it a favorable material for fixation. For these reasons, and to overcome the defects of the other metals previously used, titanium has become the standard gold for reconstruction of the maxillofacial skeleton (22).
Titanium has been used successfully as an implant material and this success with titanium implants (23-27) is credited to its excellent biocompatibility due to the formation of stable oxide layer on its surface (28, 29). The commercially pure titanium is classified into 4 grades which differ in their oxygen content. Grade 4 has the most (0.4%) and grade 1 the least (0.18%) oxygen content. The mechanical differences that exist between the different grades of titanium is primarily because of the contaminants that are present in minute quantities.
Titanium is a common choice in the repair of orbital floor fractures. In addition, the development of hybrid materials (polyethylene with reinforced titanium mesh) has further increased its use in such fractures (22). These materials have the advantage of strength and shape retention offered by titanium while the polyethylene provides a porous biocompatible surface that allows for tissue ingrowth.
The success of titanium in maxillofacial surgery is certainly due to its biological and mechanical properties (30). In fact, has been widely reported as biomaterials such titanium are able to support the bone growth (31), as their mechanical properties are similar to bone tissue (32, 33). Titanium is an inert, non corrosive and malleable metal. Furthermore, titanium offers the advantage of visibility on postoperative imaging with minimal distortion at MRI (34). More recently, titanium mesh cranioplasty has revealed to be an extremely safe and reliable alternative to autografts and even more preferable to replacement with natural bone autografts in case of large size cranial defects (35, 36).
Disadvantages of this metal are represented by the cost and possibly by aesthetic issues related to the gray color of titanium, which becomes more pronounced when soft tissue situation is not optimal and the dark color stands out through the thin mucosa.

Conclusions

The metals used for maxillofacial surgery have been developed over years to overcome the defects that emerged with their use. These defects range from problems related to metal corrosion, difficult to shape them to the required form, late-onset implant failures, to problems related to their cost and presence of scatters in radiographic examination. At last, titanium has mostly overcome the other metals in maxillofacial surgery, although the use of other metals has not yet been abandoned. The choice of the metal by the maxillofacial surgeon is still dictated by the type of fracture and by the specific mechanical property requirement in each specific case.

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Correspondence to:
L. Pacifici
Department of Oral and Maxillofacial Science
"Sapienza" University of Rome
Via Caserta 6, 00161 Rome, Italy
E-mail: prof.pacifici@libero.it