Titanium Alloys in Maxillofacial Osteosynthesis

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Titanium alloys are known for their biological, mechanical and chemical properties, which have successfully expanded their use in the maxillofacial field. The internal fixation using titanium miniplates and screws offers a new perspective for the treatment of trauma, in orthognathic surgery and maxillofacial oncology. Although, titanium is highly recommended for its excellent biocompatibility, recent research has focused on identifying the potential local and general implications of the interactions between the human tissue and the metallic particles. This present review aims to outline the existing tissue changes, cellular alterations and future perspectives regarding the use of titanium-based alloys as osteosynthesis materials, taking into consideration the existing present debate whether the routinely removal of these materials should be an indication.

Keywords: titanium ; alloys ; maxillofacial fractures ; osteosynthesis ; miniplates ; biocompatibility

1. Introduction

Maxillofacial fractures represent a common pathology and a continuous challenge for clinicians. Among this particular pathology, the most frequent are the mandibular fractures that imply particular attention regarding the treatment by achieving a proper functionality and aesthetic outcome through the reconstruction of the local anatomy, occlusion and functional activity [1]. Injuries in this segment include hard and soft tissue alterations that could occur from the frontal area to the mandible [2]. This region is the most exposed to trauma and the fractures can be localized at one or more bones from the maxillofacial area. The mechanism that produces the fracture, the direction and the magnitude determine the pattern and characteristics of the fracture line. The aetiology of these fractures includes a wide range of violence trauma, road traffic accidents, sport injuries, falls or work-related injuries [2] [3].

2. Epidemiology of Maxillofacial Fractures

The maxillofacial fractures epidemiology is different based on the lifestyle, geographic area, cultural and socio-economic factors [4][5]. The statistics show that trauma in the maxillofacial area represents 35–45% from all trauma categories[6]. The fact that this type of trauma is associated with a high morbidity rate, important aesthetic implications, severe functional alterations and a high influence upon the social life means that the maxillofacial fractures are characterized as a growing public health problem expanding worldwide [3].

The importance of understating completely the cause and the potential mechanism that produces the fracture in the facial area, as well as the severity grade and surrounding affected tissues, play an important role in deciding the proper treatment plan, the correct approach and the potential intra- and post-operative complications [7]. Research showed that the most frequent fracture in the maxillofacial area are the mandible fractures–1743 (42%), zygoma fractures (24%), orbital fractures (16%), nose fractures (9%), Le Fort fractures (5%), naso-orbito-ethmoidal fractures (1%) [3] [8].

3. Treatment Options

Treatment of the maxillofacial fractures varies based on the type of fracture, the localization and the implication of the surrounding tissue. Studies often compare the two types of treatment options—the closed reduction and the open reduction—using rigid internal fixation, each of them presenting advantages and disadvantages [9]. A proper outcome after the treatment of the fractures in this area is based on a stable fixation with a correct reduction and reposition of the fragments, efficient fixation that offers an optimal environment for healing, remodelling and revascularization of the area [10]. The surgical approach is the primary option when the existing fracture determines severe dysfunction, disfigurement and extension of the fracture site. Furthermore, the internal bone fixation approach using miniplates and screws is recommended when the intermaxillary immobilization is difficult for the patient or it has contraindications to be performed [11]. As an election material, titanium miniplates and screws proved an asset for the surgical treatment with a high biocompatibility that quickly found its use in traumatology, orthognathic surgery and maxillofacial oncology [1].

4. Healing and Repairing Process

The healing process is based on the intervention of the bone tissue, the bone marrow's cells, the periosteum and the soft tissue [12]. The homeostasis of the bone tissue is kept by the interactions of the osteoblasts, osteoclasts, bone-lining cells and osteocytes, all of them being responsible for the remodelling process [13]. When an interruption in the normal process occurs due to various causes, the aim is to regain the normal function of the tissue. A special category of cells that were discovered in the bone marrow have the power to differentiate into various other cell types, and among them are osteoblasts and chondrocytes. These cells are the mesenchymal stem cells (MSC), and they are defined through several specific surface markers (CD73, CD90 and CD105) [14]. Multiple studies have been conducted and the results revealed an important characteristic of the MSC—a characteristic that offers them a crucial role in the regenerative and reparative process of several adult tissues (bone, muscles, neuronal cells). The immunomodulatory effects of the MSC as proangiogenic, prosurvival and antiapoptosis properties transform them into an important adjuvant in tissue engineering and regenerative medicine [15] . In the oral cavity, the oral-derived stem cells (ODSC) can be obtained from the extracted teeth, mainly from the fresh dental pulp. Offering such an easy approach in the oral environment, this type of mesenchymal stem cells has gained the attention of researchers for further studies [16]. Also, similar cell populations have been identified in the periodontal ligament, dental follicle and gingival tissue with remarkable regenerative potential [16][17][18]. Further clinical studies that examined the oral bone formation after the removal of periapical cysts, describe the implication of stem-like cells in the local regenerative process, suggesting their presence in the granulation tissue [19]. These results could influence and change the perspective of bone regeneration in the maxillofacial region after the excision of cystic pathology. Multiple studies focus on reporting the existing relationship between the mesenchymal stem cells and bone tissue regeneration. The implication of the TGFβ1 gene in the differentiation process influences the mesenchymal stem cell's pathway to either an osteogenic or adipogenic cell. The use of PRP blood clot or vitamin D associated with dental-derived mesenchymal stem cells promoted the osteogenic process in the reported studies [20]. Taking into consideration the high potential of the oral cavity's tissues to provide mesenchymal stem cells that can develop into different types of tissue, the path of regenerative medicine encountered a new challenge. The oral mesenchymal stem cells are the target, possessing immunomodulatory molecules that have direct action upon the healing process and the inflammatory alterations.

Another possibility that promotes bone healing and regeneration in preclinical and clinical trials is the involvement of growth factors. The results revealed that for the expected results, the dose of growth factors is very high in order to accomplish the desired outcome, generating extreme cell multiplication [21]. In order to accelerate the bone regeneration, nanomaterials could be an option as the dimension is similar to the bone and the shape facilitates the local bioactivity, improving the bone growth. Several studies have revealed that a certain nanotopography of the inserted bone implants can influence bone regeneration. Also, nanomaterials can serve as matrices for the stem cells in order to obtain osteolineage, that could permit their differentiation [21]. Results have been obtained when bioactive coating of the implants occurred. Using titanium implants associated with bioactive coating proved to determine new bone growth at the interface. Nanoengineered biomaterials that target the regenerative potential of the bone tissue and promote the osteoblastic activity can be added to the implanted scaffold in order to stimulate and accelerate local healing.

Dental pulp stem cells (DPSCs) offer the change of using an autologous source in order to trigger and influence the regenerative process. The studies performed on culture cells with the association of human platelet lysate (PL) replacing the animal serum were a success. Human platelet lysate is biocompatible, generating no risk of viral transmission or contamination [22]. The dental pulp stem cells have osteogenic and angiogenic potential, with multiple differentiation possibilities. The study conducted by Marrazo et al. [22] analysed in vitro the effects that the added human platelet lysate had upon the dental pulp stem cells. The results showed a higher rate of the cell viability and proliferation when PL in concentration 1% was used, in comparison to the normal protocol that uses foetal bovine serum (FBS).

The medical procedures contribute to the solution of recreating a proper environment in order to regain the morpho-functional characteristics, to offer optimal conditions for the integration and the local remodelling process with the help of material substitutes. The term of biomedical devices refers to the replacement of the missing tissues using tested materials that can successfully fulfil all the desiderates of the specific area, maintaining a good interaction with the surrounding tissues [23], as shown in Table 1.

Table 1. Characteristics of metals used in maxillofacial reconstructions.

Property	Description

Elasticity Module	The amount of force required to break the material
Shear Stress	The amount of force required to break the material in a sliding type vector
Tensile Strength	The resistance of breaking under various tensions
Yield Strength	The amount of force required to deform the material

The osteosynthesis method in the maxillofacial field desires to regain the functionality and morphology of the bones, creating an optimal environment for the osteogenic process with the help of different materials that are biocompatible. The present review aims to evaluate the use of titanium alloys in maxillofacial osteosynthesis under various forms, the advantages and disadvantages that accompany their use and their long-term implications in relation with the surrounding tissues. Taking into consideration the important properties that titanium possesses, the existing studies still debate if the titanium alloys materials could be left or should be removed after a period of time due to possible alterations in the surrounding tissue and body fluids.

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