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Review Article

Overview of innovative advances in bioresorbable plate systems for oral and maxillofacial surgery

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Summary Maxillofacial osteosynthetic surgeries require stable fixation for uneventful boney healing and optimal remodeling. Although conventional titanium plates and screws for osteofixation are considered the gold standard for rigid fixation in maxillofacial surgeries, bioresorbable implants of plates and screw systems are commonly used for various maxillofacial osteosynthetic surgeries such as orthognathic surgery, maxillofacial fractures, and reconstructive surgery. Titanium plates are limited by their palpability, mutagenic effects, and interference with imaging, which may lead to the need for subsequent removal; the use of a biologically resorbable osteofixation system could potentially address these limitations. However, several problems remain including fundamental issues involving decreased mechanical strength and stability, slow biodegradation, complex procedures, and the available bioresorbable implant materials. Major advances in bioresorbable plate systems have been made with the use of bioactive/resorbable osteoconductive materials and an accelerator of bioresorption, such as polyglycolic acid. This report presents an overview of currently available resorbable implant materials and their applications, with a focus on recent innovative advances and new developments in this field.

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Contents

1. Introduction

Essential prerequisites for the stable fixation and sound healing of maxillofacial boney segments in maxillofacial osteosynthetic surgeries, such as maxillofacial fractures and bimaxillary osteotomies in orthognathic surgery, include sufficient vascularization, reduction or repositioning of bone segments, immobilization with stable fixation, uneventful boney healing and optimal remodeling [1—5]. Recent developments for standard treatment in maxillofacial surgical implant biomaterials have led to the achievement of stable fixation using a titanium plate system [1,3—5]. This contributes to patients' masticatory functional load immediately after such surgeries. The mechanical properties of titanium including its strength, ease of handling, lack of dimensional changes, minimal scatter on computed tomography (CT) scanning, and compatibility with radiography and magnetic resonance imaging have prompted its widespread adoption as the general standard [1,6,7].

However, as the need for fixation is only temporary and as metallic materials cause stress shielding of the underlying bone, these plates are often removed after the maxillofacial boney healing [1—3]. In 5—40% of cases, the titanium plates and screws are removed in a second operation once the bone has healed as titanium is associated with potential effects on facial growth, thermal sensitivity, plate migration, and interference with diagnostic imaging [3,4,8,9]. Other adverse effects of retained metallic devices include osteopenia of cortical bone induced by stress and corrosion [7—9]. Moreover, titanium particles have been found in scar tissue covering these plates, as well as in locoregional lymph nodes, and imperfect contact can occur between the metal plate and bone surface [6—9]. Most recently, it was reported that even titanium miniplates are a risk factor for the development of bisphosphonate-related osteonecrosis of the jaw [9,10]. Therefore, titanium osteofixation implant materials should be removed [5—9], and resorbable bone fixation implant materials for plate and screw devices have been developed.

Bioresorbable and biodegradable osteosynthetic fixation implants have been considered an effective fixation system that offers several advantages over titanium fixation, including the absence of corrosion and of accumulation of metal in tissues, and of the need to remove the implants after osseous healing; radiolucency; decreased pain; and reduced stress-shielding as the implants bear a smaller load initially and gradually transfer the load as they degrade [1—3,7,9]. The first study on the use of biodegradable implants was published in 1966 by Kulkarni et al. [11], who studied the biocompatibility of poly-L-lactic acid (PLLA) in animals. The use of PLLA plates and screws to fix mandibular fractures in dogs was studied, and the material was non-toxic and gradually degraded [11]. Another study presented the results of PLLA sutures in mandibular fractures with no serious tissue reactions such as severe inflammatory and immunological responses [12].

Bioresorbable implant materials allow newly formed tissue to grow into any surface irregularities. Thus, a resorbable osteofixation implant material is free of toxic and mutagenic effects. Nonetheless, there are some problems related to the use of these materials, such as an inflammatory response, rapid loss of initial implant strength, higher refracture rates, inadequate stiffness of the implants, and weakness compared to metallic implants [13—15]. Biodegradable osteofixation implants are characterized by biomaterials that disintegrate after implantation with no sign of elimination from the body. The biodegradation process depends on contact with body fluids, temperature, motion, molecular weight, the crystal form and geometry of the material, and the tissue that is implanted [13—15]. The ideal biodegradable osteofixation implant material provides appropriate strength while degrading in a predictable fashion throughout the healing process without causing adverse reactions [1,6—9].

On the other hand, the limitations of biodegradable osteofixation implants are associated mainly with their mechanical properties [13,14,16]; they are weaker than conventional such titanium metal implants, leading to low confidence levels regarding the stability of reduced fractures [13,16]. Biocompatibility may be another limitation of these materials as they can provoke adverse tissue responses that have characteristics of an inflammatory, bacterial foreign-body reaction [16,17].

However, bioresorbable implant materials for oral and maxillofacial osteosynthetic applications are currently becoming more common. These materials are safe, effective, and sufficiently flexible for use at many maxillofacial boney surgical sites [13—17]. Numerous clinical studies and several review articles have documented the feasibility of

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