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Use of Bioresorbable Plating Systems in Oral and Maxillofacial Surgery – A Review

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Abstract

Purpose: A strong and stable fixation is essential for uneventful bone healing and remodeling in any maxillofacial surgeries. Whilst the significance of the conventional titanium plates in rigid fixation, they have been replaced by bioresorbable plating systems in recent times. The constraints of titanium plates such as requirement of secondary surgery had led to the evolution of bioresorbable plates. The primary objective of this analysis is to research about the use of bioresorbable plating systems over titanium plating systems, currently available bioresorbable plating materials and to collate the benefits of the two.

Materials and Methods: An elaborate search of PubMed and Scopus database was performed based on the literature norms. The data collected were collated and reviewed accordingly. The articles were screened using keywords and inclusion criteria for the final review.

Results: About 112 articles were capitulated during the initial search. Among of which, 1 retrospective study and 6 prospective studies are also included in the final review. Out of these, 7 studies focus on the comparison of titanium plates and bioresorbable plates, 10 studies highlight about the benefits of bioresorbable plating systems, 13 studies assess the materials used in the bioresorbable plates and its recent advances.

Conclusion: The results suggest that the prevalence of bioresorbable plates is higher due to its benefits over the titanium plates. However, few disadvantages such as low stability and limited available bioresorbable materials narrow the use of bioresorbable plates in the field of medicine. Further research is needed for unbiased data.

Keywords: NIL

Introduction

Maxillofacial surgeries are a common presentation in individuals who endure trauma. Weekend sporting events and social activities especially in combination with alcohol, road traffic accidents, and interpersonal violence had unfortunately increased the incidence of maxillofacial injuries at an alarming rate. [20] Fracture with bone displacement eventually induces functional and cosmetic problems. Thus, stabilization of fractured segments is mandatory to restore normal function and appearance. Multiple surgical modalities have been concocted over time. Closed reductions with maxillomandibular fixation, open reduction with rigid fixation are some of the treatment modalities. [2]

Titanium plates are considered to be gold standard in rigid fixation of fractured segments till date. [1, 21] This adds to patient's masticatory functional load following the surgeries. [3] While being non-resorbable, titanium is utilized because of its excellent biomechanical properties such as strength,

ease of handling, decreased dimensional changes, high biocompatibility, resistance to corrosion, minimal scatter on computed tomography scans(CT), and compatibility with plain x-ray and Magnetic resonance imaging(MRI).[3, 7]

However, there are many downsides associated with titanium miniplates and screws despite providing rigid internal bone fixation. (1) They are of no use after the osteosynthesis accomplished and may act as a foreign body, making issues in future due to stress-shielding effect, (2) they may result in underlying bone atrophy, (3) palpability, (4) interference with computed tomography(CT), magnetic resonance imaging(MRI), (5) sensitive to body temperatures, (6) growth retardation and intracranial migration have also been reported.[8] Moreover, the metal plates and screws might prompt to destruction and osteoporosis in the surrounding bone tissue.[4] Consequently, there is a requirement for secondary surgery for removal for metallic fixation. In addition, titanium particles are seen in the scar tissue covering these plates as well as in locoregional lymphnodes. Recently, a new risk factor associated with titanium miniplates which is the development of bisphosphonate – related osteonecrosis of the jaw had also been documented. [1, 4, 21]

Hence, the bioresorbable plates came into existence in 1971 by Kulkarani et al as an alternative to conventional titanium plates. Initially, they were mechanically unstable, poor in maxillomandibular fixation and were bulky to be used in maxillofacial region. The bioresorbable materials used in plates and screws are polyglycolide, polyglycolic acid [PGA], polylactic acid [PLA], polydioxanone, tri-methylene carbonate.[16] Kulkarani studied the biocompatibility of poly-L-lactic acid on animals and published the first study related to this concept in 1966. This study concluded that a single polymer used in bioresorbable plates either degraded too quickly or by slow degradation with no added benefits and the materials were proved to be non-toxic.[16, 4] This later led to the development of multi-polymer bioresorbable plates, usually a combination of polyglycolic acid and polylactic acid.[16, 2, 22] Further studies presented that these bioresorbable materials showed no serious tissue reactions such as inflammatory and immunological responses.[1, 4, 14]

The bioresorbable plating systems are effective over titanium plating systems in several aspects such as absence of corrosion; allow a newly formed tissue to grow into any surface irregularities, the requirement of secondary surgery is minimal, physiological forces are transferred gradually to the healing bone, radiolucency, prevents stress-shielding effect as they naturally degrade through body fluids and enzymes.[1, 14] This process depends on their contact with body temperature, motion, molecular weight, the crystal form, geometry of material and the tissue been implanted. [8, 16, 22] The ideal bioresorbable materials are rigid and offer appropriate strength and stability without causing adverse reactions to the healing bone. [4, 14, 19, 22]

Despite these advantages, the biodegradable plating systems possess various limitations. The foremost limitation of the biodegradable plates is their mechanical properties which are weaker than conventional titanium plates, eventually leading to doubting of reduced fracture stability. They do produce adverse tissue responses such as inflammatory, bacterial foreign-body reaction. [19-22] However, the bioresorbable plating systems are currently becoming more common and are popularly used in orthognathic surgeries, pediatric mandibular fractures, zygomatic fractures in maxillofacial region.[1, 4] Multiple clinical studies and articles have reported the effectiveness of the bioresorbable plating systems and the comparable results between the use of biodegradable and conventional titanium plates in maxillofacial region.

This study displays an overview of bioresorbable materials that are available in market and their clinical applications, their modifications and improvements in oral and maxillofacial surgery.

Materials And Methods:

Literature Search:

The articles referred are collected after an extensive search of the PubMed and Scopus database that was performed based on the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. The articles published from January 2002 to January 2020 were obtained using the following keywords: bioresorbable plates and screws, bioresorbable plates versus titanium plates, bioresorbable fixation in maxillofacial surgery, and

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effectiveness of bioresorbable plates over titanium plates. The articles that were duplicated and unrelated to the topic were removed after reviewed by an initial research group. Rests of the articles were evaluated based on inclusion criteria and was scrutinized once again by separating the articles that did not satisfy any inclusion criteria. The inclusion criteria were restricted to articles that distinctively studied the advantages of bioresorbable plating systems, their applications and recent advances in the field of oral and maxillofacial surgery. Only the articles that persuaded the above inclusion criteria were selected for the final review after verified from the secondary research group.

Inclusion Criteria:

1. FOCUS: The reason behind increasing popularity of bioresorbable plates.
2. TYPE OF INTERVENTION: Bioresorbable plating systems in maxillofacial region.
3. TYPES OF OUTCOME: Any outcome variable after bioresorbable fixation or comparison of various outcome variables after bioresorbable and titanium fixation in maxillofacial region.
4. STUDY TYPES: Previously published literature reviews, meta-analysis, prospective and retrospective studies.
5. ARTICLE TYPES: Complete articles in the English language.

Exclusion Criteria:

Any article that referred to allocate and the above inclusion criteria list.

Results:

About 112 articles were obtained after a comprehensive search of PubMed and Scopus database. After the removal of the duplicate articles, 70 articles remained. The review performed by initial research group based on analysis of titles and abstracts ceded 52 studies. From these studies, 12 studies were excluded as they did not approve the inclusion criteria. After the review of second group of the left over 40 articles, 22 articles were selected for final review that had sufficient data regarding the bioresorbable plating systems.

Among these 22 articles, 6 were prospective and 1 was retrospective; 4 studies recorded pediatric patients with only mandibular fractures and the remaining 7 studies enrolled adult patients with mandibular angle, symphysis and zygomatic fractures. 3 studies used patients with maxillofacial and craniofacial fractures. 5 studies evaluated the effectiveness of bioresorbable plates over titanium plates and 1 study assessed the stability of bioresorbable fixation after orthognathic surgery. 2 articles reviewed about the clinical applications of bioresorbable plates and screws in maxillofacial region and 2 more studies provide data about recent advances in bioresorbable plating systems with comparison of different bioresorbable materials.

Discussion:

The titanium plates being gold standard for rigid fixation, had been replaced by the bioresorbable plates due to the limitations of the titanium plates. The use of bioresorbable plates are increasing in routine maxillofacial surgical procedures since the principal report of biodegradable plates and screws. Presently, several bioresorbable plating systems are found in the market. Most of the commercially available biodegradable plates and screws are derived from polymers and copolymers of glycolic acid [polyglycolide (PGA)]; lactic acid [poly-lactide (PLA)]; mixture of poly-L-lactide [PLLA] and poly-D-lactide [PDLA]; and calcium phosphates. [21, 23]

Calcium phosphates [CaPs] are chemical compounds that are naturally occurring in the earth's crust and similar to inorganic component of major normal (bones, teeth and antlers) and pathological calcified tissues of mammals. The frequently used CaPs as ceramics are β – tricalcium phosphate [β-TCP] and hydroxyapatite [HA]. B-TCP is biodegradable and promotes osteogenesis while HA is highly crystalline, most stable and least soluble CaPs. [4] Hence, HA may stay in the integrated regenerated bone tissue whereas β-TCP gets resorbed completely. In addition, CaPs have compromised mechanical properties that hinder load-bearing applications. In the quest to overcome these drawbacks, these materials were combined with polymers to deliver composite bioactivity as to form a composite with optimized properties. [4, 1]

The bioresorbable polymers are mainly high - molecular weight aliphatic polyesters. [1] Among them, the most popular materials are PGA, PLA and their co-polymers. [4] The strength of these polymers was diminished in early period and was later

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improved by the usage of self-reinforcement technology. [22] The absorption of these materials occurs in two phases: hydrolysis and fragmental metabolisation. Hydrolysis happens through penetration of body fluids into implant, followed by a chemical reaction with polymer resulting in polymer chain breakage. Fragmental metabolisation results when fragmentation of polymer continues until the final metabolisation of single lactic acid molecules into carbon dioxide and water. [2]

The first clinically used bioresorbable polymer was polyglycolic acid [PGA]. However, due to their rapid degradation, adverse tissue responses, and decreased mechanical strength after 6 weeks of implantation have limited its use in maxillofacial osteosynthesis. [1, 4, 22] Another bioresorbable polymer in this segment is polylactic acid [PLA], having high-molecular weight and two stereo isomeric forms based on the L and D configuration. They are poly-L-lactide [PLLA] and poly-D-lactide [PDLA]. [4, 22] The PLLA and PDLA had been recognized as "First Generation" materials since 1990s. Comparatively PDLA has lower crystallinity and less resistant to hydrolysis than PLLA. However, the degradation rate of PLLA is faster than PDLA resulting in its use limited only to maxillofacial bone surgery. While, PDLA being highly biocompatible and can be used for whole facial osteosynthetic surgeries including midface and mandible. [1] In spite of the prevailing advances in the bioresorbable materials, especially polymers, minimal improvements in their strength have been documented when compared to titanium plates. Moreover, addition of thickness is also needed to provide sufficient strength and to reduce complications such as palpability. [22]

Co-polymers of PGA, PLLA and PDLA were regarded as "second generation" and rapidly bioresorbable osteosynthetic materials. [1] Their properties can be managed by adjusting the ratio of glycolide to lactide for different compositions [4]. The crystalline PGA is co-polymerized with PLLA to increase the rates of hydration and hydrolysis. The ratio of monomers utilized in synthesis determines the degradation time of the co-polymers. The design of the co-polymers is made in such a way to provide 6-8 weeks of adequate strength and 12-18 months of complete resorption time. [1, 22] These co-polymers are feasible with less post-operative complication rates according to a retrospective clinical study by sukegawa et.al [1]. The bioresorbable plates gained a huge attention among surgeons and patients because these biodegradable plates offer strength when it is required and degrades naturally in contact with body fluids. [12] The masticatory load is also transiently and safely transferred to the healed bone. [12, 13] Moreover, it minimizes the requirement of secondary surgery, duration of the treatment and post-operative complications [12]. Additionally, it does not hinder the growth in growing individuals.

The clinical applications of bioresorbable plates are increasing day-by-day. In maxillofacial surgeries, they are widely used in orthodontic surgery, for craniomaxillofacial fractures, bone augmentation for dental implantation, oncological reconstruction, orbital and zygomatic fractures. However, the success rate of bioresorbable plates depends on various factors such as blood supply, type of trauma or fracture, age of patient, severity of trauma. [5, 13] Recent studies evaluated that bioresorbable plates such as PGA, PLLA and PDLA that are used for fixation of zygomatic fractures maintains the post-operative stability of bone segments and improved operational efficiency for fixing ZMC fractures in the future. [3, 15] According to the statement of Laudes.et.al., the bioresorbable plates when used for orthognathic surgeries such as in sagittal split osteotomies works similar to titanium plates in fixation and try not to force an increase in clinical morbidity [8]. Eppley after reviewing 53 isolated malar fractures fixed with bioresorbable plating systems reported with minimal clinical differences in intraoperative bone stability or postoperative long-term results in comparison with titanium plates. [9] In pediatric mandibular fractures, the biodegradable fixation systems were documented to be safe and efficient with enough strength to bear masticatory force and they are easily contourable and mouldable intraoperatively. [17-19]

Limitations:

Despite numerous positive outcomes, the bioresorbable plates do present with small incidence of complications in certain cases. In a study performed by Bujjis et al., he stated that the performance of the bioresorbable plates were inferior to titanium plates in case of non-correct occlusion and had a significantly increased rate of foreign body reaction and mobility and in addition, they are

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expensive. Postoperative edema and plate palpability has been documented in a study conducted by Edwards and kiely. [7] In another study conducted by Ensildis et al., in 57 patients reported post-traumatic sequalae (hyperesthesia or dys/paresthesia) lasting longer than 6 months [20]. The difficulty to differentiate between the plates & screw holes also prevails as the resorbable plates are transparent. The incidence of wound dehiscence and infections were also reported (most commonly in symphysis area) [10].

Conclusion:

Bioresorbable plating systems are a game changer in rigid fixation for fractures involving maxillofacial region. Being radiolucent, they do not interfere with computed tomography (CT) or magnetic resonance imaging (MRI) and offers the clinician to evaluate the progress of the healing bone. With improved developments in the past several years, the bioresorbable plates provide greater clinical success rate with minimal complications. However, larger studies and increased researchers are required for further improvement in their performance.

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