

3D PLATES IN FACIAL RECONSTRUCTION

Abstract

The chapter includes the future trends of 3D plates in Maxillofacial reconstruction. Primarily the locking, non-locking and conventional mini plates have been used but nowadays the 3D i.e. 3 dimensional mini plates are in trend as they have better stability, support and prognosis as well as less exposure while treating the patient. The 3D plates give support and stability in 3 directions which makes it different from other plating systems. There are many types of 3D plates used for facial reconstruction. The efficacy of titanium 3D plates is better over other metals. The chapter describes the 3D fixation on maxillofacial reconstruction.

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I. INTRODUCTION

Human beings have suffered from painful injuries from time immemorial. Since then, he has constantly strived hard to find some method of treating himself. We will never know with certainty the time when an early hominid first adjusted a fracture dislocation. Perhaps it happened in the previous Stone Age that a broken extremity was splinted with wood or bamboo sticks embedded in clay that was allowed to harden.

In the era of increasing auto mobilization, industrialization, and technologies, the treatment of maxillofacial injuries has attained a prominent position. Road traffic accidents, which are becoming more and more frequent, particularly have brought about an increase in maxillofacial injuries. The head is the prominent part of the body and has the highest injury rate in the entire body. Other causes of facial injuries include personal injury, falls, sports, and trauma¹. If left untreated or treated incorrectly, fractures can cause many damages such as functional, aesthetic, neurological and psychological.

Although fracture is a difficult term to define, it can be defined as "the disruption of bone continuity due to stress exceeding its elastic modulus, resulting in two or more fractures." The main goal of orthopedic surgery is to improve aesthetics and function, as well as to predict the body's recovery from previous injury. Treatment strategies for maxillary fractures have evolved over the past several decades. These procedures include reduction with maxillomandibular fixation (MMF), open reduction with metal osteosynthesis, open reduction with rigid internal fixation, or adaptive miniplate fixation².

The treatment of mandibular fractures has disadvantages such as failure to achieve reduction and stabilization, poor patient performance, malnutrition, and depression difficulty maintaining oral hygiene and losing weight. It also has effects such as muscular dystrophy, secondary changes in the TMJ, and airway obstruction, with a rate of approximately 40%³.

Open reduction and internal fixation (ORIF) of the mandible with bone plates was first described by Schede in 1888. Those who use plates and screws. Rigid immobilization using plate compression shortens the duration of MMF and restores maxillomandibular function⁴.

Over the years, many plate and screw osteosynthesis techniques have been introduced, such as the AO bicortical late system; 2D mini plate system, absorbable plate and screws, 3D mini plate system and locking mini plate system. Research continues to focus on the size, shape, quantity, and biomechanics of plates/screws/systems to improve surgical outcomes. Miniplate osteosynthesis, first proposed by Michelet⁴ in 1973 and further developed by Champy in 1976, is today's the standard in the care of mandibular fractures. Champy describes the best bones to plate to prevent twisting. The main benefits of this method include eliminating the disadvantages associated with the IMF. A relative disadvantage of traditional plate/screw technology is that the plate must fit the underlying bone perfectly and accurately to prevent segmental and screw alignment changes⁵. Changes in occlusal relationship⁵. As the screw is tightened, the screw head presses the plate against the bone, ensuring the stability of the bone. The introduction of the 3D system provides and continues to guarantee the treatment of lower jaw fractures. Advantages over other coating methods. These plates work in fixators, providing stability through a 3-dimensional plate. Titanium has proven to be suitable as an implant material for bone plates due to its excellent

biocompatibility and corrosion resistance. Titanium is a hard metal that produces a thick, consistent passivating oxide product that prevents it from penetrating surrounding tissue⁶. From a biomechanical perspective, titanium has high tensile strength and low elastic modulus. Titanium has an elastic modulus approximately half that of stainless steel, so there is less risk of stress resistance in bones⁷.

II. HISTORY

1. **Hippocrates** (460 to 375 B.C.) "Father of Medicine" was the first to describe the basic principles of modern fracture repair, reduction, and stabilization. He described direct re-approximation of the fracture segments with the use of circum dental wires. He also advocated wiring of the adjacent teeth and external bandaging to immobilize the fracture. He had the insight to realize that re-approximation and immobilization are paramount in the treatment of fractures⁸.
2. **Salerno** (1180) from Italy described the importance of establishing a proper occlusion.
3. **Guglielmo Salicetti** (1492), in his book *Cirurgia* introduced the theory of maxillomandibular fixation by stating that 'tie the teeth of the uninjured jaw to the teeth of the injured jaw'.
4. **Gilmer** (1881) described the use of two heavy rods placed on either side of the fracture that were wired together. In the middle of the nineteenth century, Buck, using an iron loop, and Kinlock using a silver wire, treated maxillomandibular fractures with an open reduction⁴.
5. **Hansmann** (1886) was the first to develop and present a procedure for the subcutaneous fixation of bone fragments with a plate screw system. He is, therefore, the inventor of plate osteosynthesis. Up to 1886, Hansmann had treated 21 bone fractures and pseudo-arthrosis with this method. Two of these were mandibular fractures making him the first to perform plate osteosynthesis on the mandible. In 1888, Schede (Circa) is credited with the first use of a true bone plate made of steel and secured with 4 screws.^{9,4}
6. **Niederdelmann and Schilli** (1972, 1973) modified the plates which possessed two holes located close to the fracture gap for screws to build up axial pressure. Two more holes were angled at 45° to exert compression at the alveolar ridge (Niederdelmann and Akuamo-Boateng, 1978): once the screws were inserted, the eccentric position of the holes led to compression at the alveolar ridge, the site where tensile stress occurs. For that reason, the plate was named EDCP meaning Eccentric DCP¹⁰.
7. **Champy et al.** (1975) modified this method to make it clinically more applicable (Champy and Lodde, 1976, 1977; Champy, 1983, 1992). Various experimental tests with two-dimensional models helped to analyze the bio-dynamics. As soon as tensile stress occurred on the plate which was fixed to the alveolar ridge, a corresponding pressure built up at the base of the tested mandible. This caused an increase in dynamic compression and stability. The dimensions of the plates could be kept small as the mini plates only had to cope with tensile stress. These studies helped to find an ideal line for osteosynthesis a line of maximum tensile stress running from the oblique line along the base of the

alveolar ridge to the mental foramen. Here one single miniplate should be sufficient. Additional torque in the region between these foramina required a second (more basal) plate. Originally; these plates were made of stainless steel which was later changed to titanium generally¹⁰.

8. **Edward Ellis** (1993) In his retrospective study of mandibular angle fractures that were treated by extra-oral open reduction and internal fixation using the AO reconstruction plate showed that a stronger bone plate with more screws on each side of the fracture can be used without compression to restore the functional integrity to the fractured mandible and was associated with a low rate of post-operative infection and malocclusion⁶.
9. **Nicholas Zachariades**, (1996) described that Lag screw osteosynthesis is a form of compression osteosynthesis in which the bone fragments are bound to one another under pressure as a result of traction from the screw. Compared with compression osteosynthesis with bone plates, it is easier to apply because the task of adapting a bone plate is eliminated, it costs less and requires limited surgical exposure and less implant material¹¹.
10. **R. Gutwald** (2010) has done a study to compare a combination of locking systems with self-tapping or self-drilling-trapping screws with a combination of conventional mini plates with self-trapping and self-forming screws. He concluded that the improved stability of the osteosynthesis with the ST-L system resulted in early ossification of the osteotomy gap and the smallest amount of callus formation¹²

At the outset of plating for maxillomandibular fractures, there were two schools, one advocating compression and the other one just stability. Miniplate osteosynthesis has changed fracture treatment and has become a valuable option during the last two decades. Advantages are the simple application via an intra-oral approach, no need to expose much bone, and the ease of adapting the plates (sometimes unnecessary) to the surface of the bone. Although over 100 years old, plate osteosynthesis is a focus of research interest in regenerative medicine.

III. ABOUT METAL

Metals for maxillofacial surgery may require specific characteristics and mechanical properties. 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 steel¹⁴. 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 revolutionized the field of maxillofacial reconstruction¹⁵. In the following sections, we will examine the use of each of these metals in maxillofacial surgery (Table 2).

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

- 1. Titanium:** Titanium exhibits mechanical properties desirable for internal rigid fixation, and, when combined with its degree of biocompatibility¹⁵, 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 the reconstruction of the maxillofacial skeleton¹⁶. Titanium has been used successfully as an implant material and this success with titanium implants¹⁷⁻²¹ is credited to its excellent biocompatibility due to the formation of a stable oxide layer on its surface²²⁻²³. Commercially pure titanium is classified into 4 grades which differ in their oxygen content. Grade 4 has the most (0.4%) and grade 1 has the least (0.18%) oxygen content. The mechanical differences that exist between the different grades of titanium are 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 fractures²⁸. These materials have the advantage of strength and shape retention offered by titanium while polyethylene provides a porous biocompatible surface that allows for tissue growth. The success of titanium in maxillofacial surgery is certainly due to its biological and mechanical properties. Has been widely reported that biomaterials such as titanium can support bone growth²⁵, as their mechanical properties are similar to bone tissue²⁶⁻²⁷. Titanium is an inert, noncorrosive, and malleable metal. Furthermore, titanium offers the advantage of visibility on postoperative imaging with minimal distortion at MRI²⁸. More recently, titanium mesh cranioplasty has been 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 defects²⁹⁻³⁰. The 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 the soft tissue situation is not optimal and the dark color stands out through the thin mucosa.

2. **Plating System:** Classification of Plating System³¹

- Luhr Vitallium maxillofacial systems
- Mandibular compression screw system
- Mini system
- Microsystem
- Mandibular reconstruction system
- Champy's system
- AO/ASIF maxillofacial implant system
- DCP, EDCP
- Reconstruction plates
- The Würzburg titanium system for rigid fixation

3. **What are Miniplates**³¹

The length of mini plates varies between 2 and 9 cm and their thickness is 0.9 mm. They are available in different lengths such as 2-hole, 3-hole, 4-hole, 6-hole, 8-hole, 16-hole or extension plate. 4 hole and 6 hole plates with intermediate space are available. 2.1 mm is the minimum diameter of the hole in the plate with a tilt angle of 30°. A wide variety of pre-shaped plates like L, X, Y, T, and K, delta shaped, and 3D- and H-shaped plates are also available.

4. **What is Screw**³¹ (figure 1)

- All screws are cortical and self-tapping and have a cruciform head.
- Available in lengths of 5, 6, 7, 9, 11, 13, and 15 mm.
- 2 mm is the diameter of the screw with 1.6 core diameter of thread.
- The screw thread is 10/10, so that one turn of the screw corresponds to 1 mm penetration into the bone.
- 2.8 mm is the screw head diameter, and it is designed such that it allows insertion at a 30-degree angle concerning the plate surface.
- The drill has the same diameter as the core of the screws—1.6 mm. This ensures firm anchorage of the self-tapping screws.

5. **Biomechanical Properties of Screw**³¹

- The outer diameter or outer part is approximately 0.8 to 2.0 mm. It is the diameter of the head of the screw. Surgical bone screws clamp the plate and bone together.
- The pitch of the screw is calculated from one point of the thread to the corresponding point of the adjacent thread, on the same axis of the screw.
- The difference between the diameter and the outer part is the thread depth.
- The distance between the tip of the screw and the head of the screw is the length of the threadless rod.
- The distance between the screw tip and the plate is the length of the shank and plate.

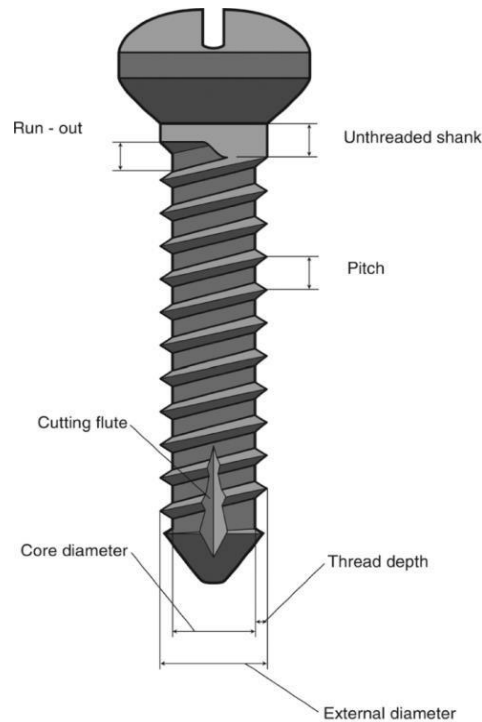


Figure 1: Screw

6. Three-Dimensional (3D) Plates³¹: The two mini plates are connected by interconnecting crossbars which are used as 3D plates. Technically, they are not three-dimensional structures, but their closed quadrilateral shape provides stability in all three dimensions.

7. Different types of 3D Plates

- Rectangular plate (fig.13)
- X Shape plate (fig.3)
- Square plate (fig.12)
- Double square plate (fig.12)
- Double or triple rectangle plate (fig.13)
- Double Y shape plate (fig.2)
- I shape plate (fig.5)
- Z shape plate (fig.7)
- H shape plate (fig.6)
- Delta plate (fig.11)
- Trapezoid plate (fig.9)
- Grid plate (fig.8)
- Sub Y shape plate (fig.10)
- Trifix plate (fig.14)
- Struts plate (fig.15)



Figure 2: Double Y shape



Figure 3: X shape



Figure 4: Y shape



Figure 5: I shape



Figure 6: H shape



Figure 7: Z Shape



Figure 8: Grid plate



Figure 9: Trapezoid Condyle Plate

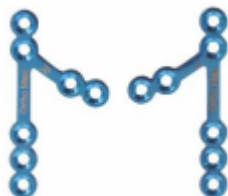


Figure 10: Sub Y plates



Figure 11: Delta plate

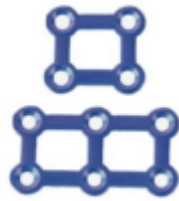


Figure 12: Square Plate

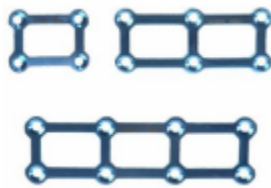


Figure 13: Rectangular Plate

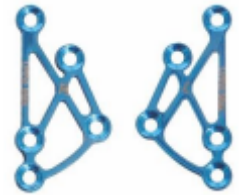


Figure 14: Trifix plate



Figure 15: Strut Plate

8. Advantages of 3D Plates

- 3D plates were indeed easy and simple to use.
- Significant reduction in operating time could be achieved with the use of 3D plates which makes it a time-saving.
- Patients treated with 3D plates showed lesser postoperative pain in 1st week, 1st month, and 3rd month.
- Patients treated with 3D plates showed a lower incidence of post-operative infection.
- Other complications were found to be extremely rare.
- This 3-D plating system can be used with satisfactory results, especially in anterior mandible fractures.
- This technique does not require expensive armamentariums.
- These plates ensure 3D stability and the period of immobilization was not necessary as in other systems.
- The morbidity associated with prolonged immobilization is reduced.
- This system is associated with minimal incidence of complications.
- This system requires a lesser area of exposure.
- Close approximation.
- Greater stability across the fracture site.
- Less alteration in the osseous or occlusal relationship upon screw tightening.

- 9. Disadvantages:** The probable limitations of 3D plates may be excessive implant material due to the extra vertical bars incorporated for countering the torque forces, cases where the fracture line passes through the mental foramina region, and the angle of the mandible where 3D plates cannot be adopted.

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