Efficacy of Titanium Mesh Osteosynthesis in Maxillofacial Fractures

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Abstract

Introduction Trauma is steadily increasing in the modern world and thus becoming a major public problem. Maxillofacial injuries constitute a substantial proportion of cases of trauma and occur in a variety of situations like road traffic accidents, interpersonal violence, falls or as a result of contact sports. The aim of this prospective study was to evaluate the efficacy of titanium mesh for osteosynthesis of maxillofacial fractures.

Materials and Methods Fifteen patients of maxillofacial fractures who were treated with titanium mesh were included in this prospective study. The patients were evaluated preoperatively, intraoperatively and postoperatively at 7th day, 3rd week, 6th week and 12th week.

Results The mean age of fifteen patients was 31.3 years with a male:female ratio of 14:1. The most common mode of injury was road traffic accident (86.6%). The mean time interval between injury and surgical procedure was found to be 7.6 days. The majority of fracture sites (88%) were comminuted. 93.3% of the patients achieved good occlusion by 12th week postoperatively. Postoperative complications included residual hypoaesthesia in four patients and wound dehiscence in one patient.

Conclusion We conclude that titanium mesh is a versatile option for maxillofacial fractures. It provided good stabilization especially in comminuted fractures. As a fixation method, it was quick in placement and highly adaptable, and thus, it proved to be valuable in restoring the form and function in maxillofacial trauma patients.

Keywords Comminuted fractures · Facial injuries · Semi-rigid fixation · Three-dimensional stability

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Introduction

Maxillofacial fractures occur in a significant proportion of trauma patients as a result of the prominent position of the head. The changing pattern in the aetiology of facial trauma over the last three decades has been influenced by socioeconomic factors, geographic region as well as modes of transportation. The major factors reported worldwide are traffic accidents, assault, falls, sports-related and occupational injuries. These injuries lead to cosmetic and functional disability in the facial trauma patients and are of primary concern to the maxillofacial surgeon. The management of maxillofacial complex fractures thus remains a challenge for oral and maxillofacial surgeons, demanding both skill and a high level of expertise.

The treatment of facial fractures has evolved greatly over the years, from supportive bandages, splints, circum-mandibular wiring, extraoral pins, and semi-rigid fixation with transosseous wiring to rigid fixation. Traditionally, stainless steel wire was used for osteosynthesis in maxillofacial surgery until the work of Michelet [1] and Champy [2], which led to wide acceptance of monocortical miniplates. Miniplates have been known to provide functionally stable fixation and prevent micromovements of the bony fragments under function.

Other advantages of miniplates include avoidance of maxillomandibular fixation, better oral hygiene and reestablishment of midface vertical dimension. However, they have certain drawbacks also, such as thermal sensitivity, loosening of one or more screws during the convalescent period which necessitates plate removal.

These shortcomings led to the development of three-dimensional (3D) concept of stabilization and can be achieved with 3D miniplates, curved strut plates and mesh systems. The biomechanical stability achieved by these systems helps in combating the torsional and bending forces along with the advantages of simplified adaptation to the bone without distortion or displacement. Combining all the features of 3D stability, mesh has an added advantage of being versatile in nature. The semi-rigid nature of TiMesh osteosynthesis allows micromovements at the healing bone ends and prevents stress shielding along with acceptable postoperative aesthetic results [3, 4].

The applications of titanium mesh in the maxillofacial region include osteosynthesis in traumatology especially for comminuted fractures [3], craniofacial reconstruction [5], mandibular reconstruction [6], augmentation of atrophic maxilla and mandible [7] and orthognathic surgery (stabilization of LeFort I and ramal osteotomies) [8]. The objective of this study was to evaluate the efficacy of titanium mesh for osteosynthesis of maxillofacial fractures based on its intraoperative use and also postoperative clinical and radiographic assessment.

Materials and Methods

Fifteen patients with maxillofacial fractures who reported to our department from September 2013 to November 2014 and required open reduction and internal fixation were selected for the study. The age of the patients ranged from 18 to 55 years (mean age 31.3 years). Diagnosis of the fracture was made on the basis of detailed history with thorough clinical and radiographic examination. *Radiographic examination* included orthopantomogram (OPG), postero-anterior view of mandible (PA view) and occipit-omental projection (Water's view). *Haematological investigations included* complete blood count (CBC), liver

and renal function tests, ELISA for HIV, Australian antigen for hepatitis B and anti-HCV antibody test for hepatitis C, *complete urine analysis* and any other investigation as per individual patient's requirement. The preoperative assessment included age and gender of the patient, anatomic location of the fracture, aetiology and type of fracture, time period between injury and treatment, occlusion and maximum interincisal opening.

Preoperatively, Inj. Augmentin 1.2 g (Glaxo SmithKline Pharmaceuticals) was administered intravenously. It was continued till the first postoperative day. Subsequently, all patients were prescribed oral Tab Augmentin 625 mg (Glaxo SmithKline Pharmaceuticals) thrice a day for a period of 1 week. The surgical procedure was carried out either under local anaesthesia with premedication or general anaesthesia.

Fracture segments were reduced with intermaxillary fixation (IMF) using upper and lower Erich arch bars. Internal fixation was achieved using 0.5-mm titanium mesh for midface fractures and 0.6-mm titanium mesh for mandibular fractures. According to the location, extent of fracture and comminution, the desired size of mesh was cut using a mesh cutter from the 16 × 16 hole square sheet. The mesh was adapted to the bone taking care of the neurovascular bundle (if involved in the fracture segments), with the help of bending pliers. Fixation was achieved using 1.5- or 2.0-mm screws of appropriate length with a minimum of two screws on each side of the fracture line (Figs. 1, 2). Perioperatively, time taken for adaptation and fixation of implant was noted. Intermaxillary fixation (IMF)/intermaxillary elastic traction was given postoperatively in patients wherever needed.

Postoperative assessment was carried out both clinically and radiographically on 7th day, 3rd week, 6th week and 12th week. *Clinical evaluation* included assessment of

Fig. 1 Fracture site exposed (right parasymphysis)

Fig. 2 Fixation of fracture site

occlusal outcome and maximum interincisal opening. Occlusal outcome was categorized as *good*—equivalent to premorbid occlusion, *fair*—minor discrepancies in occlusion for which either no treatment or occlusal adjustment was required, *poor*—required reoperation to achieve acceptable occlusion. *Radiographic evaluation* included assessment of fracture reduction in radiographs and was graded as *good*—anatomic reduction, *fair*—minor radiographic spacing of fractures, *poor*—significant discrepancy. *Complications* if any were documented.

Data were collected and tabulated using Microsoft excel. Statistical analysis of results was performed using SPSS (version 15.0) and included paired *t* test for evaluating maximum interincisal distance. Results were considered statistically significant if $p < 0.05$.

Results

The age of the patients ranged from 18 to 55 years (mean age 31.3 years), with the maximum incidence of fractures in 25–34 years age group. The male:female ratio was 14:1. The most common aetiology was road traffic accident (86.6%) (Fig. 3). The mean time interval between injury and surgical procedure was found to be 7.6 days (range 3–22 days). A total of thirty fracture sites were present in fifteen patients. Eight patients (thirteen fracture sites) had isolated middle third fractures, four patients (nine fracture sites) had isolated mandibular fractures, and three patients (eight fracture sites) presented with combined mandibular and maxillary fractures (Table 1; Fig. 4). Majority of the fracture sites (88%) were comminuted.

Out of 15 patients, preoperative occlusion was disturbed in ten patients (66.7%). Out of these 10 patients, five

Fig. 3 Aetiology of fracture

patients had fractures of the middle third, three patients had mandibular fractures, and two had combined maxillary and mandibular fractures (Fig. 5). Six out of ten patients (60%), with disturbed occlusion, achieved good occlusion following open reduction and internal fixation. Occlusion was graded as fair in the remaining four patients (40%). Two of these four patients obtained good occlusion by 6th week following occlusal adjustment/guiding elastics. Rest of the two patients with fair postoperative occlusion had combined maxillary and mandibular fractures. Out of these, one patient with mandibular parasymphysis fracture, unilateral LeFort I fracture with associated unilateral condylar fracture achieved good occlusion by 7th postoperative day after giving intermaxillary elastic traction, whereas occlusion remained as fair in the other patient till the last postoperative follow-up (Fig. 6).

On evaluation of postoperative radiographs, good anatomic reduction and fair reduction were observed in 50% of the fractures each at 7th day, 3rd week and 6th week postoperatively. However, by 12th postoperative week, 54.2% and 45.8% of the fractures were graded as having good and fair reduction in radiographs, respectively (Fig. 7). Condylar fractures ($n = 5$) and coronoid fractures ($n = 1$) were excluded from evaluation regarding radiographic reduction as these fractures were managed conservatively.

The maximum interincisal distance preoperatively was observed to be 25.13 ± 08.94 mm. This improved to 28.57 ± 08.50 mm, 30.53 ± 09.58 mm, 36.20 ± 06.01 mm and 38.87 ± 04.40 mm at 7th day, 3rd week, 6th week and 12th week postoperatively, respectively. On comparing the preoperative mean interincisal distance with postoperative mean interincisal distance, a highly statistically significant difference was seen at 3rd week ($p = 0.019$), 6th week ($p = 0.000$) and 12th week ($p = 0.000$) (Fig. 8). The average time taken for fixation of titanium mesh per fracture site was 16.23 ± 4.67 min.

Table 1 Anatomic location of fracture and distribution of fracture sites

Types of fracture	No. of patients (<i>N</i>)	No. of fractures	Side involved		%
			Right	Left	
Middle third fractures	8	13			43.3
Zygomatico-maxillary complex fracture	2	2	1	1	6.7
Zygomatico-maxillary complex with Palatal split	1	2	2	–	6.7
Bilateral LeFort I fracture	1	2	1	1	6.7
LeFort I fracture with contralateral Zygomatico-maxillary complex fracture	1	2	1	1	6.7
Unilateral LeFort II fracture	1	1	1	–	3.3
Bilateral LeFort II fracture	1	2	1	1	6.6
LeFort II fracture with contralateral zygomatico-maxillary complex fracture	1	2	1	1	6.6
Lower third (mandibular) fractures	4	9			30
Parasymphysis fracture	1	1	1	–	3.3
Parasymphysis + bilateral condylar fracture	1	3	1	2	10
Body fracture	1	1	–	1	3.3
Body + angle + bilateral condylar fracture	1	4	2	2	13.4
Combined fractures	3	8			26.7
Mandibular parasymphysis + bilateral LeFort I fracture	1	3	2	1	10
Mandibular parasymphysis + unilateral LeFort I + condylar fracture	1	3	3	–	10
Zygomatico-maxillary complex fracture with coronoid process fracture	1	2	2	–	6.7
Total	15	30	19	11	100

Fig. 4 Distribution of fracture sites

Eleven patients (73.3%) presented with preoperative sensory disturbances. Out of these 11 patients, 5 patients (33.3%) had hypoaesthesia and 6 patients (40%) had anaesthesia (on sharp and blunt test evaluation). At 12th week follow-up, 4 patients out of 6 patients with

preoperative anaesthesia still complained of residual sensory nerve impairment. Intraoral wound dehiscence with exposure of the implant was observed in the parasymphysis region at 7th postoperative day in one patient (6.66%).

Fig. 5 Preoperative occlusion status

Discussion

Fixation of fractures using titanium mesh has been known to be practiced in USA since the Vietnam War. Production of Titanium mesh started in 1968, and its refinement occurred over time with better instrumentation [3].

The malleable and semi-rigid nature of titanium mesh, coupled with lack of elastic memory, prevents subsequent stress shielding in the area [3]. It has been documented to be used in the treatment of complex cases such as fractures of highly atrophic edentulous mandibles, discontinuity defects and in comminuted fractures where the use of

miniplates is often difficult and unsatisfactory. It permits functionally and aesthetically satisfactory restoration of bony continuity regardless of size or site of the defect. On comparison with miniplates, it provides better stabilization of complex mandibular fractures because of its geometry and the excellent physical and biomechanical properties. It achieves significantly better three-dimensional stability and thus prevents the development of fracture line infection and non-union [4].

In the present study, the mean age of the patients was 31.3 years (range 18–55 years), which is consistent with the findings of Bataineh [9], Lee et al. [10] and Kostakis et al. [11]. Out of fifteen patients, there were fourteen male patients (93.3%) and only one female patient (6.7%). In accordance with the present study, Al Ahmed et al. [12] and Arangio et al. [13] also found definite male predilection (92% and 83%, respectively) in their studies on trauma.

The most common mode of injury was road traffic accident (86.6%), followed by assault (6.7%) and interpersonal violence (6.7%). Bataineh [9], Al Ahmed et al. [12] and Kostakis et al. [11] also reported road traffic accidents (55.2%, 75% and 50.8%, respectively) as the leading cause of injury. Fractures of middle third of face (56.7%) were the most common followed by mandibular fractures (43.3%). Majority of the fracture sites (88%) were comminuted.

The time interval between trauma and treatment of an open fracture has been documented to be the determining factor for the degree of infection [14]. Therefore, early surgical stabilization and careful debridement of the operative site, along with immediate antibiotic therapy, are the factors that need to be emphasized. In our study, the

Fig. 6 Postoperative occlusion status

Fig. 7 Radiographic evaluation of fracture sites

Fig. 8 Maximum interincisal distance

time interval between initial injury to surgical procedure ranged from 3 to 22 days, with an average of 7.6 days. Courtney [15] and Ellis [16] have also reported the mean time interval between injury and surgical procedure to be 7 days (1–16 days) and 5.58 days (1–28 days), respectively.

Preoperative malocclusion was present in ten (66.7%) patients and was normal in five (33.3%) patients. On the 7th postoperative day, following open reduction and internal fixation, seven patients (70%) had good occlusal relationship, and the remaining three patients (30%) had fair occlusion. Out of these three patients, a good occlusal

relationship was achieved by occlusal equilibration in one patient (bilateral LeFort I fracture). In the second patient (unilateral LeFort II fracture with contralateral zygomatico-maxillary complex fracture), intermaxillary elastics were used for guiding the occlusion. Post-trauma occlusal discrepancy in this patient could be attributed to haematoma, swelling and inhibition of muscular movement due to the fractured zygomatico-maxillary complex [17]. Occlusal discrepancy in this case could also be attributed to the presence of comminution of all the fracture sites [18]. The use of guiding elastics for minor postoperative malocclusion has been documented by Fordyce et al. [19]. In the

third patient (bilateral LeFort I fracture with mandibular parasymphysis fracture), postoperatively intermaxillary fixation (IMF) was given for 15 days. All the fracture sites were comminuted in this patient. The occlusion in this patient continued to be graded as fair till 12th postoperative week. Fordyce et al. [19] in their study have stated that for the protection of fixation and immobilization of mandible, postoperative IMF can be used in comminuted fractures.

Concomitant condylar fractures may result in malocclusion due to muscular guarding and ramal shortening. In order to overcome the resultant malocclusion in conservatively managed patients, postoperative intermaxillary elastic traction has been documented by Fordyce et al. [19]. In the present study, intermaxillary elastics were given in a total of three patients with associated condylar fractures. Two patients with bilateral condylar fractures were given elastic traction for 3 weeks, whereas one patient with unilateral condylar fracture was given elastic traction for 1 week in order to achieve closed reduction in condylar fractures.

Dai et al. [20] also evaluated the use of titanium mesh in comminuted mandibular fracture management and found good occlusal relationship postoperatively in 100% of the patients, which is nearly equivalent to the present study findings in which 93.3% of the patients obtained good occlusion relationship by 6th week postoperatively and it was maintained till 12th week postoperative follow-up visit.

The preoperative mean interincisal distance in our study was 25.13 ± 8.94 mm (mean $\pm$ SD). At 7th postoperative day, it improved to 28.57 ± 8.70 mm, and by the 6th postoperative week, it was 36.20 ± 06.01 mm. As intermaxillary elastic traction was given for a period of three weeks in two patients with associated bilateral condylar fractures and intermaxillary fixation (IMF) was done in one patient with bilateral LeFort I with mandibular parasymphysis fracture for 15 days, mouth opening improved in these patients by physiotherapy and normal range was achieved by 12th week postoperative evaluation. Significantly reduced mouth opening in patients treated with 4 weeks or more of immobilization has been reported by Amaratunga [21]. The author attributed the reduced mouth opening to muscle disuse atrophy along with scarring in the region of fracture following tissue disruption and haematoma formation. Decreased mouth opening in one patient of zygomatico-maxillary complex fracture with associated coronoid process fracture in the present study could be attributed to pain and reflex muscle spasm which was relieved by limiting mandibular movement, thus resulting in decreased mouth opening. This limitation in mandibular movement has been known to improve with time as the primary inflammation subsides [22]. Mouth opening in this patient improved with postoperative physiotherapy. Also,

the zygomatico-maxillary complex fracture in this patient was comminuted. Rapidis et al. [23] have stated that severely comminuted fracture of the zygoma along with coronoid process fracture may result in decreased mouth opening. Mobilization of the mandible in such cases should be encouraged to prevent ankylosis.

The average time taken for implant fixation per fracture site was 16.23 ± 4.67 min in the present study. Chakraborty et al. [24], however, reported the average time taken from exposure of the fracture site to the placement of last screw as 32 min per mandibular fracture site using a stainless steel mesh, which is greater than the findings of the present study.

The percentage of maxillofacial fractures in the present study with good anatomic reduction and fractures with fair reduction (with minor radiographic spacing of fractures), as assessed on radiographs, was 54.2% and 45.8%, respectively, at 12th postoperative week. However, on comparing only mandibular fractures in the present study, postoperative radiographs revealed good and fair reduction in 75% and 25% of the patients, respectively, which is comparable to the findings of Hsu et al. [18].

Postoperative complications included residual hypoesthesia in four patients and wound dehiscence in one patient. The incidence of post-traumatic sensory disturbances of the inferior alveolar nerve following mandibular fractures (83.3%) is slightly higher than that of the infraorbital nerve following midfacial fractures (72.7%). This is in contrast to the findings of Schultze-Mosgau et al. [25] who reported higher incidence of post-traumatic sensory disturbances of the infraorbital nerve following midfacial fractures (65%) than that of the inferior alveolar nerve following mandibular fractures (46%). In the present study, 66.7% patients of zygomatico-maxillary complex fractures had post-traumatic sensory disturbances that further decreased to 33.3% at 12th week of postoperative follow-up.

Another complication encountered was intraoral wound dehiscence with exposure of the implant in the parasymphysis region on 7th postoperative day in one patient (6.7%) with combined maxillary and mandibular fractures. Coe-pack was applied until healing occurred by secondary intention. In consistence with the present study findings, Chakraborty et al. [24] also reported mesh exposure in 8.7% of the patients with mandibular fractures managed with stainless steel mesh.

Conclusion

Titanium mesh was found to be highly adaptable and a versatile option for maxillofacial fracture fixation. As a fixation method, it was quick with excellent physical and biomechanical characteristics. It was chosen over other

conventional plating systems because it was more malleable and allowed better contouring at the fracture site. It provided good fixation and stabilization of comminuted fractures as it has multiple holes for screw placement. It has further advantages of reducing stress-shielding effect and thus improving functional bone healing due to its semi-rigid nature. The cost of titanium mesh with other titanium implants was comparable in our study as the mesh was mostly used in patients with comminuted fractures. A larger number of implants would have been needed to achieve stabilization and fixation in such patients, thus leading to increase in expenses for the patient. Also, the complication rate of titanium mesh was found to be acceptable. Hence, titanium mesh was found to be valuable in restoring the form and function of the maxillofacial region without causing functional disability and morbidity to the patient.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Author Contribution This manuscript has been read and approved by all the authors, the requirements for authorship as stated have been met, and each author believes that the manuscript represents honest work.

Ethical Approval This article does not contain any studies with animals performed by any of the authors.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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