Technical Note

Shaping of comminuted midface fractures with stock Titanium mesh: a technical note

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Abstract – Multiply fragmented fractures of the maxillofacial region are difficult to fix with traditional miniplate osteosynthesis because of the extremely small size of fragments, complex three-dimensional anatomy, thin bone unable to hold screws and multidirectional pull of muscles. We intend to present a technical note on a case series of extremely comminuted midfacial fractures reconstructed with stock Titanium mesh, cut to shape and used to mold the small fragmented segments into the shape of the facial bones. Severe fragmentation of midface leads to facial hollowing, tissue prolapse and asymmetry even after major facial buttresses are fixed and reconstructed. Simple stock Titanium mesh can be used to reconstruct these severe fragmentations of thin bones of the midface as shown in the series and avoid late and unsightly complications.

Introduction

A rigid steel mesh was introduced in the early 1960s for use in facial trauma, after which a slightly malleable Vitallium mesh was introduced [1]. The industrial production of Titanium mesh begun during the Vietnam war and was used for semi-rigid fixation of comminuted fractures because of its malleable handling characteristic [2]. Since then Titanium mesh has been used sporadically as a fixation tool for fractures of anterior wall of the frontal bone, orbital wall, anterior maxilla [3]. Titanium mesh has also been used for fixation of midface osteotomies as well as a carrier for cancellous bone grafts and alveolar augmentation [4]. Fractures of the zygomaticoorbital region are the most common maxillofacial injuries [5]. High-velocity road traffic accidents (RTA) is the major aetiology and the severity of fracture is proportional to the impact of the injury [5]. Some high-speed RTA can present with comminution of thin orbital walls as well as relatively stronger orbital rims.

Zygomatic bone has a compact and relatively dense central body; therefore, fractures usually occur in the four processes of zygomatic bone but in some cases of high impact delivered directly to the zygomatic body, the comminution of the zygomatic body can occur along with orbital rim and wall fractures. The reduction and fixation of typical tripod and tetrapod zygomatic fractures have been well established in

literature but comminution of the zygomatic body presents with a unique situation where typical miniplate osteosynthesis cannot be used to fix multiple small fragments and reduce the zygomatic-orbital region to preinjury state. Comminution of orbital rim fractures also presents with a similar situation where mini/microplates cannot be fixed due to the presence of multiple small fragments [6]. Comminution of medial zygomatic process and anterior maxilla which also forms the lateral nasal wall leads to soft tissue prolapse, chronic maxillary sinusitis as well as chronic nasal congestion in the long term [7,8].

The purpose of this article is to present a technical note on a series of cases where titanium mesh was used for the reconstruction of the severely comminuted zygomatic body, zygomaticomaxillary complex, orbital walls and rim, frontal and Nasoorbitoethmoidal (NOE) fractures that were not amenable to normal miniplate fixation techniques and present medium-term outcomes with the use of titanium mesh.

Technical note

This case series was performed in the department of Oral & Maxillofacial surgery at a University teaching hospital from January 2018 to December 2019. Within the current study; consecutive patients of all age with comminuted fractures of any facial bone were included ($n=12$). All patients had undergone clinical investigation, A CT scan with the acquisition of 3D reformatted images and planned for surgical management

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Fig. 1. (A) Comminution of the lateral wall of the orbit, body of Zygoma and Zygomaticomaxillary buttress along with orbital floor fracture. (B) Accurately shaped and moulded Zygomaticomaxillary complex and orbital floor with a single spanning Titanium Mesh with Mandibular symphysis bone graft used at the zygomaticomaxillary buttress.

under general anaesthesia. Inclusion criteria were fractures with fragmentation smaller than 2 mm and multiple fragments, more than 4 in number, which was confirmed on the CT scan measurement. Multiply fractured bone with larger fragments and fewer number of segments were excluded as they are better managed by micro/miniplate osteosynthesis. All the patients completed their postoperative investigations and their immediate follow-up. All cases were analysed retrospectively by retrieving their medical record from the central record system. We used a similar specific treatment protocol in all of them, where a stock 0.6–1 mm titanium mesh was cut and shaped according to the part of the face that was being reconstructed, intraoperatively. Preoperative 3D printing was not available, hence a single anatomic skull model was used as a rough guide and the mesh was customized with multiple attempts until a satisfactory fit was obtained. All the cases were operated within 48 hours of admission as per the protocol of the unit. We obtained data on radiographic reduction from postoperative CT scan, the patient reported symmetry of the face, the patient reported diplopia or vision changes after surgery, impaired wound healing, incidence and cause of removal of the implant and any unanticipated problems with the titanium mesh. The study was approved by the ethical clearance committee of the institutional review board.

Technique

Case 1

A 15-year female was attacked by a wild bear in a forest and presented with severe comminution of right zygomatic-orbital complex with multiple facial lacerations. Enophthalmos and Hypoglobus were observed due to the comminuted orbital floor and widening of orbital volume due to lateral displacement of

the lateral orbital wall (Fig. 1A and B). The initial ophthalmic evaluation determined loss of vision and planned for enucleation if the patient developed any signs of sympathetic ophthalmitis in the contralateral eye. Osteosynthesis was performed through an existing laceration and a 4 × 4 cm size, 0.6 mm thickness continuous titanium mesh (Orthomax, India) was meticulously cut according to the shape of the defect in the orbital floor and zygomatic body. This single piece of Titanium mesh was used to mould and shape the comminuted fractures and fixed with 2 × 6 mm titanium screws (Orthomax, India). Post-operative CT scan confirmed absolute mirror image reduction of fracture segments compared to the uninjured contralateral rim (Fig. 1C and D). The patient regained light perception diminished vision in the right eye and no signs of sympathetic ophthalmitis in the contralateral eye so enucleation was not performed. She was followed up for 6 years and has no major defects except a minor facial asymmetry as well as gradually improvement of vision in the right eye.

Case 2

An 18-year male presented with comminuted fracture of right lateral orbital rim due to RTA. The fracture was not extending into the orbit and was confined to the lateral orbital rim (Fig. 2A–C). The Fracture was exposed through a lateral eyebrow incision and the comminuted fragments were moulded into shape with a 0.6 mm Titanium mesh (Agomed, Germany). An important technical note during shaping the orbital rims with a Titanium mesh is to be in a strictly subperiosteal plane and adapt the ends of titanium mesh inside the orbital rim to the concavity immediately posterior to the orbital rim with a blunt instrument (a plate adapter works well), otherwise, the mesh will be protruding towards the orbital soft tissue (Fig. 2D–F). Post-operative CT scan confirmed absolute mirror

Fig. 2. Preoperative axial (A) and coronal (B and C) sections showing comminuted fracture of the right lateral orbital rim. Postoperative axial (D) and coronal (E and F) sections showing accurate reduction of right lateral rim fragments. Postoperative 3D reformatted images (G, H and I) showing the titanium mesh shaped and adapted to the right lateral orbital rim and cupping the minute bone fragments in shape.

image reduction of fracture segments compared to the uninjured contralateral orbital rim (Fig. 2G–I). The patient was followed up for three years and has no complications.

Case 3

A 34-year male was assaulted and suffered an isolated orbital floor fracture. On ophthalmic examination, he had enophthalmos and diplopia in the inferior gaze. The isolated orbital floor fracture extended posteriorly to the posteromedial ledge of the orbit (Fig. 3A, B). The fracture was approached through a transconjunctival incision with a lateral canthotomy and reduction of orbital contents was performed. The floor defect was spanned with a 0.6 mm Titanium mesh (Agomed, Germany) that was cut into defect size on the table based on CT scan measurements and fixed with 2×6 mm screws at anterior

orbital rim. Post-operative Orbital CT scan reveals accurate reconstruction of the orbital floor defect (Fig. 3C, D and E). The patient was followed up for 2 years and has no ophthalmic and cosmetic complaints.

Case 5 and 9

A 45-year male was attacked by a wild bear near a forest and presented with comminution of left Nasomaxillary process and simple mandible symphysis fracture along with soft tissue lacerations (Fig. 4A and B). Fixation of mandibular fracture was done with 2 mm miniplates and comminuted left Nasomaxillary fracture was repaired with a 0.6 mm Titanium mesh (Agomed, Germany) cut and shaped to the lateral nasal wall and piriform aperture (Fig. 4C). The patient belongs to a poor community far from the city and was lost to follow up. A similar case of high-

Fig. 3. (A) Preoperative coronal and (B) sagittal scan showing the orbital floor defect which was reconstructed with a cut and shaped titanium mesh and adapted to the orbital floor. Post-operative coronal and sagittal (C and D) view showing the mesh spanning the defect. 3D reformatted image of the orbital defect being spanned by the titanium mesh (E).

speed RTA presented with a continuous fracture of right NOE, Medial orbital wall and a fragmented lateral nasal wall along with right infraorbital rim (Fig. 4D). Reduction of the fragments and shaping was done with a continuous 0.6 mm titanium mesh (Agomed, Germany) cut to fit the shape of Fronto nasal buttress, medial orbital wall and lateral nasal wall with a single mesh and fixed with 2×6 mm screws.

Case 8

A 34-year male presented with a fracture of the anterior wall of frontal bone and Fragmentation of medial orbital rim (Fig. 5A and B). The fracture was accessed through an existing laceration and fragmented medial orbital rim was moulded into shape with a 0.6 mm Titanium mesh (Agomed, Germany) cut to fit the fracture size and fixed with 2×6 mm screws (Fig. 5C and D). The patient was followed up for 3 years and has no complications.

Twelve cases of comminuted maxillofacial fractures were analysed. A slight male predilection showed (9, 75% and 3 female 25%) with mean age 34.16 years old. All the included cases were in the midface and none in the mandible. According to medical histories in 7 cases (77.14%), the cause of the fracture was RTA, 2 cases (17.14%) was Animal attack, 1 case of assault (2.85%) and explosion in 1 case (2.85%). During initial clinical investigation asymmetry of the face was observed in 7 cases (17.14%), hypoglobus in 2 cases and loss of vision in one case. Radiological investigation revealed the majority of patients had extreme fragmentation (>10 fragments). The range of follow-up is from 1 to 6 years (Tab. I).

Discussion

We have presented a technical note with few representative cases where draping and shaping of minute fragment comminution of facial fractures were achieved with Titanium mesh. Titanium is malleable and has good handling properties that are required for bending and shaping the mesh to the complex three-dimensional shape of the midface [9]. In our experience, we found that the fragmentation of midface bones can occur in conjunction with the typical pattern of fractures. We routinely used titanium mesh of large size to cut out and customize a single spanning implant that can hold the multiple comminuted fragments into the desired shape as shown in the reported cases (Fig. 6). Conventional miniplates cannot be used to fix such fragmented bones. The other advantage of titanium mesh is its ability to provide support or cupping of the fragments as it can be moulded to fit the exact curves and dimensions of the zygoma, orbit, maxilla and frontonasal region. In the case of depressed orbital roof fractures along with frontal bone anterior wall fractures, a single piece of titanium mesh can be used to reduce and support the anterior wall of frontal bone as well as to adapt and mould the depressed supraorbital rim and orbital roof [10,11]. We achieved moulding of comminuted orbital rims with a small titanium mesh rolled into the shape of orbital rims. Appropriately trimmed and sized titanium mesh is a cheaper alternative as reconstructive material for orbital floor and medial wall fractures compared to orbit specific implants and custom implants [12]. They are made of similar material and have similar biocompatibility and mechanical properties as well as the mesh system allows fibrous ingrowth and acts as a scaffold for bone formation [6,12]. We have been able to reconstruct

Fig. 4. (A) 3D reformatted CT scan showing comminution of the left lateral nasal wall. (B) Titanium mesh cut and adapted to the left lateral nasal wall and nasomaxillary buttress to hold the minute bone fragments in place. (C) Titanium mesh shaped to span the fractured frontonasal region and (D) spanning the anterior maxilla.

orbital floor in nearly all cases with simple titanium mesh cut to the shape of the defect without requiring expensive custom orbital floor implants. It is imperative to have a sound idea of dimensions and curves of orbital walls and the importance of resting the posterior end of these implants on a stable bony ledge to ensure the end is not protruding in the maxillary sinus. The ease with which Simple rectangular titanium mesh can be cut and adapted to orbital wall defects is a boon for maxillofacial surgeons without access to the custom implants or expensive stock orbital implants [13]. One issue of importance is the management of sharp cut ends of mesh that can potentially injure soft tissue or even cause globe injury. These sharp ends need to be trimmed and rounded with a rotary trimmer or a file before application. Another trick is to insert the orbital floor mesh in such a way that the blunt edges of the mesh goes inside the orbit and cut end towards the rim [6].

Thin titanium mesh can also be folded upon themselves to provide thicker volume restoring implants in cases of bone loss. Titanium mesh can be used to hold small comminuted fragments with mini-screws if there are small-sized fragments

that allow screw placement. In case of severe comminution where the minute fragments of bone are not amenable to screw fixation, titanium mesh can be adapted and moulded over the minute fragments to hold them in a place like bone grafts [14]. Although miniplates and microplates have widespread usage for midfacial fractures, they have an innate problem of not being able to withstand three-dimensional movements and they cannot hold the fragments of bones in all three dimensions. 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 [15]. 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. The semi-rigid nature of Titanium Mesh allows micromovements at the healing bone ends and prevents stress shielding along with acceptable postoperative aesthetic results. Titanium mesh combines the versatility of a mesh system with multidimensional stability provided by a 3D system.

Fig. 5. Preoperative 3D reformatted CT scan showing the left medial orbital rim and roof fracture (A) which was reconstructed with a continuous titanium mesh. (B) Postoperative 3D reformatted image showing the adapted titanium mesh spanning the medial orbital roof defect.

Titanium mesh has also been used as a carrier for bone grafts in dentoalveolar and mandibular reconstruction and is effective at acting as an osteoconductive scaffold for the graft. Though we have not been able to experience with the application of titanium mesh in mandibular fractures [15].

Conclusion

Titanium mesh is a versatile and easy to use, inexpensive system that was used for semi-rigid fixation of extremely comminuted and minutely fragmented fractures of the frontal bone, NOE, Zygomaticomaxillary complex and orbital walls in our case series, which could not be fixed with miniplates. The titanium mesh has been available for a long time, and our series shows that it can be used to shape extremely fragmented midface fractures. It has good histocompatibility and allows tissue ingrowth as well as acts as a scaffold for osteogenesis. It is easily bendable, can be cut into and shaped to the complex three-dimensional anatomy of the facial bones and used to

mould and hold the comminuted facial bone fragments into shape. There are very few complications observed with the use of Titanium mesh in our experience. A future direction of our research will be to provide a point of care 3D printed models of the fractures and defects for presurgical trimming and adaptation of the mesh.

Ethical approval

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Table I. Case summaries with medium term outcomes. RTA = Road Traffic Accident.

Patient no.	Age/Gender	Aetiology	Fracture	Follow up	Complications	Remarks
1	15/F	Animal attack	Comminuted Right ZMC fracture	6 Years	None	Extreme hypoglobus with globe in maxillary sinus on presentation Partial vision in right eye at followup
2	18/M	RTA	Comminuted Right lateral orbital rim	3 years	None	Normal vision on Ophthalmic exam
3	34/M	RTA	Left Orbital floor	3 years	None	Enophthalmos and diplopia on presentation corrected after surgery
4	32 /M	RTA	Left orbital Floor	3 years	Epiphora and Chronic Maxillary sinusitis	Implant removal was done
5	45/M	Animal attack	Comminuted Right NOE Type II and medial maxillary wall	1 year and lost to follow up	None till follow up	None
6	64/F	Explosion	Comminuted Right Anterior wall of frontal bone and supraorbital rim	3 years	Soft tissue dehiscence and implant exposure	Implant removal was done
7	24/M	Assault	Right Orbital floor and inferior orbital rim	2 years	None	Restricted motility in superior gaze at presentation Normal binocular vision in followup
8	27/F	RTA	Left Medial supraorbital rim	2 years	None	None
9	23/M	RTA	Left lateral nasal wall and Mandible	1 year and lost to follow up	Lost to follow up	None
10	34/M	RTA	Left Anterior wall of maxilla	1 year	Chronic maxillary sinusitis	Implant removal was done
11	42/M	RTA	Right orbital floor	1 year	None	Hypoglobus on presentation corrected after surgery
12	52/M	RTA	Anterior wall of frontal bone	1 year	None	None

Fig. 6. Skull diagrams of presented cases with location of comminuted fracture and titanium mesh adaptation. (A) Lateral orbital rim, (B) Zygomaticoorbital complex, (C) Orbital floor, (D) Lateral nasal wall and media maxilla, E anterior frontal bone and medial orbital roof.

References

1. Sengezer M, Sadove RC. Reconstruction of midface bone defects with vitallium micromesh. *J Craniofac Surg* 1992;3:125–133.
2. Pacifici L, DE Angelis F, Orefici A, Cielo A. Metals used in maxillofacial surgery. *Oral Implantol (Rome)* 2017;9:107–111.
3. Kumar R'M, Suiyavanshi RK, Kotrashetti SM. Efficacy of titanium mesh in various maxillofacial surgeries. 2016;6:3.
4. Kuttenger JJ, Hardt N. Long-term results following reconstruction of craniofacial defects with titanium micro-mesh systems. *J Cranio-Maxillo-Facial Surg* 2001;29:75–81.
5. Lee K. Global trends in maxillofacial fractures. *Cranio-Maxillofac Trauma Reconstr* 2012;5:213–222.
6. Gear AJL, Lokeh A, Aldridge JH, Migliori MR, Benjamin CI, Schubert W. Safety of titanium mesh for orbital reconstruction. *Ann Plast Surg* 2002;48:1–9.
7. Kloss FR, Stigler RG, Brandstätter A, Tuli T, Rasse M, Laimer K, *et al.* Complications related to midfacial fractures: operative versus non-surgical treatment. *Int J Oral Maxillofac Surg* 2011;40:33–37.
8. Lozada K, Kadakia S, Abraham MT, Ducic Y. Complications of midface fractures. *Facial Plast Surg* 2017;33:557–561.
9. Ellerbe DM, Frodel JL. Comparison of implant materials used in maxillofacial rigid internal fixation. *Otolaryngol Clin North Am* 1995;28:365–372.
10. Sakat MS, Kilic K, Altas E, Gozeler MS, Ucuncu H. Comminuted frontal sinus fracture reconstructed with titanium mesh. *J Craniofac Surg* 2016;27:e207–e208.
11. Zavattero E, Boffano P, Bianchi FA, Bosco GF, Berrone S. The use of titanium mesh for the reconstruction of defects of the anterior wall of the frontal sinus. *J Craniofac Surg* 2013;24.
12. Al-Khdhairi OBH, Abdulrazaq SS. Is orbital floor reconstruction with titanium mesh safe? *J Craniofac Surg* 2017;28:e692–e 694.
13. Park HS, Kim YK, Yoon CH. Various applications of titanium mesh screen implant to orbital wall fractures. *J Craniofac Surg* 2001;12:555–560.
14. Massa AF, Otero-Rivas M, Rodríguez-Prieto MÁ. Titanium mesh in the reconstruction of a malar defect: a case report. *Int J Dermatol* 2014;53:1278–1280.
15. Ma J, Ma L, Wang Z, Zhu X, Wang W. The use of 3D-printed titanium mesh tray in treating complex comminuted mandibular fractures. *Med (United States)* 2017;96:1–5.