·Clinical Research·

Reconstruction of complex orbital fracture with titanium implants

Wen-Shu Yi[1], *Xue-Liang Xu*[1], *Jian-Rong Ma*[2], *Xin-Rong Ou*[3]

[1]Department of Ophthalmology, Xiangya Hospital, Central South University, Changsha 410008, Hunan Province, China
[2]Department of Neurologic, Xiangya Hospital, Central South University, Changsha 410008, Hunan Province, China
[3]Department of Oral and Maxillofacial, Xiangya Hospital, Central South University, Changsha 410008, Hunan Province, China
Correspondence to: Xue-Liang Xu. Department of Ophthalmology, Xiangya Hospital, Central South University, Changsha 410008, Hunan Province, China. xuxueliang8341@yahoo.com.cn
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Abstract

• AIM: To evaluate the effectiveness and safety of complex orbital fracture reconstruction with titanium implants.

• METHODS: A retrospective review of 46 patients treated with complex orbital fractures reconstruction using titanium implants from January 2005 to December 2008 was conducted. The following data were recorded: age, gender, mechanism of injury, preoperative and postoperative orbital CT, visual acuity, diplopia, ocular motility and Hertel exophthalmometer.

• RESULTS: The most common cause was motor vehicle accident (47.8%), followed by industrial injury (30.4%). All patients had improved appearance after operation and CT scan at one week after operation showed the fracture defects of orbit and neighboring areas had been reconstructed. Forty-six cases had various degrees of enophthalmos before operation. Among them, 32 cases were completely corrected, 11 cases improved obviously and 3 cases had no improvement after operation. Thirty-six patients with visual acuity ≥ 20/60 revealed diplopia of various degrees, including 26 patients had diplopia in right ahead and/or reading positions. At the sixth month after operation, diplopia disappeared in five patients, 7 patients still had diplopia in right ahead and/or reading positions, 14 patients had diplopia in positions rather than right ahead and reading positions (<20°) and ten patients had diplopia only at peripheral gazing (>20°). All patients had various degrees of ocular motility disorders before operation. At the sixth month after operation, eyeball movement disorder disappeared in 9 patients, 31 patients showed improvement and 6 patients had no improvement. Complications of implant infection, rejection and displacement were not reported after operation.

• CONCLUSION: The application of titanium implants in the repair of complex orbital fractures greatly improves the appearance and functional results, which is a favorable material for plastic surgery of complex orbital fracture.

• KEYWORDS: complex orbital fractures; titanium; reconstruction
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INTRODUCTION

Orbit is located in the middle face with prominent position and complex structure, and is closely linked with the adjacent craniofacial organization. Orbital fractures which involve not only orbital walls, but also the rim and the adjacent parts, such as the frontal, maxillary, zygomatic fractures, are called complex orbital fractures clinically[1-3]. Patients with this kind of fracture always suffer from seriously damaged appearance and significant dysfunction. Complex orbital fracture requires reconstruction to restore ocular function and aesthetics as soon as possible. Successful orbital and periorbital reconstruction following traumatic fracture depends on thoughtful preoperative planning, meticulous operative dissection and proper selection of implant type, size and contour. The optimal material for orbital reconstruction remains controversial. However, several studies have shown the reliability and safety of titanium in reconstructing internal orbital defects[4,5]. Titanium has excellent biocompatibility and demonstrates integration in adjacent bone, which results in low infection rate and rare postoperative migration of implants after titanium reconstruction. Titanium can be contoured to fit virtually any internal orbital defects because of its significant tensile strength and malleability. In addition, titanium is easily visualized on postoperative CT [6]. These characteristics determine titanium to be well established as an implant material in orbital and adjacent craniofacial skeleton reconstruction.

From January 2005 to December 2008, we together with the neurological or oral and maxillofacial surgeon performed

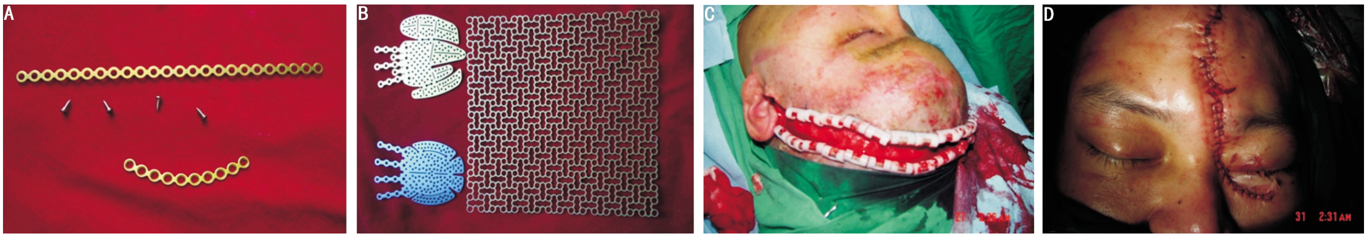

Figure 1 Materials use in the operation and wound incision A: Titanium plates and nails; B: Titanium meshs with different specifications. Upper left for the exclusive use of orbital floor, lower left for the medial orbital wall and right for the frontal bone, zygomatic and other defects; C: Cranial coronary incision; D: Original wound incision.

reconstructive operations on 46 patients with complex orbital fractures using titanium implants. The purpose of current study was to present our experiences with titanium implants in the repair of orbital and adjacent craniofacial skeleton defects after traumatic fracture.

SUBJECTS AND METHODS

Subjects The records of 46 patients who were treated at the Department of Ophthalmology, Xiangya Hospital, Central South University, China for complex orbital fractures between January 2005 and December 2008 were retrospectively reviewed. There were 34 male (73.9%) and 12 female patients (26.1%). Mean age was 30.96 years, with a range of 5-59 years old.

Methods The timing of surgical repair was 10 days to one year after trauma. Among them, 7 cases were performed within 1 month, and 39 cases were above 1 month. The most common cause of complex orbital fractures in the current series was the motor vehicle accidents (22 patients, 47.8%), followed by industrial injury (14 patients, 30.4%), assaults (8 patients, 17.4%) and falling (2 patients, 4.3%). All fractures were divided into several types according to the sites of bone fracture: there were 7(15.2%) patients with cranio-orbital fractures, 16 (34.8%) patients with orbital-maxillary-zygomatic fractures and 14(30.4%) with naso-orbital-ethmoid fractures, 5 (10.9%) cases with concomitant cranio-orbital and orbital maxillary zygomatic fractures and 4 (8.7%) cases with concomitant orbital maxillary zygomatic and naso-orbital-ethmoid fractures. Debridement and suture were performed for 37 patients (80.4%), who presented scars of various lengths on the faces. Five of the 37 patients underwent simple reduction of zygomatic, maxillary and nasal bones at the same time when management of wounds by other specialists was performed. Five patients had concomitant ptosis. Six patients presented laceration of the lacrimal canaliculus, and eight patients presented medial canthus displacement and widened distance between canthus. All patients were followed up for six months to three years. Indices of visual acuity, diplopia, eyeball movement and degree of exophthalmos were evaluated at the sixth month after operation.

Patients had undergone examinations of visual acuity, anterior segment, fundus and degree of exophthalmus preoperatively, then one week, three month, six months and a year after operation. Red glass test was performed in patients with visual acuity of $\geqslant$20/60. Orbital CT scans were performed for all patients before and one week after operation, including horizontal, coronary, sagittal scans and three-dimensional reconstructions.

All operations were conducted under general anesthesia. Different incisions or combined approaches were used according to different types of fracture, and appropriately sized and shaped titanium plates and meshes were used to repair different bone fractures (Figure 1A). For cranio-orbital fracture, cranial coronary incision or original wound was used as entering port (Figure 1B,C), the scalp was flipped to expose the cranial and orbital fracture area, then collapsed and displaced supraorbital margin was explored and reduced, followed by ebonation and repairing of fractured orbital margin and/or frontal bones with titanium plates and nails. The frontal bone defect was repaired with titanium meshes. For those with orbital wall fractures, the subperiosteal detachment was used to expose the fracture site, followed by ebonation and reduction of the hernia back into orbit. The titanium mesh was made into appropriate size and properly shaped to fit the orbital wall curvature, thereby repairing the fracture defect. For orbital maxillary zygomatic fracture, approaches through the frontal coronary incision or original wound combined with the incision beneath lower eyelash were used to enter the lower orbital margin, cutting the periosteum to expose the fracture site of lower orbital wall. Soft tissues that had herniated into the maxillary sinus were reduced. Separation was performed at the superficial layer of temporal deep fascia from the temporal nodule, entering temporal fat pad 2cm above the zygomatic arch. Superior margin of the zygomatic arch was exposed by separating along the superficial layer of temporal muscles. Frontal bone periosteum was cut on the lateral side of orbital margin, followed by cutting of processus frontosphenoidalis ossis zygomatici, superior periosteum of the zygomatic arch to expose the lateral orbital wall, zygomatici and zygomatic arch. The displaced zygomatic body was retracted and reduced to fit infra-orbital

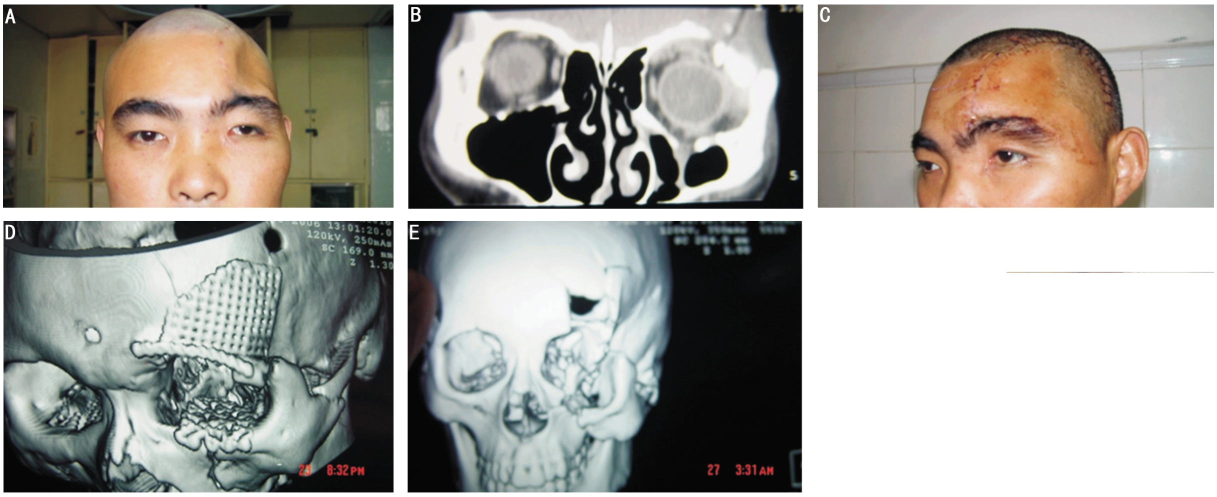

Figure 2 Patient with left collapsed frontal area and enophthalmos A: Before operation; B: Horizontal CT scan revealed fractures of supraorbital margin, lateral wall and floor, and soft tissue herniation into the maxillary sinus; C: Postoperative picture showed the collapsed frontal area became full and enophthalmos was corrected; D: Postoperative three-dimensional reconstructive CT scan showed fractures were repositioned and reconstructed; E: Pre-operative three-dimensional reconstructive CT scan revealed fractures of zygoma, orbital floor, supraorbital margin and frontal bone.

margin and later-orbital margin. The lateral orbital wall and zygomatic arch were reduced and fixed with titanium plates and nails (Figure 1D). The maxilla was reduced and occlusal relationship was recovered, which was then tied by steal lines. Titanium mesh was made into appropriate size to fit the size and curvature of the lower orbital wall, then implanted into it and fixed with titanium nail to the orbital margin. For fractures involving inner orbital wall and orbital margin, the incision was made in the medial canthus, and then soft tissues were separated under the periosteum to expose fracture area. Soft tissues herniated to the fracture slit and ethmoid sinus were reduced to normal position, and then removed the bone fragment. Titanium mesh was used to repair the defect of the orbital wall. Eight patients with coexisting medial canthal malformation had undergone plastic surgery.

RESULTS

With bone fractures in different sites, the preoperative presentation of these patients included ptosis, collapse of frontal, temporal or zygomatic bones, asymmetric facial expression, enophthalmos, medial canthal displacement and widened medial canthal distance. CT scan revealed fractures of orbital wall, orbital margin as well as neighboring cranio-facial bone. Because plastic surgery was not performed simultaneously for five patients with ptosis, their symptoms were not relieved, and secondary operation was needed. Facial complexions of all patients were generally symmetric, and collapsed area became full. Eight patients with medial canthal malformation had their medial canthus distance reduced. CT scans at one week after operation showed the fracture defects of orbit, and neighboring areas had been reconstructed (Figure 2).

There were 22 patients with preoperative visual acuity of ⩾20/20, 14 with ⩾20/60 but <20/20, nine with 20/400 to 20/60 (monocular low vision) and one no light perception. Their postoperative visual acuity had little change compared with that of preoperation.

Generally speaking, all patients had more than 2mm enophthalmos before operation, including 29 between 2mm-4mm, 17 between 5mm-7mm. Up to the six months after operation, the differences of both eyeballs were within 1mm for 32 patients whose enophthalmoses were completely corrected. 11 patients had improved with 2mm-5mm reduction of the eyeball, yet with 2mm-4mm difference compared with healthy side. Three cases showed no improvement(Table 1).

Red glass test of 36 patients with visual acuity ⩾20/60 revealed diplopia of various degrees, including 27 patients had diplopia in right ahead and/or reading positions, four patients had diplopia in positions rather than right ahead and reading positions (<20°), and five patients had diplopia only at peripheral gazing (>20°). At six months after operation, diplopia disappeared in five patients. Seven patients had diplopia in right ahead and/or reading positions. 14 patients had diplopia in positions rather than right ahead and reading positions (<20°) and ten patients had diplopia only at peripheral gazing (>20°) (Table 1).

The 46 patients all had various degrees of ocular motility disorders before operation, passive eyeball traction test was positive in 43 patients, including five patients had mild limitations in one or several directions, 21 patients had limitations of movement in one or several directions but can surpass midline, 17 patients showed complete limitation in one or several directions and three patients had eyeball

Table 1 Comparison of degree of enophthalmos and diplopia between preoperative and 6 months after operation

Sign	Preoperative (*n*)	Postoperative 6 mo. (*n*)
Degree of enophthalmos		
≤1mm	0	32
2mm-4mm	29	11
5mm-7mm	17	3
Diplopia		
No diplopia	0	5
In right ahead and/or reading positions	27	7
In positions rather than right ahead and reading positions (<20°)	4	14
At peripheral gazing (>20°)	5	10

fixation. Passive eyeball traction test was negative in all patients postoperatively. And at the sixth months after operation, eyeball movement disorder disappeared in 9 patients, 31 patients showed improvement and 6 patients had no improvement.

No complications of implants infection, rejection and displacement were reported after operation. Numbness in skin areas innervated by infraorbital nerve reported by 13 patients preoperatively was not significantly improved while another 3 patients relieved at six months after operation.

DISCUSSION

Because of the complexity and particularity of orbital anatomic features, orbital fracture is not only the issue of ophthalmology, but also combined fractures of neighboring cranialfacial bones, which was termed complex orbital fractures.The involving areas are broad, including ophthalmology, oral and maxillofacial surgery, Otolaryngology-Head & Neck Surgery and neurosurgery. The fracture may impair the patients' facial appearance, resulting in functional disorders and psychological problems. Although the operation is technically demanding, prompt surgery must initiate to restore its cosmetics and functions.

The present study showed that the complex orbital fracture had male predominance (73.9%), and the traffic accident (47.8%) is a leading cause, followed by industrious injury (30.4%) and fighting (17.4%). This result is in accordance with report of Gear *et al* [4] In contrast, Hwang *et al*[1] reported that although the fracture had male predominance, the leading cause was fighting, followed by traffic accident. But, as Hwang *et al* [1] analyzed the causes based on orbital fractures caused by both simple blowout fractures and complex fractures instead of separating complex orbital fracture, the results are not contradictory.

Complex fractures are commonly combined with open wound, as presented in our study, with the rate as high as 80.4%. The wound is large, deep and irregular, the resultant scars may add more challenges for the repair and reconstruction of orbital complex fractures. Due to fractures in different site, complex orbital fracture is commonly accompanied with ptosis, medial canthus malformation, lacrimal passage injury, collapse or displacement of orbital margin, zygomatic arch displacement, depressed forehead, diplopia, enophthalmos and ocular motility disorders. Thus it is much more severe than simple orbital blowout fracture. In our study, complex orbital fracture results in much more severe cosmetic damage and functional disorders, with some patients showing enophthalmos of 5mm-7mm. Thirty-six patients with visual acuity of more than 20/60 all had diplopia, most of whom had diplopia in right ahead and/or reading positions. Therefore, the complex orbital fracture can severely damage the facial cosmetics and functions, and the plastic surgery of orbital fracture is of vital importance.

With respect to the timing of the surgery, most authors propose early surgical intervention [7-11]. Early intervention can reduce the herniated soft tissue back into normal position, thereby reducing the incidence of ischemia, scar forming, necrosis and atrophy of intraorbital soft tissues and facilitating recovery of the appearance and function. If operation is conducted later, soft tissues around the orbit may adhere extensively, showing scar formation and atrophy. It will make the reduction particularly difficulty, or even the reduction is performed, the function may not recovered as desirable [9,11,12]. However, for those with complex fracture which always had coexisting cranial or other visceral organ injuries, orbital operation cannot be performed until the vital signs are stable. Thus, early operation is impossible for them, and old complex orbital fracture is common in clinical settings, which remarkably compromises the efficacies of surgery [10,13,14]. Among the 46 patients included in the present study, only seven received operation within one month after injury. Other 5 patients had undergone reduction operations of zygomatic bone, maxillary and nasal bone other specialties early after injury, however, plastic surgery of the orbit and its deep fractures were not performed simultaneously. It may be attributable to knowledge shortage of orbital anatomic features and the consequences of the fractures. In our study, CT scans of all patients after operation showed good fracture reduction, and passive traction test was negative, suggesting the reduction of herniated soft tissue to normal sites. At six-month follow up, symptoms of diplopia, eyeball collapse and eyeball movement were significantly improved. However, a few patients were not improved, which may be attributable to the injury of soft tissues and nerves innervating extraocular muscles, as well as to the atrophy and fibrosis of extraocular muscles and postorbital fat.

Management of complex orbital fracture includes accurate orbital margin reduction, anatomic reconstruction of orbital wall and fulfilling of intraorbital contents [2,15]. The surgeon can adjust the curvature of titanium mesh to reduce orbital volume instead of increasing fulfilling contents. Multidisciplinary approaches participated by neurosurgery, oral and maxillofacial surgery and Otolaryngology-Head and Neck Surgery and neurosurgery are mandatory in treating complex fractures involving cranial bone, maxilla, zygoma, zygomatic arch and nasal bone [14]. Accurate reduction of orbital margin is fundamental to the anatomic reconstructions of orbital wall, which can be favorably conducted by titanium plate and nail fixation after orbital margin reduction [16,17]. Attentions should be paid at orbital wall reconstruction. Incision should be made at orbital margin to excise periosteum; tissues should be separated under periosteum while maintaining its intact; herniated tissues should be reduced after exposing fracture site to release extraocular muscle compression; great attention should be paid at dissecting pre-and post ethmoid sinus vessels, as well as infraorbital nerves and vessels; optic nerve should be avoided when fracture is involving orbital apex. With respect to the materials, titanium mesh can be easily fixed with little incidence of slippage. However, titanium mesh is hard and iatrogenic injury is likely to occur if it is not appropriately implanted [18,19]. We use titanium mesh to repair orbital wall defects and titanium plate to repair fractures of orbital margin and neighboring structures. Consequently, no complication of iatrogenic injury, infection, discharging and displacement was reported. Cerebrospinal Rhinorrhea is a frequent complication in Cranio-Orbital operation. Fortunately, there was no patient suffer from it. We conclude that the key to avoid Cerebrospinal Rhinorrhea is to protect the Cerebral Dura Mater carefully during the operation and restore the Cerebral Dura Mater if broken. In conclusion, complex orbital fracture involves extensive structures, badly influences patients' appearance and functions and is technically demanding in treatment. The use of titanium implants in the repair of complex orbital fracture can greatly improve the facial appearance and functional disorders, which, therefore, is the favorable material for plastic surgery of complex orbital fracture.

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