ORIGINAL ARTICLE

Evolving concepts in the management of orbital fractures with enophthalmos: A retrospective comparative analysis

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Summary *Background/introduction:* Enophthalmos, a common sequela following orbital trauma, may not be immediately evident, and it is often diagnosed late or inadequately treated. Managing orbital fractures with enophthalmos can be challenging and unpredictable.
Purpose(s)/aim(s): This study evaluated the long-term enophthalmos outcome following surgical correction for different types of orbital fractures at various time intervals.
Methods: Medical charts of 304 patients with orbital fractures were retrospectively reviewed. Several factors, including surgical timing, fracture zones, and orbital wall fractures, were analyzed. The improvement rate of enophthalmos following corrective surgery was compared with respect to the type of orbital wall fracture and surgical timing. Orbital wall fractures were classified into three types according to the number of walls involved: single-wall fracture (Type I orbital wall fracture), two-wall fracture (Type II orbital wall fracture), and three-to-four-wall fracture (Type III orbital wall fracture).
Results: The most common pattern of facial injury is facial fracture involving the bony orbit and adjacent facial bones (Zone II). The overall incidence of enophthalmos in the present study was 56.9%. The incidence of residual enophthalmos following corrective surgery was 11.8% in Type I, 27.4% in Type II, and 16.4% in Type III orbital wall fractures ($p \leq 0.001$). The improvement rates for enophthalmos at various time intervals, <2 weeks, within 2 −4 weeks, and >4 weeks, were 65.6%, 80%, and 76.2%, respectively; however, a significant difference was not observed ($p = 0.194$).

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Conclusion: Orbital fractures with enophthalmos can be corrected at various time intervals with a comparable improvement rate. Surgical indications and surgery timing for orbital fractures with enophthalmos should be individualized on the basis of the severity of injury and type of orbital wall fracture.

1. Introduction

Over the past decades, the advent of new technology in oculoplastic surgery and comprehensive knowledge of the complex anatomy of the internal orbit have revolutionized the management of orbital trauma. Enophthalmos, a common sequela following orbital trauma, may not be immediately evident, and it is often diagnosed late or inadequately treated. Despite these new advances, it is difficult to identify patients who are at risk of enophthalmos following orbital fractures. Managing orbital fractures with enophthalmos is challenging and unpredictable because of the consequences of uncontrolled tissue responses within the internal orbit following adjacent bony orbital injuries or undiagnosed orbital wall fractures.[1–3] These challenges are further complicated by the controversial concerns related to the indications, surgery timing, and surgical techniques of exposure and reconstruction. Two formidable tasks in managing orbital fractures with enophthalmos are identifying the ideal time for restoring the anatomy of the internal orbit to the preinjury state and minimizing the stigmata of bony orbital fractures. Therefore, prompt recognition and management of these injuries are essential for ensuring long-term stability and satisfactory outcomes.

The importance of early surgery for orbital fractures has been emphasized in the literature; however, guidelines for addressing the concerns regarding delayed or late surgical correction for enophthalmos have not yet been developed.[4–6] Corrective surgery for enophthalmos becomes difficult following pathophysiological changes within the traumatized internal orbit. Consequently, many surgeons have reluctantly attempted late repair to prevent cicatricial contractures, distorted anatomy, and potential harm to the vital structures of the internal orbit such as the extraocular muscles, ocular vascular supply, and cranial nerves. In recent years, improved imaging modalities, alloplastic materials, and surgical techniques and instruments combined with the increasing desires of patients for aesthetic improvement have motivated a few surgeons to engage in challenging surgical endeavors.[7–9] Therefore, the principles in the management of orbital fractures essentially with regard to the surgical timing and long-term enophthalmos outcome following surgery must be critically re-evaluated. We present a retrospective study evaluating the long-term enophthalmos outcome following surgical correction for orbital fractures at various time intervals. The objective of the present study was to provide guidelines for managing orbital fractures based on the type of orbital wall fracture and appropriate timing of surgery.

2. Materials and methods

Data were retrieved through a retrospective chart review from the patient database registered in the department of Plastic and Reconstruction Surgery. A total of 421 consecutive patients received orbital reconstruction for orbital fractures at the Plastic and Reconstructive Surgery Department, Chang Gung Memorial Hospital, during July 2000–December 2011. Patient charts were reviewed according to the criteria designed for the study. Only patients who had undergone surgical correction with implants for traumatic orbital fractures performed by a single surgeon (C.T. Chen) and postoperative follow-up of more than 12 months were selected for the study. Surgical indications of orbital reconstruction included nonresolving oculocardiac reflex, a "white-eyed" blowout fracture, and early enophthalmos or hypoglobus requiring immediate surgical repair, as well as the presence of diplopia in conjunction with positive forced duction test results and computed tomographic (CT) evidence of orbital tissue entrapment or large orbital floor fracture of >50% of the floor area causing late enophthalmos.[10] Patients younger than 7 years, those with globe ruptures or incomplete data, and those lost during postoperative follow-up were excluded from the study. For each patient, the age, sex, mechanism of injury, Glasgow Coma Scale (GCS) scores, fracture zones, number of orbital wall fractures, degree of enophthalmos, time interval between trauma and surgical intervention, and improvement of enophthalmos following surgery were recorded.

According to the mechanism, injuries were divided into three subgroups: motorcycle accident, car accident, and others (including assaults, sports-related injuries, and industrial accidents). The severity of head injury on admission was assessed using the GCS, and injuries were classified as severe (GCS score <8), moderate (GCS score of 9–12), and mild (GCS score of 13–15) accordingly.[11] Facial bone fractures were classified into four fracture zones according to X-ray and CT findings: Zone 1, fracture involving the bony orbit alone; Zone II, fracture of the bony orbit with adjacent facial bones such as zygoma, maxilla, nasal, and nasoethmoidal bones; Zone III, fracture of the bony orbit with either the upper or the lower one-third of facial bones; and Zone IV, orbital and panfacial fractures. These zones of facial bone fracture defined the severity of the fracture sustained in association with orbital fracture. High-resolution CT scans in axial and coronal views remain an integral component of patient evaluation because they enable precise identification of orbital wall fractures. Orbital wall fractures were classified into three types

according to the number of walls involved: single-wall fracture (Type I orbital wall fracture), two-wall fracture (Type II orbital wall fracture), and three-to-four-wall fracture (Type III orbital wall fracture).

All patients with orbital trauma had ophthalmologist consultations and assessments on admission, prior to and after surgery, and during follow-up. The presence of enophthalmos was assessed using Hertel's exophthalmometer on admission, prior to the surgery and during follow-up. Hertel's exophthalmometer accurately measures the differences between the globe position of the injured and uninjured sides provided that the lateral orbital rim is intact and symmetrical in position. However, when the lateral orbital rim was malpositioned because of trauma, the superior orbital rim was measured using Naugle's exophthalmometer as the reference point. Enophthalmos is considered significant when the measurement is $\geq$2 mm between the eyes. Time intervals between injury and surgical correction were divided into categories of <2 weeks, 2–4 weeks, and >4 weeks. The improvement rate of enophthalmos at various time intervals following surgical correction was later compared and examined. All data obtained were analyzed using the Student t test, chi-square test for contingency tables, or Fisher probability exact test (2-tailed). Statistical results were considered significant when $p \leq 0.05$.

3. Results

Medical charts of 421 consecutive patients were screened and analyzed. We identified 304 patients eligible for participation following exclusion according to the criteria defined. Of the eligible patients, 218 (71.7%) were males and 86 (28.3%) were females. The age of the patients ranged from 7 years to 74 years; the mean age was 27.6 years. One hundred and ninety-five patients (64.1%) received orbital reconstruction within 2 weeks of the initial trauma. The average time interval between injury and surgery in this group was 6.7 days. The mean postoperative follow-up period for all patients in the present study group was 15.7 months (range: 12–70 months).

The most common mechanism of injury in the present study was motorcycle accidents, accounting for 209 patients (68.8% of patients), followed by car accidents involving 55 patients (18.1%) and others involving 40 patients (13.1%). Motorcycle accidents accounted for the highest number of orbital traumas, of which 68.8% involved Type I, 67.1% Type II, and 70.5% Type III orbital wall fractures. Among traumas resulting from car accidents, 18.8% involved Type I, 15.1% Type II, and 19.7% Type III orbital wall fractures. Among orbital traumas resulting from assaults, sports-related injuries, and industrial accidents, 12.4% involved Type I, 17.8% Type II, and 9.8% Type III orbital wall fractures (Figure 1). No significant differences were observed between the fracture types according to the mechanism of injury ($p = 0.671$). Sixteen patients (5.3%) had a GCS score of <8 on admission and required cerebral protection in the intensive care unit because of associated severe intracranial injuries. Fifteen patients (4.9%) had GCS scores of 9–12, whereas 273 patients (89.8%) had GCS scores of 13–15 on admission. Patients who were fully
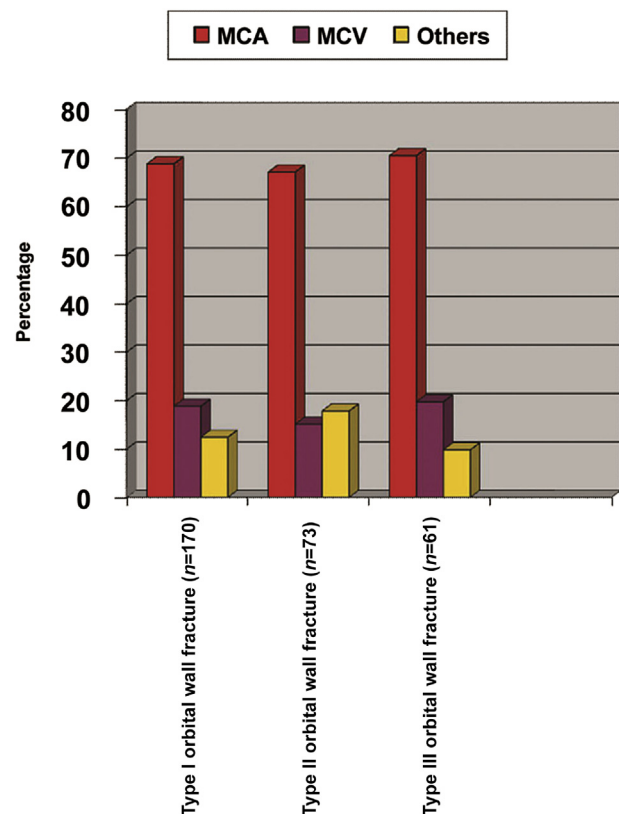

Figure 1 Distributions of the mechanism of injury and type of orbital fracture. MCA = motorcycle accident; MCV = car accident.

conscious on admission were more likely to be diagnosed with Type II (95.9%), followed by those with Type I (90%) and Type III (81.9%) orbital fractures. Patients who sustained severe intracranial injuries, with a GCS score of <8, exhibited a higher incidence of severe orbital fractures involving three to four orbital walls (11.5%; Figure 2). However, no significant differences were observed between the fracture types according to the severity of the associated head injury ($p = 0.093$).

In the present study, 97 patients (31.9%) had Zone I, 124 (40.8%) had Zone II, 70 (23%) had Zone III, and 13 (4.3%) had Zone IV facial bone fractures. Orbital wall fractures, based on their types, were classified into three groups according to the CT findings.

Single-wall orbital fracture was the commonest presentation for all types of facial trauma (Table 1). Among patients whose trauma was localized only to the bony orbit, 65% had Type I orbital wall fractures; however, when the extreme impact of the trauma was dissipated to a larger area, it caused severe damage to the facial bones and the bony orbit. Therefore, the number of orbital wall fractures was directly proportional to the severity of facial trauma. Approximately 9% of Type III orbital wall fractures were observed in Zone I facial bone fractures, whereas Zone IV facial bone fractures accounted for 38.5% of Type III orbital wall fractures ($p = 0.005$) (Figure 3).

The present study revealed that 173 patients (56.9%) were diagnosed with enophthalmos following orbital wall fractures. The severity of enophthalmos was determined by the
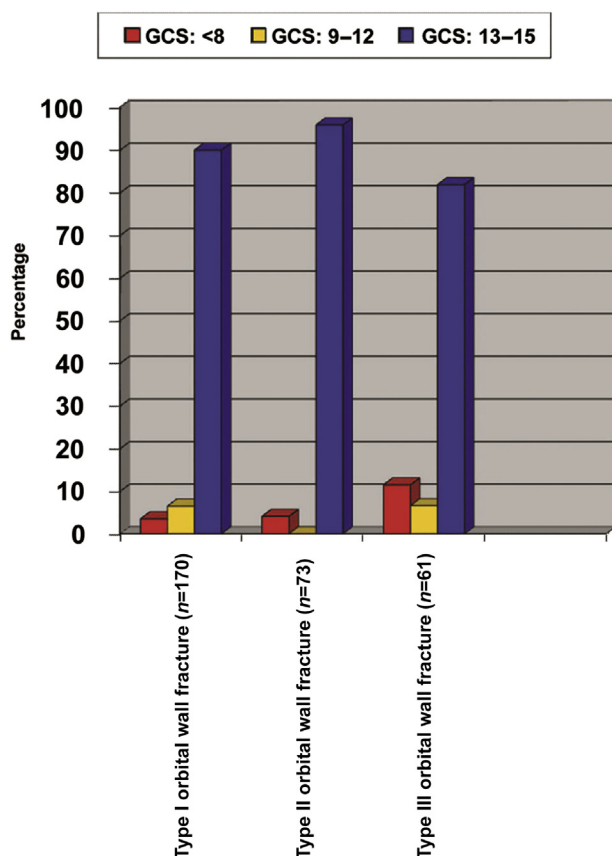
Figure 2 Association between the type of orbital fracture and conscious status. GCS = Glasgow Coma Scale.

complexity of orbital fractures. Of the patients diagnosed with Type III orbital wall fractures, 85% had significant preoperative enophthalmos compared with those with other types of orbital fractures ($p \leq 0.001$). Residual enophthalmos following corrective surgery was found to be significantly higher ($p < 0.001$) in patients with Type II fractures (27.4%). The correction rate was highest for Type III orbital fracture among all fractures involving fewer walls; however, no significant difference in the correction rate was observed between the types of orbital wall fractures (Table 1).

The enophthalmos outcome differed according to the surgery timing. Patients treated within 2 weeks had a significantly lower incidence of preoperative enophthalmos ($p < 0.002$); nevertheless, orbital fractures treated within 2–4 weeks exhibited the highest improvement rate of 80% with less residual enophthalmos (14.3%). Regardless of the timing of orbital fracture reconstruction, the residual
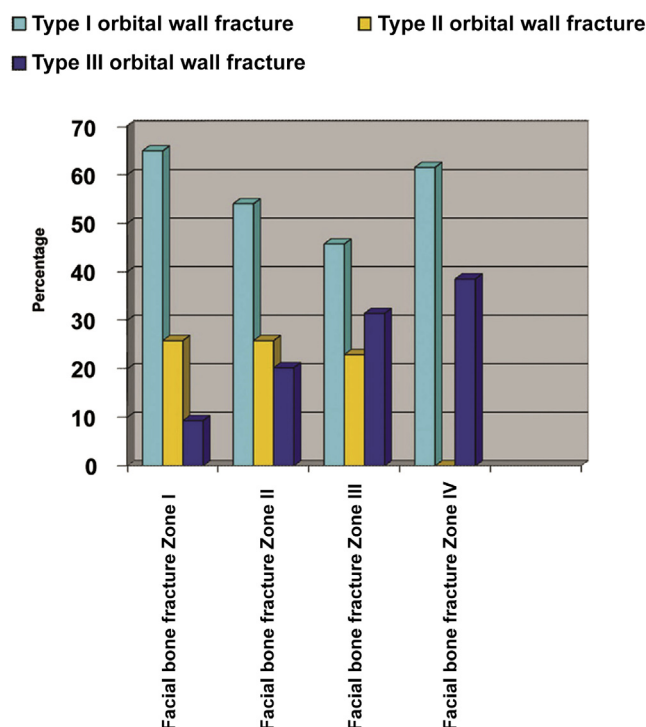

Figure 3 Association between the type of orbital fracture and zone of facial bone fracture.

enophthalmos for patients treated at <2 weeks, 2–4 weeks, or >4 weeks after injury was not statistically significant ($p = 0.904$). The correction rate was highest for patients treated between 2 weeks and 4 weeks; however, no significant difference was observed between each treatment time ($p = 0.194$) (Table 2).

4. Case presentations

4.1. Case 1

Type I fracture: Reconstruction of a left orbital medial wall blowout fracture was performed using a mesh implant. The preoperative CT scan is presented in Figure 4A and the postoperative CT scan in Figure 4B.

4.2. Case 2

Type II fracture: A right orbital floor blowout and orbital medial wall depressed fracture was corrected using an

Table 1 Influence of types of orbital wall fractures on the enophthalmos outcome following surgery.

Types of orbital fractures	Preoperative enophthalmos	Postoperative enophthalmos	Correction rate
Type I (1-wall fracture)	67 patients	20 patients	70.1%
$N = 170$ patients	(39.4%)	(11.8%)	
Type II (2-wall fracture)	54 patients	20 patients	63%
$N = 73$ patients	(74%)	(27.4%)	
Type III (3–4-wall fracture)	52 patients	10 patients	80.8%
$N = 61$ patients	(85.2%)	(16.4%)	
p	≤ 0.001	≤ 0.001	0.126

Table 2 Outcome of enophthalmos treated at various time intervals.

Intervention time	Preoperative enophthalmos	Postoperative enophthalmos	Improvement rate
≤2 wk $N = 195$ patients	96 patients (49.2%)	33 patients (16.9%)	65.6%
2−4 wk $N = 49$ patients	35 patients (71.4%)	Seven patients (14.3%)	80%
≥4 wk $N = 60$ patients	42 patients (70%)	10 patients (16.7%)	76.2%
p	≤0.002	≤0.904	0.194

implant. The preoperative CT scan is depicted in Figure 5A and the postoperative CT scan in Figure 5B.

4.3. Case 3

Type III fracture: A left orbital wall enlargement was caused by an orbital floor fracture, a medial wall blowout fracture, and a zygomatic fracture with an enlarged lateral orbital wall. An implant was used for three-wall reconstruction. The preoperative CT scan is depicted in Figure 6A and the postoperative CT scan in Figure 6B.

5. Discussion

The present study provides a demographic assessment of a large series of surgically treated orbital fractures in our population. The statistically significant results in the present study provide a useful demographic pattern and are clinically relevant. The commonest mechanism of orbital fractures is motor vehicle accidents or assaults, depending on the geographical setting and population.[12,13] Orbital fractures are more common in males than in females, and the highest-risk group is young male patients.[14,15] In this study, the male-to-female patient population ratio was 2.5:1. Motorcycles are the most common mode of daily transportation in our population; therefore, motorcycle accidents were the most prevalent orbital fracture mechanism.

The reported incidence of enophthalmos associated with facial bone fractures varies in the range of 12.5−65%.[14,16,17] However, the incidence of enophthalmos associated with orbital trauma reported in the present study was 56.9%.

The incidence of enophthalmos in our series was high because all enrolled patients, excluding those receiving conservative treatment, received surgical intervention. The majority of the motorcyclists sustained enophthalmos following orbital fractures because of the extreme forces exerted on their unprotected facial bones. Moreover, the extreme forces resulting in facial bone fractures at various sites transmitted a deformation force within the bony orbit, causing various patterns of orbital wall fractures. These data clearly revealed that patients with multiple orbital wall fractures were associated with lower GCS scores as a consequence of intracranial injury. Therefore, diagnosing and optimally managing these orbital fractures sustained because of life-threatening injuries are more difficult than these are for patients with localized orbital wall fractures alone.[18−20] Often, the management of life-threatening injuries takes precedence over that of orbital fractures, leaving orbital deformities to be treated at a later date, resulting in a high incidence of morbidity.

Enophthalmos is a common sign of orbital fracture. Enophthalmos ≥2 mm is aesthetically unacceptable and requires surgical correction. The severity of enophthalmos and treatment outcome following surgery are related to the number, location, and size of orbital wall fractures. Raskin et al[9] reported that immediate enophthalmos is commonly associated with orbital medial wall fracture of more than two-thirds involvement in combination with floor fracture. Hawes and Dortzbach[21] recommended using tomography to estimate the fracture size and concluded that large orbital floor fractures (≥15 fracture volume units or one-half of the orbital floor) are likely to be associated with significant enophthalmos following surgery. The fracture volume unit was determined by multiplying the fracture width (cm),
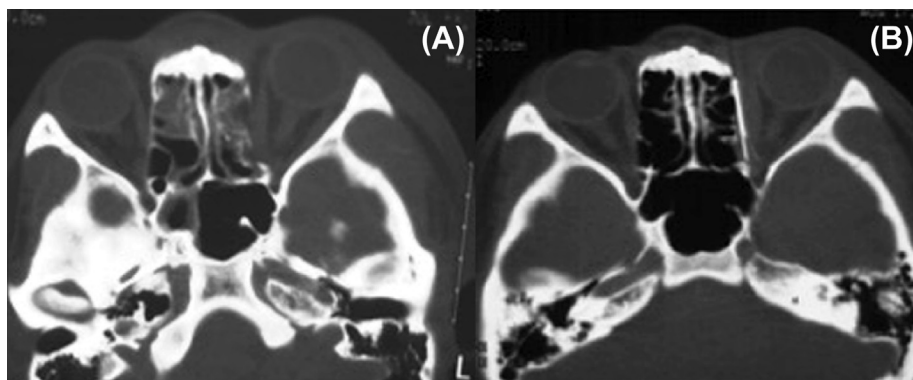

Figure 4 Type I fracture. (A) Preoperative CT revealed left orbital medial wall blowout fracture. (B) Postoperative CT revealed that the left orbital medial wall was reconstructed well using a titanium mesh implant. CT = computed tomography.
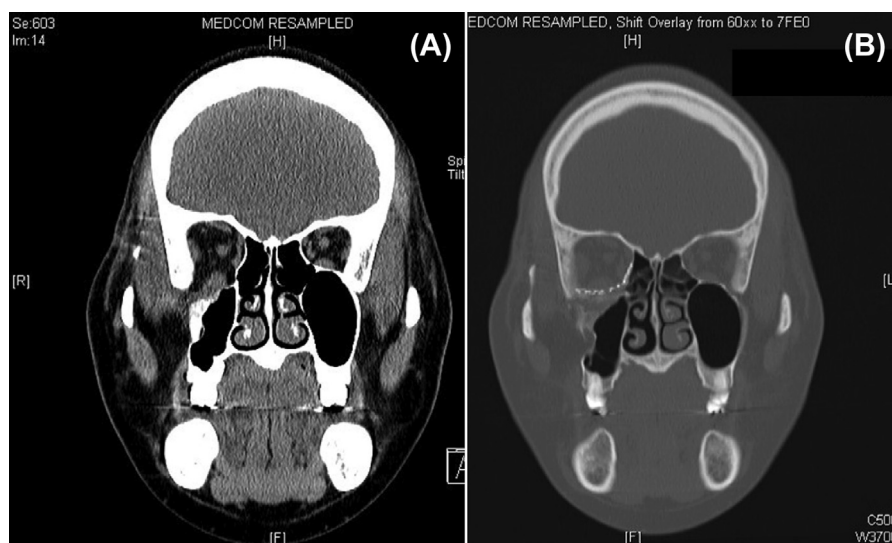
Figure 5 Type II fracture. (A) Preoperative CT indicated right orbital floor blowout and orbital medial wall depressed fracture. (B) Postoperative CT revealed that the right orbital floor and medial orbital wall reconstructed using a titanium mesh implant had an orbital shape similar to that of the floor and wall on the normal side. CT = computed tomography.

fracture length (cm), and fracture depth (cm) of prolapsed orbital tissue. Pearl[22,23] has reported that fracture of the posterior orbital floor produced more volumetric loss behind the axis of the globe than anterior floor fractures did, resulting in significant enophthalmos. Most orbital fractures are not confined to only one specific area but may involve various parts of the orbital floor simultaneously. Consequently, the specific location of the most symptomatic orbital floor is difficult to determine, particularly in unconscious, traumatized patients.[20] These undiagnosed fractures require surgical intervention at a later date in almost 50% of cases.[18]

The present study revealed that an increased number of orbital wall fractures are proportionate to an increased incidence of enophthalmos. Orbital fractures, such as Type III orbital fractures, were associated with the highest incidence of enophthalmos of 85.2% compared with single-wall (39.4%) and two-wall (74%) fractures. Despite the severity of orbital injury and the high incidence of enophthalmos, the incidence of residual enophthalmos following surgery in patients with Type III orbital fractures was low (16.4%). Conversely, for Type II orbital wall fractures, the incidence of residual enophthalmos following surgery was higher (27.4%), probably because when an extreme force
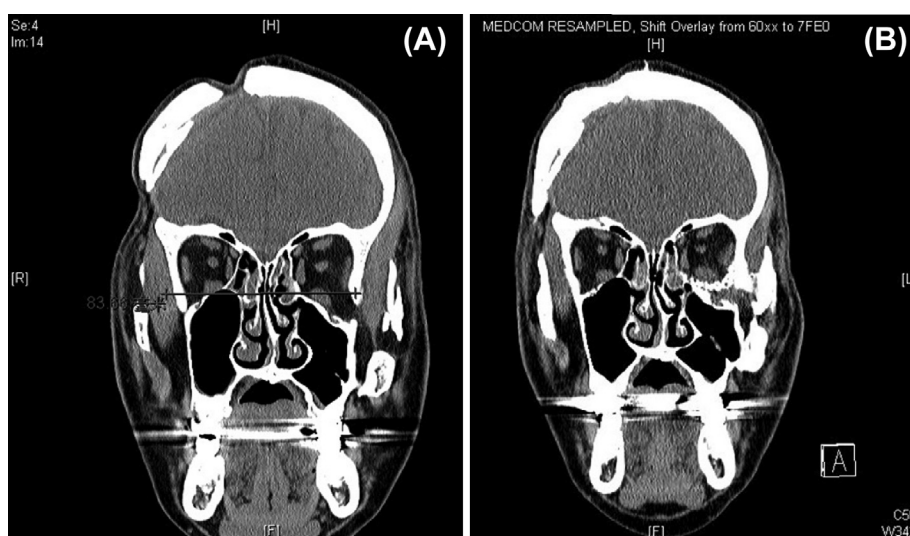

Figure 6 Type III fracture. (A) Preoperative CT revealed left orbital floor fracture, medial orbital wall fracture, and lateral displacement of the lateral orbital wall because of zygomatic fracture. (B) Postoperative CT showed the left orbital floor, medial orbital wall, and lateral orbital wall reconstructed using titanium mesh and Medpor implants to reduce the orbital volume. CT = computed tomography.

trauma to the face is suspected, the acute intervention approach varies. Clinicians are more vigilant concerning the diagnosis of complex orbital fractures and employ an aggressive treatment approach. Therefore, overcorrection with implants during surgery for patients with Type III orbital fractures routinely occurs. By contrast, treating minor deformities of patients with Type I orbital fractures is relatively easy. However, the appropriate corrective volume for patients who sustain Type II orbital fractures is difficult to determine. Overcorrection during surgery may frequently result in postoperative exophthalmos in these cases, whereas minor orbital fractures are often managed inadequately, because small orbital wall fractures are often missed or not apparent during initial radiological investigations. These undiagnosed orbital wall fractures may remain untreated, resulting in unfavorable postoperative consequences. In general, residual enophthalmos is often a result of the failure to perform adequate surgical correction because of severe soft-tissue edema or an undetected neighboring orbital fracture segment, particularly in complex orbital fractures.[20] In addition, conditions caused by unpredictable cicatricial contracture and fat atrophy of the intraorbital content following surgery may contribute to the unfavorable postoperative recovery outcomes. Hence, patients who are at risk of developing enophthalmos must be followed for at least 6 months for detecting changes to enable prompt secondary surgery at a later stage.[24]

Many authors agree that early repair of orbital fractures before the onset of edema or after its resolution offers the ideal opportunity to facilitate exposure for appropriate surgical reduction and fixation.[3–5] Rarely, the immediate surgery for orbital fractures is indicated in "trapdoor fracture" when significant enophthalmos occurs in association with orbital soft-tissue entrapment, resulting in oculocardiac reflex and diplopia.[25,26] For most orbital floor fractures, a 2-week window of observation was suggested in the absence of urgent surgical indications for orbital floor repair.[21] Nevertheless, a prolonged period of observation before surgical intervention may yield suboptimal outcomes. Hawes and Dortzbach[21] reported that delays in the timing of orbital floor reconstruction beyond 2 months yielded inferior results compared with early surgery. Dulley and Fells[27] observed that 72% of patients who had surgery 6 months after initial trauma had enophthalmos, whereas the percentage was 20% in patients who had surgery within 2 weeks of trauma.

Regardless of the timing of surgery, the primary goal of surgery is to reconstruct the orbital wall to its pretrauma condition. The present study revealed that the enophthalmos incidence was not influenced by the time interval between injury and surgery. Enophthalmos treated at <2 weeks following orbital trauma exhibited a lower improvement rate compared with enophthalmos treated at 2−4 weeks and >4 weeks following trauma. Significant enophthalmos is usually not immediately apparent following initial orbital trauma. In severe orbital trauma, the edema of the periorbital tissue may even cause proptosis on the injured side. Consequently, any surgical correction of enophthalmos should be decided after the tissue edema subsides to yield favorable esthetic outcomes.[8,17,28] Hence, it is not necessary to repair all orbital fractures immediately, and the indications for surgical repair should be individualized. A delay in the surgery for varying periods of time is feasible and does not affect the treatment outcome.

6. Conclusion

The present study demonstrated that the concepts of treatment for orbital fractures with enophthalmos have evolved over time. The severity of head injury has no adverse influence on the number of orbital wall fractures; however, the severity of associated facial fractures significantly affects the number of orbital wall fractures. Enophthalmos can be treated at various time intervals following initial injury with a comparable outcome. Irrespective of the type of facial fracture, all possible sites of fractures within the bony orbit should be identified and meticulously reduced for ensuring satisfactory correction even in the most severe orbital wall fractures. The timing of surgery in orbital fractures should be individualized on the basis of the severity of injury and type of orbital wall fracture. Long-term follow-up following surgery is necessary for ensuring the stability and adequacy of surgical correction.

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