Surgical Timing and Fracture Type on the Outcome of Diplopia After Orbital Fracture Repair

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Background: Orbital fractures and the concomitant soft tissue injuries within the bony orbit result in well-recognized complications such as diplopia and enophthalmos. Guidelines for timing and indications for surgery for achieving an optimal outcome remain elusive. This study examined the effects of timing and fracture type on the outcome of orbital fracture repair.

Material and Methods: Data on 255 patients treated for orbital fractures were retrospectively reviewed to determine the effects of the facial bones involved in the fractures, the types of orbital wall fracture, the timing of surgical repair, and diplopia evident before and after corrective surgery on surgical outcomes.

Results: The incidence of posttraumatic diplopia increased with the number of orbital wall fractures ($P < 0.001$). The rate of diplopia resolution after corrective surgery was slow in the first 3 months irrespective of the severity of orbital wall fracture. The diplopia resolution rate for type I orbital wall fractures was significantly higher than that for type II and type III fractures. Patients treated within 2 weeks of sustaining an orbital fracture exhibited a higher diplopia resolution rate than did patients treated 2 to 4 weeks and more than 4 weeks after sustaining the fracture (58% vs 38.1%).

Conclusions: A higher number of orbital wall fractures are associated with a higher incidence of diplopia and a poorer long-term result. The timing of surgical repair influences the diplopia outcome. Performing corrective surgery for orbital fractures with diplopia after 2 weeks tends to result in a slower complete recovery rate.

Key Words: orbital fracture, surgical timing, diplopia

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Fractures of the bony orbit are common in patients with blunt trauma to the face and skull. Orbital fractures and the concomitant soft tissue injuries within the bony orbit often result in well-recognized complications such as diplopia and enophthalmos. The incidence of diplopia after orbital fractures ranges from 15% to 86%.[1–4] Persistent diplopia often causes major physical disabilities when the orbital fracture is not treated adequately. Promptly recognizing and treating an orbital fracture is imperative to reducing the risk of posttraumatic diplopia. The management of orbital fractures is extensively described in the literature, with philosophical approaches varying from conservative treatment to immediate surgery.[5–7] However, the guidelines for timing and indications for surgery for achieving an optimal outcome remain elusive.

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Most orbital fractures do not need to be repaired immediately, depending on the severity of injury and fracture type. Putterman et al[8] recommended a conservative approach for orbital blowout fractures with no incidence of persistent diplopia or cosmetically unacceptable enophthalmos. Specific types of orbital fractures, particularly trapdoor orbital fractures involving the orbital floor among children, demand immediate surgery to prevent morbidity.[9,10] Surgery within the first 2 weeks of orbital floor fractures in children resulted in more complete return of normal ocular motility. Several studies have also reported that the early repair of orbital fractures produces superior outcomes for diplopia resolution,[11,12] and other studies have proposed that repair is possible even months after the initial injury.[13,14] Nevertheless, many authors agree that in the absence of urgent surgical indications, repairing orbital fractures within 2 weeks is acceptable.[5–7,15,16]

Although many studies have proposed that the earliest timing of orbital fracture repair should be within 2 weeks, evidence is scant regarding how early the surgical management of orbital fractures should be initiated and the prognosis if delayed surgical intervention is undertaken. Most relevant guidelines are based on noncomparative retrospective studies in which the course of recovery and prognosis of diplopia are often insufficiently documented. Therefore, the purpose of this study was to evaluate the outcomes of diplopia after orbital fractures by comparing different surgical timings and fracture types. By reviewing our cases retrospectively, we hope to guide the future management of diplopia associated with orbital fractures.

MATERIALS AND METHODS

Four hundred twenty-one consecutive patients with orbital fractures received orbital reconstruction at the Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, between July 2003 and December 2014. Through a retrospective review of medical records, 255 patients were identified after patients with globe injury, optic nerve injury, or incomplete clinical records and those who were younger than 7 years or lost to follow-up were excluded. The collected data were analyzed to determine the age, sex, mechanisms of injury, Glasgow Coma Scale (GCS) score, fracture zones, number of orbital wall fractures, and timing of surgical intervention.

The mechanism of injury was divided into 3 subgroups as follows: motorcycle accident, car accident, and other (including assault, sports-related injury, and industrial accidents). The GCS scores recorded for patients with facial trauma at the time of admission were classified into severe head injury (scores lower than 8), moderate head injury (scores of 9–12), and mild head injury (scores of 13–15) categories. All facial bone fractures were classified into various fracture zones according to x-ray, computed tomography (CT), and intraoperative findings. Four zones of facial fracture were identified in this study, namely zone I: fractures of only the bony orbit; zone II: fractures of the bony orbit and adjacent facial bones, such as the zygoma, maxilla, nasal, and nasoethmoidal bones; zone III: fractures of the bony orbit and either the upper or lower third of facial bones; and zone IV: orbital and panfacial fractures (Fig. 1). Facial bone fractures were categorized into various zones to define the severity of fracture patterns sustained in association with orbital fractures. By examining the CT and intraoperative findings, orbital fractures were also classified into 3 types

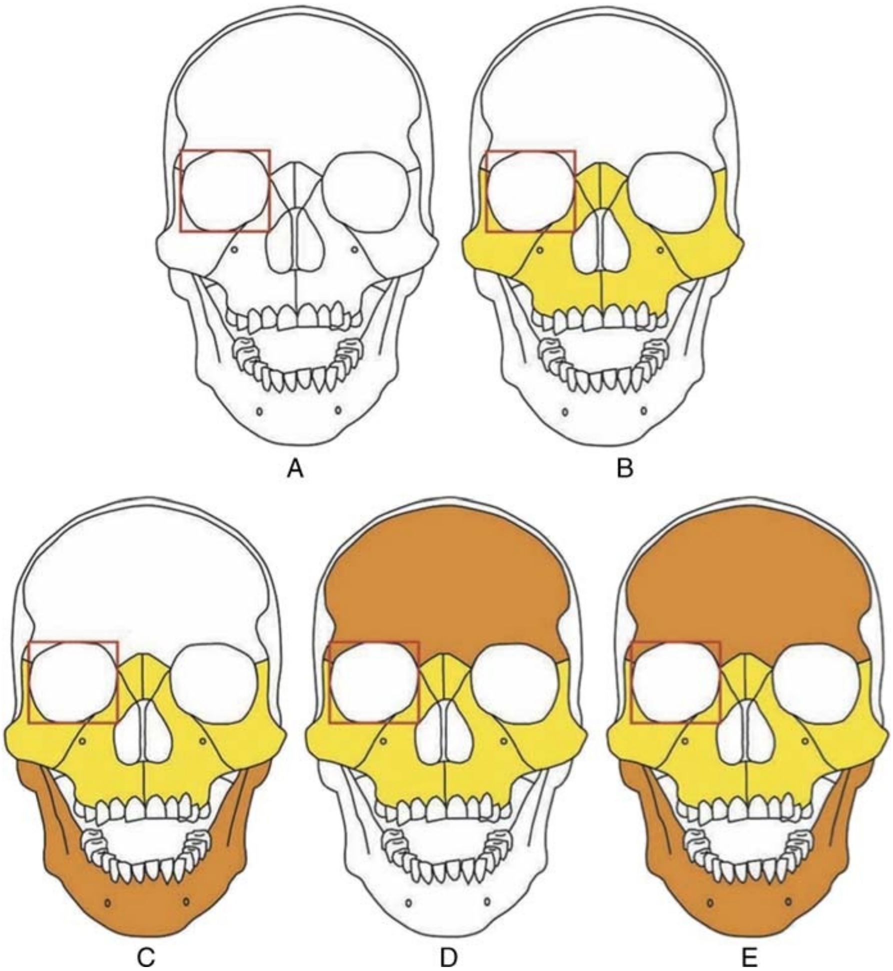

FIGURE 1. Four zones of facial fracture: (A) zone 1: fracture involving only the bony orbit; (B) zone II: fracture of the bony orbit with adjacent facial bones such as zygoma, maxilla, nasal, and nasoethmoidal bones; (C and D) zone III: fracture of the bony orbit with either the upper or lower third of facial bones; and (E) zone IV: orbital and panfacial fractures.

according to the number of orbital walls involved: type I (1 wall fracture), type II (2 wall fractures), and type III (3 or 4 wall fractures). This classification was intended to simplify statistical analysis. If we were to classify the patients according to the exact number of wall fractures, then the total number of wall fractures would be much higher than the number of patients. Thus, the statistical analysis would be more complex.

Patients admitted with orbital trauma were assessed by an ophthalmologist on admission and before and after surgery. Orbital reconstruction was performed by a single surgeon. Porous polyethylene implants (Medpor; Porex Surgical Inc, College Park, GA) were used for repairing the orbital wall defects in all patients. After the corrective surgery, the progress of diplopia was followed up and recorded every 3 months. Diplopia was considered clinically present when double vision was reported in any direction of gaze, even in extreme gaze or after corrective surgery, irrespective of severity. Completely resolved diplopia was defined as the absence of diplopia in all visual fields. Patients with orbital fractures were treated at different time intervals, depending on the severity of injury, other concomitant life-threatening injuries, and delays in referral from other hospitals. The time from injury to surgical correction was divided into 3 groups: within 2 weeks, 2 to 4 weeks, and more than 4 weeks. Diplopia outcomes were later compared according to the type of orbital wall fracture and time before surgery. Statistical analysis for comparing the study groups was performed using the χ^2 test, Fisher exact test for independent data, and McNemar test for paired samples. Statistical results were considered significant when $P \leq 0.05$.

RESULTS

The medical records of 255 patients fulfilled the study criteria. Of these patients, 181 (71%) were men and 74 (29%) were women, representing a male-to-female ratio of 2.4:1. The age of the patients ranged from 7 to 74 years, with the mean age being 27.6 years. One hundred forty-three (56.1%) patients exhibited type I orbital wall fractures, and 60 (23.5%) and 52 patients (20.4%) were diagnosed with type II and type III orbital wall fractures, respectively. Patients with diplopia after surgical correction were followed up for 12 to 70 months, with the average follow-up duration being 14.2 months. The most common mechanism of injury among the patients referred to our institution was motorcycle accidents (67.8%), followed by car accidents (17.7%) and others such as assault, sports-related injury, and industrial accidents (14.5%). Fourteen (5.5%) patients had GCS scores lower than 8 on admission and required intubation and treatment in the intensive care unit because of associated intracranial injuries. Thirteen (5.1%) and 228 (89.4%) patients had GCS scores of 9 to 12 and 13 to 15 on admission, respectively. The incidence of diplopia among the patients with orbital fractures was 45.5%. The demographic data obtained in this study revealed no significant association between the fracture type and

TABLE 1. Fracture Type and Mechanism of Injury

Fracture Type	MCA	MCV	Others
Type I (1 wall fracture), n = 143	98 (68.5%)	25 (17.5%)	20 (14%)
Type II (2 walls fracture), n = 60	39 (65%)	9 (15%)	12 (20%)
Type III (3–4 walls fracture), n = 52	36 (69.2%)	11 (21.2%)	5 (9.6%)
P		0.586	

Others: Assaults, sports injury, industrial accident, and others.
MCA, Motor cycle accident; MCV, motor car accident.

mechanism of injury or GCS score; however, type III orbital fractures were associated with a higher incidence of poor GCS scores (Tables 1 and 2).

The relationship between the orbital fractures and severity of associated facial fractures was analyzed. Seventy-seven (30.2%) patients exhibited zone I facial bone fractures, 107 (42%) patients exhibited zone II fractures, 58 (22.7%) patients exhibited zone III fractures, and 13 (5.1%) patients exhibited zone IV fractures. A significant correlation existed between the orbital wall fracture type and facial fracture zone ($P = 0.036$). Among all facial fracture patterns, zone II facial fractures involving midfacial bones such as the zygoma, maxilla, and nasal bones were the most susceptible to orbital wall fracture ($P = 0.036$). Type II (46.6%) was the most common orbital wall fracture among zone II patterns, followed by type III (42.3%) and type I (39.8%) (Table 3).

The occurrence of preoperative diplopia varied with the orbital wall fracture type. Of patients who sustained type I orbital wall fractures, 32% were diagnosed with preoperative diplopia, whereas 65% and 59.6% of patients with type II and type III orbital wall fractures, respectively, had preoperative diplopia. A significantly higher incidence of posttraumatic diplopia was observed in patients with a higher number of orbital wall fractures ($P < 0.001$). The degree of diplopia resolution was low in the first 3 months after corrective surgery, irrespective of the severity of the sustained orbital wall fracture. After 3 months, the degree of improvement was significantly higher in type I orbital wall fractures than in type II and type III fractures ($P = 0.031$). Complete recovery from diplopia was 65.2% in patients with type I orbital wall fractures after 12 months of follow-up. Patients with type III orbital wall fractures exhibited the slowest complete resolution of diplopia (35.5%) after surgery in the same follow-up duration ($P = 0.029$). The rate of complete diplopia resolution after corrective surgery was inversely related to the severity of orbital wall fracture (Table 4).

The timing of surgical intervention was also examined in relation to the outcome of diplopia. One hundred sixty-seven (65.5%) patients received surgical intervention in the form of open reduction and internal fixation within 2 weeks of the initial trauma. The average time before surgical intervention in this group was 6.7 days. Thirty-nine (15.3%) patients were treated within 2 to 4 weeks after trauma, with the mean surgical intervention time being 17.9 days. Forty-nine (19.2%) patients received surgical correction after 4 weeks, with the average time being 190.6 days. Of patients treated within 2 weeks, 44% were diagnosed with preoperative diplopia, whereas 39% and 55% of patients who received surgery within 2 to 4 weeks and after more than 4 weeks,

TABLE 2. Fracture Type and GCS Score

Fracture Type	GCS, <8	GCS, 9–12	GCS, 13–15
Type I (1 wall fracture), n = 143	6 (4.2%)	8 (5.6%)	129 (90.2%)
Type II (2 walls fracture), n = 60	2 (3.3%)	1 (1.7%)	57 (95%)
Type III (3–4 walls fracture), n = 52	6 (11.5%)	4 (7.7%)	42 (80.8%)
P		0.125	

TABLE 3. Associations Between the Types of Orbital Wall Fracture and Facial Bone Fracture Zones

	Facial Fracture Patterns			
Types of Orbital Fracture	Zone I, n = 77	Zone II, n = 107	Zone III, n = 58	Zone IV, n = 13
Type I (1 wall fracture), n = 143	50 (35.0%)	57 (39.8%)	28 (19.6%)	8 (5.6%)
Type II (2 walls fracture), n = 60	19 (31.7%)	28 (46.6%)	13 (21.7%)	0 (0%)
Type III (3–4 walls fracture), n = 52	8 (15.4%)	22 (42.3%)	17 (32.7%)	5 (9.6%)
P		0.036		

respectively, were diagnosed with preoperative diplopia. The incidence of preoperative diplopia was not significantly associated with the surgical timing ($P = 0.260$), although patients treated after 1 month exhibited a greater likelihood of preoperative diplopia. However, patients treated within 2 weeks exhibited a significantly higher diplopia resolution than did the patients treated within 2 to 4 weeks and beyond 4 weeks at the 6-month follow-up ($P = 0.03$).

The incidence of residual postoperative diplopia among patients who received surgery within 2 weeks was 41.9% at 12 months of follow-up. Among patients who received surgery within 2 to 4 weeks or beyond 4 weeks, the incidence of residual postoperative diplopia was 60% and 63%, respectively ($P = 0.115$). The outcome of diplopia after corrective surgery for these 3 groups did not vary significantly among follow-up intervals. To reduce selection bias, a strategic analysis based on a 2-week cut point was used. At 12 months of follow-up, patients who received surgical correction within 2 weeks showed a higher resolution rate than did those who received treatment later (58.1% vs 38.1%), with the difference approaching statistical significance ($P = 0.053$; Table 5).

DISCUSSION

Similarly to the findings of previous reports,[1,4,17] the demographic assessment of the current study revealed that orbital fractures are more common in men than in women, with the male-to-female ratio being 2.4:1. Orbital fractures are more prevalent among young adults, and the average age of the patients in this study was 27.6 years. In our study population, the incidence of diplopia associated with orbital fractures was 45.1%, which is similar to that reported by al-Qurainy et al,[3] who observed double vision in 58% of orbital blowout fractures. Motorcycle accidents were the most common cause of facial trauma resulting in orbital fractures, probably because motorcycles were the most common mode of daily transportation in the study group. The pattern of facial bone fractures and number of orbital wall fractures and intracranial injuries indirectly represented the severity of injury sustained by those injured in motorcycle accidents. This correlation was similar to that observed by al-Qurainy et al,[3] who reported that the major causes of diplopia were road traffic accidents, blowout fractures, and comminuted malar fractures.

Various controversies exist concerning the management of orbital fractures and associated diplopia, mainly regarding the indications and ideal time for surgical intervention. Numerous authors have advocated different treatment approaches for orbital fracture–caused diplopia from immediate to delayed surgical intervention. However, there is still a lack of consensus on when corrective surgery should be performed for orbital fractures. Nevertheless, most authors concur that immediate surgery is required for orbital soft tissue entrapment associated with oculocardiac reflex, particularly in trap-door orbital floor fractures in children. Urgent surgical intervention is warranted to prevent

TABLE 4. Progress of Diplopia After Corrective Surgery for Different Types of Orbital Fracture

	Diplopia				
Types of Orbital Fracture	**Preoperative**	**Postoperative, <3 mo**	**Postoperative, 3–6 mo**	**Postoperative, 6–9 mo**	**Postoperative, 9–12 mo**
Type I (1 wall fracture), n = 143	46	(+) 38 (82.7%)	(+) 25 (54.3%)	(+) 21 (45.7%)	(+) 16 (34.8%)
		(−) 8 (17.3%)	(−) 21 (45.7%)	(−) 25 (54.3%)	(−) 30 (65.2%)
Type II (2 walls fracture), n = 60	39	(+) 36 (92.3%)	(+) 29 (74.4%)	(+) 24 (61.5%)	(+) 21 (53.8%)
		(−) 3 (7.7%)	(−) 10 (25.6%)	(−) 15 (38.5%)	(−) 18 (46.2%)
Type III (3–4 walls fracture), n = 52	31	(+) 29 (93.5%)	(+) 25 (80.6%)	(+) 20 (64.5%)	(+) 20 (64.5%)
		(−) 2 (6.5%)	(−) 6 (19.4%)	(−) 11 (35.5%)	(−) 11 (35.5%)
P	<0.001	0.228	0.031	0.183	0.029

(+) Residual diplopia present; (−) diplopia resolved completely.

life-threatening complications from such pediatric orbital fractures.[9,10] Jordan et al[18] recommended surgery within a few days of injury for "white-eyed blowout" fractures in young patients to avoid permanent motility restriction. Early surgery is required for these patients to prevent late muscle damage and contracture. Delaying surgery by 2 weeks in these patients offers little benefit and may harm their ocular motility.

When urgent surgical indications are absent, most authors recommend surgical repair within 2 weeks of the initial injury. Surgical intervention within the first 2 weeks tends to yield a more complete return to normal ocular motility. The benefits of early surgical intervention cannot be ignored, because the release of incarcerated orbital soft tissue before the manifestation of ischemia, scarring, and atrophy is crucial to preventing undesirable complications. Furthermore, exploring the orbital floor early may reveal numerous false-negative cases that may be missed or increase the subsequent risk of persistent diplopia.[19–21] Wilkins and Havins[22] and Tajima et al[23] have reported superior outcomes for diplopia from early repair compared with delayed surgery. These authors believe that diplopia not resolved within 2 weeks of trauma is unlikely to resolve spontaneously. Therefore, surgical intervention is imperative for releasing incarcerated orbital content and restoring the anatomy of the internal orbit to prevent sequelae. Hawes and Dortzbach[11] advocated a similar approach, proposing repair within 2 weeks for patients with fractures larger than one half of the orbital floor or with substantial extraocular muscle dysfunction caused by entrapment, regardless of the fracture size.

By contrast, some authors have argued that delayed surgery or the secondary management of orbital fractures yields favorable outcomes. Putterman et al[8] reported satisfactory results for delayed surgery in patients with orbital blowout fractures after 4 to 6 months of observation. Mathog et al[13] revealed that orbital repairs performed 2 to 54 months after injury yielded 63.6% complete and 27.3% partial resolution. Later, they reported that surgery after 6 to 24 months yielded 75% complete and 8% partial resolution.[24] Similarly, Roncevic and Stajcic[14] reported 77.3% complete resolution among 53 patients who received surgery after 3 to 36 months. In our study, the proportion of postoperative residual diplopia was the highest (63%) among patients treated after more than 1 month compared with that reported in other studies because cases of minimal diplopia were recorded as positive findings. The comparison of different surgical times in this study revealed superior diplopia outcomes among orbital fractures treated within 2 weeks. Corrective surgery for orbital fracture-associated diplopia beyond 2 weeks is associated with a slower recovery.

The advent of high-resolution CT has improved the assessment of the anatomy of the internal orbit and demonstrated the clinical significance of fractures. Hypothesizing that the degree of orbital wall fracture, extraocular muscle contusion, nerve injury, and edema determine the treatment outcome is logical.[8,25–29] The current study demonstrated that the prognosis for complete resolution of diplopia was inversely related to the number of orbital wall fractures. In other words, the number of orbital wall fractures reflects the degree of soft tissue injury. Patients who presented initially with fewer orbital wall fractures exhibited the highest complete recovery rate for diplopia after surgery. Harris et al[30] provided indirect evidence of this finding by using CT data to predict the severity of soft tissue injury and concluded that a greater degree of soft tissue injury correlates with poorer ocular motility outcomes. Orbital fractures associated with greater degrees of soft tissue incarceration or displacement are presumed to involve greater intrinsic damage and subsequent fibrosis causing poorer motility outcomes. Ultimately, urgent surgical intervention for these injuries should be considered. Gilbard et al[28] performed CT assessment of orbital fractures to identify

TABLE 5. Progress of Diplopia With Different Surgical Times for Orbital Fractures

	Diplopia				
Delayed Operation Time	**Preoperative**	**Postoperative, <3 mo**	**Postoperative, 3–6 mo**	**Postoperative, 6–9 mo**	**Postoperative, 9–12 mo**
<2 wk (n = 167)	74	(+) 67 (90.5%)	(+) 46 (62.2%)	(+) 35 (47.3%)	(+) 31 (41.9%)
*Average time: 6.7 d		(−) 7 (9.5%)	(−) 28 (37.8%)	(−) 39 (52.7%)	(−) 43 (58.1%)
2–4 wk (n = 39)	15	(+) 14 (93.3%)	(+) 13 (86.7%)	(+) 12 (80%)	(+) 9 (60%)
*Average time: 17.9 d		(−) 1 (6.7%)	(−) 2 (13.3%)	(−) 3 (20%)	(−) 6 (40%)
>4 wk (n = 49)	27	(+) 26 (96.3%)	(+) 20 (74.1%)	(+) 18 (66.7%)	(+) 17 (63%)
*Average time: 190.6 d		(−) 1 (3.7%)	(−) 7 (25.9%)	(−) 9 (33.3%)	(−) 10 (37%)
P	0.260	0.624	0.134	0.030	0.115
*P**		0.458*	0.097*	0.019*	0.053*

*Comparison between <2 weeks only with combined 2–4 and >4 weeks.

(+) Residual diplopia present; (−) diplopia resolved completely.

patients at risk of diplopia 1 month after injury without surgery. The position of the inferior rectus muscle in relation to the orbital floor identified using CT scans remained a reliable predictor of continued diplopia. Patients with an entrapped inferior rectus on CT scans invariably presented with clinically significant diplopia and were considered candidates for surgical intervention. The ability to assess the orbital and extraocular muscle anatomy has improved the guidelines for treating diplopia associated with orbital fractures. Therefore, to ensure optimal treatment outcomes, the indications and timing of surgery should be tailored according to the number of orbital wall fractures and degree of soft tissue involvement.

Solitary orbital roof fracture is uncommon but does occur. Cossman et al[31] reported that 8 (13%) of 60 patients had isolated orbital roof fracture. Of the 8 patients, 3 sustained multisystem injuries. All of the 8 patients required no surgical intervention for the roof fracture. No complications were observed in nonoperative groups over a mean follow-up duration of 19.6 ± 7.8 months. Orbital roof fracture is usually involved in multisystem injury. Haug et al[32] reported that 95% of patients with orbital roof fracture sustained an associated frontal sinus fracture. In our series, no solitary orbital roof fracture was observed. Patients with orbital roof fracture had other orbital wall fractures and were classified into the type II or type III fracture group.

Orbital fracture–associated diplopia should be treated according to the preoperative assessment of the number of orbital wall fractures and appropriate surgical intervention time. The severity of injury to the internal orbit is reflected by the number of orbital wall fractures. An increase in the number of fractured orbital walls involved is associated with an increased incidence of diplopia and poorer long-term outcomes. The results obtained in this study by comparing groups with different times before surgery demonstrated that the timing of surgical correction influences the treatment outcome for this potentially troublesome problem. The final outcome of diplopia is also dictated by the severity of orbital wall fractures, appropriate identification of the pathological sites, and adequate reduction and rigid fixation of the fractures. In summary, the outcome of orbital fracture–associated diplopia is significantly influenced by the number of orbital wall fractures in addition to the timing of surgical intervention. Corrective surgery for orbital fractures with diplopia within 2 weeks is recommended.

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