Abstract

Purpose: This study evaluated outcomes of surgical treatment for enophthalmos after pediatric orbital blowout fracture. Associations of fracture type, fracture site, time from injury to treatment, and type of surgical procedure with treatment outcomes were assessed.

Methods: The medical records of 200 children and adolescents (38 girls and 162 boys) with orbital fractures treated in the authors' department from 1975 to 2015 were reviewed retrospectively. The main causes of injury were accidental blows to the orbit and sports injuries. This study included only patients with fracture of the floor and/or medial wall of the orbit, which is referred to in the English literature as pure, or internal, blowout fracture. Patients with fracture of the orbital rim, lateral wall, or roof were excluded. Surgical treatment was performed for 178 patients; the other 22 children were treated conservatively.

Results: In the surgically treated group, treatment outcomes did not differ in relation to the severity of post-traumatic enophthalmos. The setting of the eyeball improved in 83% of patients.

Conclusion: The severity of post-traumatic enophthalmos was not associated with surgical outcome in children.

Keywords: diplopia, enophthalmos, orbital fracture in children, posttraumatic enophthalmos, pure blowout orbital fracture in children

Introduction

Orbital fractures constitute 3% to 50% of facial skull injuries [1-5]. Pediatric orbital fractures differ clinically from those in adults because of differences in the structure of the bone, the proportions between the facial and cerebral skull, and development of the paranasal sinuses [5]. The classical triad of symptoms for blowout fracture in adults is double vision, enophthalmos, and impairment of sensation in the infraorbital area. In addition, swelling in the area of the orbit, periorbital hematoma, subconjunctival ecchymosis, limitation of eye movement, especially upgaze, may be present.

In pediatric orbital fractures, the main symptoms include limitation of eye movement and diplopia. A characteristic sign of pediatric blowout fracture is corrective positioning of the head, due to diplopia. In children, so-called white-eyed blowout fractures are frequent [6]. This is a linear fracture of the floor of the orbit, with entrapment of the periorbital tissue but no major loss of bone structure [7-10]. Another common orbital fracture in children is trapdoor fracture, which constitutes 27% to 90% of all orbital fractures [1-3,11-13]. Enophthalmos in orbital fractures is usually not discussed. Nausea and vomiting, which may be the only symptoms of orbital fracture, can mimic neurological signs of central nervous system damage, and the possibility of orbital fracture may not be considered [7,14,15]. Computed tomography (CT) is the standard procedure to evaluate orbital injuries in children [16], while magnetic resonance imaging is an alternative for older children. The optimal timing for surgical treatment after orbital fracture is unclear; however, most surgeons favor earlier intervention, especially for children [1,4,9,11,17,18]. The indications for surgical treatment are limitation in eye movement, enophthalmos, herniation of periorbital tissues, and presence of evident bone defects of the orbit floor [19]. Urgent surgical intervention is required when an oculocardiac reflex is present, usually in trapdoor fracture [14]. Some surgeons feel that treatment of pediatric orbital fracture should be as conservative as possible. However, failure to provide timely surgical treatment could severely affect development and sight [20]. In addition to functional impairment, enophthalmos can result in limitation in eye movement and diplopia, and in adverse aesthetic outcomes for the midface [21,22]. This study evaluated the effect of enophthalmos on treatment outcomes for pediatric orbital blowout fracture.

Materials and Methods

The medical records of 200 patients (38 girls and 162 boys) younger than 18 years (range, 4-18 years; average, 12.1 years) treated for isolated fracture of the orbital floor in the authors’ department between 1975 and 2015 were reviewed. Data were collected on cause of injury, fracture site, fracture type, and clinical findings (including enophthalmos), diplopia type, time from injury to treatment, treatment type, and treatment outcome. This study included only patients with isolated fracture of the orbital floor and/or medial wall fracture (i.e. “pure blowout” or internal blowout fracture). Patients were excluded if they had any other fracture of the facial skull, including at the rim, lateral wall, or roof of the orbit.

Diplopia type was assessed by using the classification of Krystkowka, as shown in Fig. 1. Upon initial presentation to the clinic, after surgery, and before discharge from hospital, patients were examined by an ophthalmologist using an orbital chart in the authors’ department. Another examination was performed at about 1 month after surgery. When diplopia was persistent or slowly improving, a control examination was performed at intervals of 1 to 3 months.

Enophthalmos was assessed with a Hertel exophthalmometer before and after surgical treatment. Exophthalmometry was performed during ophthalmological examination (after injury), during the surgical procedure (at the start and end of surgery), and during the ophthalmological control examination in the outpatient office. Intraoperative exophthalmometry was performed by the first and second surgeon. This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the relevant Institutional Ethical Board (No. 1072.6120.64.2020). Because only medical files were obtained, the Review Board approved the study without the need for patient consent, as long as all personal information remained confidential. The values for evaluated variables before and after surgery were assessed. The postoperative observation period ranged from 1.5 to 18 months. The criteria of recovery were 0-1 mm of enophthalmos, complete restoration of eye movement, and absence of double vision. Qualitative variables in groups were compared by using the chi-square test (with Yates correction for 2 × 2 tables) or Fisher exact test, when the low expected numbers appeared. The analysis adopted a significance level of 0.05. A P value of less than 0.05 was considered to indicate statistical significance. Analysis was performed with the R, version 3.6.1, software package (R Core Team, Vienna, Austria). Surgical
indicators were determined individually on the basis of the clinical condition of the patient and imaging findings. From the beginning of the 1990s to the 20th century, CT scanning was the standard imaging procedure, and slice thickness decreased from 2 mm to 0.5 mm over time. Before CT scanning, plain radiography (Water’s view) was used for diagnostic procedures. Indications for surgical treatment were persistent double vision, impaired eye movement, enophthalmos greater than 2 mm, and extensive fracture of the orbital bone. Surgical treatment consisted of revision of the fracture site, with release of herniated tissues, or revision, tissue release, and reconstruction of the bone defect by autogenous bone graft. The procedures were performed under general anesthesia. Passive eye movement was assessed with a three-point scale (+, no mobility; ++, limitation of passive mobility; +++ , full passive mobility) at the start and end of the surgical procedure. The preferred approach was transconjunctival incision, which does not leave a visible postoperative scar. In patients with fracture and soft tissue damage around the injury site, wound access was used. Because of the site of the fracture, most of the patients had sensory impairment of the infraorbital area, which usually resolved after surgery. No detailed information on sensory impairment was collected, because the study group comprised children and any data obtained would not have been measured objectively.

**Results**

The most common cause of injury was an accidental blow to the periorbital area (n = 74, 37%), followed by sport injuries (n = 47, 23.5%). The causes of injury are shown in Table 1.

The most common fracture site was the orbital floor (n = 176, 88%), followed by the floor of the medial wall. The fracture sites are shown in Table 1. Fracture site was significantly associated with enophthalmos, and orbital floor fracture was significantly associated with greater enophthalmos, which was not true for medial wall fracture, as shown in Table 2. The effectiveness of surgical treatment of post-traumatic enophthalmos in relation to fracture site was also assessed, and the setting of the eyeball improved in 83% of patients (Table 2). Fracture with an orbital floor defect was noted in 151 (75.5%) patients; the other patients had a linear orbital fracture. Fracture types are presented in Table 1. Loss of consciousness occurred in 31 (15.5%) patients, and concussion was noted in 32 (16%). The injury was accompanied by brain contusion in 3 (1.5%) patients. The most common symptoms were nausea and headache, in 72 (36%) patients. Traumatic injuries occurred in 13 (6.5%) patients. These included retinal concussion, in 4 (2%) patients, as well as anisocoria, blurred borders of the optic nerve disc, conjunctival hematoma, and hemorrhage with retinal contusion. One patient with upper orbital fissure syndrome had reduced visual acuity (0.3), and one patient had post-traumatic blindness. Diplopia was noted in 188 (88%) patients. The most common type of diplopia was diplopia across the entire field of view (type V), in 91 (48.5%) patients, and during upgaze and downgaze (type II), in 42 (22.3%) patients.

Enophthalmos was observed in 125 (62.5%) patients: 58 (29%) had enophthalmos of less than 2 mm, and 67 (33.5%) had enophthalmos of 2-5 mm. The association of enophthalmos severity with treatment outcomes is shown in Table 3. Treatment outcomes were not associated with severity of posttraumatic enophthalmos. The association of time from injury to Table 1 Characteristics of patients

| Cause of injury                        | Number of patients (%) |
|---------------------------------------|------------------------|
| Accidental blow to the periorbital area | 74 (37)                |
| Sports injury                         | 47 (23.5)              |
| Assault                               | 35 (17.5)              |
| Fall                                  | 19 (9.5)               |
| Road traffic accident                 | 17 (8.5)               |
| Other                                  | 8 (4)                  |

| Fracture site                     | Number of patients (%) |
|----------------------------------|------------------------|
| Floor                             | 176 (88)               |
| Floor and medial wall            | 14 (7)                 |
| Medial wall                       | 10 (5)                 |

| Fracture type                   | Number of patients (%) |
|---------------------------------|------------------------|
| With bone defect                | 155 (75.5)             |
| Linear                          | 49 (24.5)              |

| Type of treatment               | Number of patients (%) |
|---------------------------------|------------------------|
| Conservative                    | 22 (11)                |
| Surgical                        | 178 (89)               |
| Reconstruction with bone graft  | 132 (74.2)             |
| Tissue release                  | 46 (25.8)              |

| Complications                   | Number of patients (%) |
|---------------------------------|------------------------|
| Suppuration                     | 2 (1)                  |
| Hematoma                        | 2 (1)                  |
| Dura mater exposure             | 1 (0.5)                |

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**Table 2 Association of fracture site with enophthalmos before and after surgical treatment**

| Preoperative enophthalmos | Orbital floor (n = 176) | Medial wall or floor and medial wall (n = 24) | P value |
|---------------------------|-------------------------|---------------------------------------------|--------|
| 0-1 mm                    | 109 (61.93%)            | 24 (100.00%)                                | <0.001 |
| 2-5 mm                    | 67 (38.07%)             | 0 (0.00%)                                   |        |

**Table 3 Association of enophthalmos severity with surgical outcome in 178 patients with orbital blow-out fracture**

| Surgical outcome | 0 mm enophthalmos (n = 53) | 1 mm enophthalmos (n = 58) | 2-5 mm enophthalmos (n = 67) | P value |
|------------------|-----------------------------|-----------------------------|------------------------------|--------|
| Complete recovery| 32 (60.38%)                 | 28 (48.28%)                 | 34 (50.75%)                  | 0.38   |
| Improvement      | 12 (22.64%)                 | 24 (41.38%)                 | 23 (34.33%)                 |        |
| No improvement   | 9 (16.98%)                  | 6 (10.34%)                  | 10 (14.92%)                 |        |

**Fig. 1** The Krysztofow classification of diplopia. The dark region indicates the area of double vision.
treatment with change in enophthalmos after surgical treatment was also assessed. The time from injury to surgery ranged from days to months because of differences in the time of referral to the Department, as shown in Table 4. In the evaluated patients, treatment outcomes were not associated with the time to surgical intervention. In addition, patient age was not associated with change in enophthalmos, as shown in Table 5.

Conservative treatment was selected for 22 patients (11%), and 178 patients (89%) underwent surgical treatment. Transconjunctival orbital floor revision with removal of herniated tissues was performed in 46 patients, and 132 patients underwent revision, tissue release, and reconstruction of the defect by autogenous bone transplantation. All treatment methods are described in Table 1. The association of type of surgery with treatment outcome is illustrated in Fig. 2. The outcome did not differ in relation to whether release of herniated tissues or reconstruction of the orbital defect was selected. The most common donor site for the autogenous bone graft was the anterior wall of the maxillary sinus and iliac crest (42/132 patients). The method of orbital reconstruction was not associated with change in enophthalmos (Fig. 3). Complications developed in 5 of 200 patients, as shown in Table 1.

**Discussion**

The main cause of injury in this study was an accidental blow to the orbit; the second most common cause was sports injury. Among patients older than 13 years, assault was a frequent cause, and 94% of assault victims were boys. These results are consistent with those of previous studies [23-25].

The proportions of the facial and cerebral skull differ between adults and children, and some studies [26] reported that the most common site of orbital fracture in children is the orbital roof and lateral wall. Bansagi and Meyer [16] found that children younger than 7 years have thicker paranasal sinus walls, a more abundant Bichat fat pad, and a flatter and smaller midface than adults. Thus, fracture of the orbital floor is rare in younger children. It is important to note that fractures of the orbital roof, which most often affect children younger than 4 years, who lack fully developed paranasal sinuses, can lead to transfer of the injury directly to the orbital roof. The youngest child in the present study was 4 years of age. The present study was 4 years of age. The youngest child in the present study was 4 years of age. The present study was 4 years of age. The youngest child in the present study was 4 years of age.

**Table 4** Association of time from injury to surgical treatment with treatment outcome

| Change in enophthalmos, before/after treatment | Time from injury to surgical treatment |
|-----------------------------------------------|----------------------------------------|
| 0-14 days (n = 32)                            | 15-30 days (n = 70)                     |
| 1-3 months (n = 58)                           | 4-6 months (n = 11)                     |
| >6 months (n = 7)                             |                                        |
| 2-5 mm/0-1 mm                                | 11 (34.37%)                            |
| 2.5 mm/2-5 mm                                | 3 (9.38%)                              |
| 0-1 mm/0-1 mm                                | 18 (56.23%)                            |

**Table 5** Association of patient age with enophthalmos severity before and after surgical treatment

| Age, years | Preoperative enophthalmos | Postoperative enophthalmos |
|------------|---------------------------|----------------------------|
| <9 (n = 54) | 35 (70.37%)               | 44 (93.62%)                |
| 10-12 (n = 49) | 32 (65.31%)               | 40 (90.91%)                |
| 13-15 (n = 56) | 35 (62.50%)               | 44 (93.62%)                |
| >15 (n = 41) | 27 (65.85%)               | 39 (97.50%)                |

**Fig. 2** Treatment outcome in relation to type of surgery

**Fig. 3** Enophthalmos severity, before and after treatment, in relation to surgical procedure
that surgical treatment should be performed as soon as possible, principally because trapdoor fracture leads to muscle ischemia and, thus, irreversible change to eye position and movement. According to Wei and Durairaj [17], 83% of studies reported that treatment outcomes were better for patients who underwent surgical treatment shortly after injury than for those who had surgery later. Although earlier surgical treatment is usually preferred, some studies found that surgery was possible only after soft tissue swelling resolved and that diplopia stabilized several days after injury [33,34]. In the present study, 32 children were treated surgically at up to 14 days after injury, 70 were treated within 15-30 days after injury, and 76 were treated more than 1 month after injury. Although outcomes were slightly better for earlier surgery, the difference was not significant.

Cobb et al. [5] found that bone elasticity in children was a factor in trap door fractures. Baek et al. [1] and Wei and Durairaj [17] reported that this is the most common type of orbital fracture in children and accounts for 27% to 93% of all pediatric orbital fractures. White-eyed blowout fracture is a unique pediatric orbital fracture in which ocular hematoma, subconjunctival ecchymosis, and enophthalmos are absent; [5] however, a reduction in eyeball mobility, especially during upgaze, and general symptoms such as nausea, vomiting, and bradycardia caused by the eye-heart reflex (the Aschner-Dagnini reflex) may occur. Radiological findings for white-eyed fracture may be limited [9] and include fissure of the fracture or a trap door fracture, ie, the typical “green stick” fracture. Diagnostic imaging is essential after injury because, in the absence of CT scans, general symptoms such as vomiting and bradycardia could suggest central nervous system damage [7]. In the present patients, these observations were not confirmed, but typical blowout fracture with orbital tissues herniation was most common. Nausea and vomiting were present in 72 patients, but no bradycardia or other symptoms that would suggest a need for immediate surgical intervention were observed.

Fracture of the orbital floor was associated with worse enophthalmos, and the severity of post-traumatic enophthalmos in children did not significantly affect surgical outcomes. Transconjunctival access is preferred for pediatric orbital fractures. In addition, autogenous bone grafting is a safe, effective method of reconstructing orbital floor defects in children [35-37].

Conflict of interest
The authors declare no conflict of interest.

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