Correlation of Types of Orbital Fracture and Occurrence of Enophthalmos

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Abstract: We sought to investigate the correlation between type of orbital fracture and occurrence of traumatic enophthalmos. The 119 patients with orbital fractures were divided into the enophthalmos group (71 cases) and the nonenophthalmos group (48 cases). The 2 groups were compared by location and type of orbital fracture based on observation of computed tomography scans. We found the incidence of medial wall fractures significantly higher in the enophthalmos group (76.06%) than in the nonenophthalmos group (22.92%, $\chi^2 = 32.63$, $P < 0.05$). The incidence of combined medial-inferior wall fractures was also significantly higher in the enophthalmos group (52.93%) than in the nonenophthalmos group (12.5%, $\chi^2 = 23.21$, $P < 0.05$). However, the incidence of lateral-inferior wall fractures was significantly lower in the enophthalmos group (36.62%) than in the other group (58.33%, $\chi^2 = 4.11$, $P < 0.05$). In most cases of lateral-inferior orbital wall fracture in the enophthalmos group, the zygomatic complex was displaced toward the lateral-posterior direction. The combined medial-inferior wall fracture is likely the primary type of multiple wall fracture leading to traumatic enophthalmos. Enophthalmos caused by a combined lateral-inferior fracture may be correlated with lateral-posterior displacement of the zygomatic complex.

Key Words: Orbital fracture, enophthalmos, correlation

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Two major complications of orbital fractures are enophthalmos, or posterior displacement of the eyeball, and diplopia, with enophthalmos representing both a significant cosmetic deformity and a challenge for surgeons. In the 4 walls of the orbit, the medial wall and the inferior wall are the most common fracture sites and may be responsible for most occurrences of enophthalmos.[1–3] We here conducted a retrospective review of 119 cases of unilateral impure orbital fracture to evaluate the clinical relationship between site and type of orbital fracture and occurrence of enophthalmos.

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METHODS

We retrospectively reviewed the cases of 119 patients referred to Peking University School of Stomatology Oral and Maxillofacial Wound Center from 2003 to 2010, all of whom sustained unilateral impure orbital fractures. They were dichotomized into those with significant enophthalmos (>2-mm difference in the eminence of the eyeballs, enophthalmos group) and those without enophthalmos (nonenophthalmos group) measured by Hertel exophthalmometry. The study design was approved by the hospital's institutional review board, and all patients provided written informed consent to participate.

The enophthalmos group included 71 cases with a male-to-female ratio of 1.84:1. Patients ranged in age from 16 to 59 years (mean, 32.2 years). The nonenophthalmos group included 48 cases with a male-to-female ratio of 2.43:1. The age in this group of patients ranged from 7 to 53 years (mean, 30.5 years). Table 1 shows the cause of injury for all patients. In both groups, motor vehicle accident (MVA) was the main cause of injury (Table 1).

Spiral computed tomographic (CT) of the patients were obtained before the operation. Computed tomographic images of the patients were analyzed, and the fracture sites recorded (Table 2). As shown in Figure 1, the recorded fracture sites were termed F (frontal, orbital roof), N (nasal, the orbital medial wall), M (maxillary, the orbital inferior wall), and Z (zygomatic, the orbital lateral wall) (Table 3).[4] Statistic analysis was done to compare the differences in fracture site and combined fracture type. All statistical analyses were conducted using SPSS version 12.0 (SPSS Inc, Chicago, IL).

RESULTS

Orbit Wall Fracture Sites

In the 71 cases in the enophthalmos group, 156 orbital wall fractures were recorded, with an average of 2.2 orbital wall fractures per case. Of these, 78.87% (56/71 cases) had orbital inferior wall (M) fractures, followed by 76.06% (54/71 cases) with medial wall fractures (N), 53.52% (38/71 cases) with lateral wall fractures (Z), and 11.27% (8/71 cases) with superior wall fractures (F).

The 48 cases in the nonenophthalmos group had 84 orbital wall factures, an average of 1.8 orbital wall fractures per case. In this group, 81.25% (39/48 cases) had orbital inferior wall (M) fractures, 68.75% (33/48 cases) had lateral wall fractures, 22.92% (11/48 cases) had medial wall fractures, and 2.08% (1/48 cases) sustained superior wall fractures.

The χ^2 test showed no significance difference in the incidence of fractured orbital inferior wall between the 2 groups ($\chi^2 = 0.1$, $P = 0.751$). However, the enophthalmos group had a significantly

TABLE 1. Causes of Fractures

Cause	Enophthalmos Group, %	Nonenophthalmos Group, %
MVA	54 (76.06)	36 (75)
Assault	4 (5.63)	3 (6.25)
Industrial accident	8 (11.27)	2 (4.17)
Fall	2 (2.82)	4 (8.33)
Explosive injury	2 (2.82)	0
Gunshot	1 (1.41)	0
Sport	0	3 (6.25)

higher incidence of posterior orbital medial wall fracture than the nonenophthalmos group ($\chi^2 = 32.63$, $P < 0.05$, odds ratio = 10.68).

Combined Fracture Types

The medial-inferior orbital fracture and the lateral-inferior orbital fracture were the 2 main types of combined fractures sustained.

In the enophthalmos group, 40 cases (52.93%) had combined medial-inferior orbital fractures (including the 3 types of M + N, M + N + Z, and M + N + Z + F), and 28 cases (36.62%) had combined lateral-inferior orbital fractures (including the 4 types of M + Z, M + N + Z, M + Z + F, and M + N + Z + F). In the nonenophthalmos group, the incidence of medial-inferior orbital fractures and that of lateral-inferior orbital fractures were 12.5% (6/48 cases) and 58.33% (28/48 cases), respectively. The χ^2 test showed a significantly greater incidence of combined medial-inferior orbital fractures in the enophthalmos group than in the other group ($\chi^2 = 23.21$, $P < 0.05$, odds ratio = 9.03). The incidence of combined lateral-inferior orbital fractures was significantly greater in the nonenophthalmos group than in the enophthalmos group ($\chi^2 = 4.11$, $P < 0.05$).

Clinically, the combined medial-inferior orbital fracture was usually caused by injury to the naso-orbital-ethmoid (NOE) area in the center of the midface; the combined lateral-inferior fracture was usually caused by injury to the zygomaxillary complex (ZMC), lateral to the midface. Thus, it is necessary to analyze both.

Combined Medial-Inferior Orbital Fractures

Burm and colleagues[2] described the superior medial wall of the maxillary sinus as the bony buttress that supports these orbital walls. The combined medial-inferior orbital fractures were classified by whether the bony buttress collapsed.

In the 40 cases in the enophthalmos group with combined medial-inferior orbital fractures, 21 did not have posterior collapse of the bony buttress. The bony buttress formed the boundary of the simultaneous collapse of the orbital medial wall and the orbital inferior wall. In these cases, most of the orbital medial walls presented as punched-out fractures, and the orbit inferior walls mostly pre-

TABLE 2. Walls of Fractures

Wall	Enophthalmos Group	Nonenophthalmos Group	Total
M	56	39	95
N	54	11	65
Z	38	33	71
F	8	1	9
Total	156	84	240

M indicates fracture of the orbital floor (maxillary); N, fracture of the orbital medial wall (nasal-ethmoid); Z, fracture of the zygomatic wall (lateral wall); F, fracture of the orbital roof (frontal)

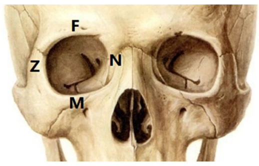

FIGURE 1. Sites of orbital fracture. F indicates fracture of the orbital roof (frontal); N, fracture of the orbital medial wall (nasal-ethmoid); M, fracture of the orbital floor (maxillary); Z, fracture of the zygomatic wall (lateral wall).

sented as trapdoor fractures in which the bony buttress acted as the axis (Fig. 2). In the 19 cases in which the bony buttress collapsed, the medial-inferior walls both presented as punched-out fractures, with the junction zone of the medial-inferior walls mostly moving downward. As a result, the orbital contents were accordingly displaced (Fig. 3).

In 6 cases who had combined medial-inferior orbital fracture in the nonenophthalmos group, 4 cases did not have collapse of the bony buttress. In the other 2 cases, the bony buttresses collapsed, but the medial-inferior walls showed no distinct displacement.

Combined Lateral-Inferior Fractures

Among the 28 cases of combined lateral-inferior fracture in the enophthalmos group, the medial or frontal walls were also found to be fractured in 21 cases. The ZMCs of 27 cases were displaced toward to the lateral-posterior direction. The other case showed a comminuted fracture of the zygomatic bone and injury to the outer inferior wall.

Among 28 cases of combined medial-lateral fracture in the nonenophthalmos group, the ZMCs of 13 cases were displaced inward; 8 cases had no distinct displacement; 7 cases were displaced toward the lateral-inferior direction. Injuries to the inferior walls were mostly at the lateral part of these areas.

DISCUSSION

Enophthalmos is mainly caused by trauma resulting in orbital fracture. Enophthalmos may have functional consequences such as diplopia and eyelid retraction. For most cases, the concern is aesthetic. Usually, 2 mm of relative enophthalmos is considered cosmetically significant. The reports by Migliori and Gladstone[5] and Koo et al[4] have shown that a difference of less than 2 mm of the projection of 2 eyeballs would not lead to obvious vision malformation. Most studies also consider an enophthalmos of greater than 2 mm as the indication for surgical treatment.

TABLE 3. Types of Fractures

Type	Enophthalmos Group	Nonenophthalmos Group	Total
M	5	8	13
N	4	4	8
Z	1	3	4
M + Z	7	25	32
N + Z	7	1	8
M + N	21	3	24
M + F	2	0	2
N + F	1	0	1
F + Z	0	1	1
M + N + Z	17	3	20
N + Z + F	2	0	2
M + Z + F	2	0	2
M + N + Z + F	2	0	2
Total	71	48	119

FIGURE 2. Combined medial-inferior wall fracture without collapse of the bony buttress. The arrow indicates no injury to the bony buttress on the right side of the face.

High-energy trauma may cause complex orbital fractures, which may lead to enophthalmos. Seider et al[6] classified these into localized orbital trauma (LOT) and multiple trauma (MT). Group comparison showed that MT was caused mostly by MVA and LOT mostly by high falls. The MT group had a significantly higher incidence of multiple wall fractures than the LOT group. Meanwhile, secondary enophthalmos occurred more frequently in the MT group than in the LOT group. A report by Tong et al[7] found that impure orbital fractures were mostly caused by high-energy trauma and pure orbital fractures mostly caused by low-energy trauma. Nolasco and Mathog[1] also found that orbital fractures caused by MVAs were usually more severe than those from other causes, such as violence and sports. In this study, the main cause of injury in both groups of cases was MVA. As a result, the average numbers of orbital walls injured per patient were 2.2 in the enophthalmos group and 1.75 in the nonenophthalmos group.

The orbit is located in the midface and surrounded by complex maxillofacial structures, so that orbital fractures are often accompanied by fractures to the neighboring maxillofacial features. As a result, orbital fractures are difficult to classify clearly. Several classifications have been proposed, but they often focus on one specific part of the midface and do not analyze the dynamic features of these interrelated, but independent, anatomic units. Carinci and colleagues[8] introduced a classification involving the following 4 aspects: (1) fracture site (F, frontal; N, nasal; M, maxillary; and Z, zygomatic); (2) fragment movement (in, out); (3) ocular movement impairment (yes, no); and (4) eyeball position (exophthalmos, enophthalmos). This classification considers the orbit as an independent unit and includes both fracture site and clinical symptoms. The recording method is also easy to remember and apply. Thus, we here used this classification to record fracture site and type, facilitating analysis.

Naso-orbital-ethmoid and ZMC fractures are the 2 most common types of fractures with orbital involvement. The medial-inferior walls are usually affected in NOE fractures. The lamina papyracea of the medial wall and the superior wall of the infraorbital canal have been shown to be extremely thin (<0.5 mm).[9] Their thinness and lack of support make the medial-inferior walls the most frequently fractured. The orbital bony defects generated cause orbital volume expansion with herniation of the orbital tissue into the maxillary sinus and/or ethmoid air cells adjacent to these walls, leading to enophthalmos.[10–14] Unlike in NOE fractures, the lateral and inferior walls are mostly affected in ZMC fractures. The lateral wall, which has a thickness of 1.25 ± 0.14 mm,[9] separates the orbit from the temporalis muscle laterally and is less likely than other walls to break and herniate the orbital tissue when fractured. Thus, medial-inferior wall fractures caused by NOE fractures are more liable to lead to enophthalmos than lateral and inferior wall fractures caused by ZMC fractures.

In this study, the inferior and medial walls were the 2 most common fracture sites in the enophthalmos group. The combined medial-inferior wall fracture was the most common type of multiple wall fracture. Comparison of fracture sites and types in the 2 groups indicated a close relationship between the incidence of combined medial-inferior fracture and the occurrence of posttraumatic enophthalmos. Such results are similar to those found in other studies. Jank and colleagues[3] analyzed complications in patients who had orbital fractures with and without medial wall involvement. They found that orbital fractures with involvement of the medial wall showed a significantly higher incidence of diplopia and exophthalmos than those without involvement of the medial wall. The incidence of enophthalmos is also higher in the former group, but there was no statistical significance. The combined medial-inferior fracture was the most common multiple wall fracture type in their study. Nolasco and Mathog[1] classified medial orbital wall fractures into 4 types depending on location and severity of injury. They found a higher incidence of enophthalmos in type II orbital fractures (combined medial-inferior fractures) than in type I fractures (pure medial wall fractures). Burm and colleagues[2] analyzed 76 cases with orbital blow-out fractures. Most had pure medial wall fractures, followed by combined medial-inferior fractures. Of those with pure medial wall fractures, 40% presented with enophthalmos; 69% of those with combined medial-inferior fractures presented with enophthalmos. Based on the observation of coronal CT, they divided the combined medial-inferior wall fractures into whether they had collapse of the bony buttress. They found injuries were more complex and severe in those with collapse of the bony buttress.

We also observed this phenomenon. Among cases with combined medial-inferior fractures, the orbital medial wall mostly presented as a punched-out fracture. The inferior walls presented various forms according to whether the bony buttress collapsed. In cases without collapse of the bony buttress, the orbital inferior walls usually presented a trapdoor fracture attached to the buttress. However, in cases with combined medial-inferior fracture and collapse of the bony buttress, the orbital medial-inferior walls mostly presented as a punched-out fracture. It is still unclear if collapse of the bony buttress increases the incidence of enophthalmos, but the bony buttress may provide a support point and landmark to aid orbit reconstruction and facial surgery.

The combined lateral-inferior fracture, mostly caused by ZMC fracture, was the other common multiple wall fracture type in our study. In these cases, the incidence of enophthalmos was low. The retrospective study by Carinci and colleagues[8] showed that zygomatic fractures were the main type of periorbital fracture, but only a few such cases had enophthalmos. In our study, the incidence of combined medial and lateral wall fractures in the nonenophthalmos group was higher than that in the enophthalmos group. We found that, in those with combined lateral-inferior wall fractures in the enophthalmos group, the zygomatic bones all moved in the lateral and posterior directions. In these cases, most of the fractures involved more than half of the orbital inferior walls. The displacement of the zygomatic bones in the nonenophthalmos group was not irregular, and the fractures involved only lateral portions of the inferior orbital walls. In terms of the mechanism of enophthalmos

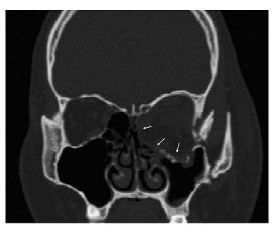

FIGURE 3. Combined medial-inferior wall fracture with collapse of the bony buttress. The arrows show the punched-out fracture presentation of the medial and inferior walls of the left side of the face.

caused by zygomatic fractures, Manson et al[15] and Clauser et al[16] observed that outward displacement of the zygomatic bone and bone loss near the greater wing of the sphenoid bone would lead to a defect near the inferior orbital fissure, potentially causing orbital volume expansion and leading to enophthalmos. Pearl[17] found that the orbital lateral edge was normally equal to the eyeball equator in the anterior-posterior direction. Posterior displacement of the zygomatic bone would therefore force the eyeball posteriorly.

In our study, the combined lateral-inferior fracture was not the main fracture type causing enophthalmos. Enophthalmos in this type of orbital fracture may have been caused by 2 factors: orbital volume expansion causing the orbit wall defect and posterior traction on the orbit support system caused by zygomatic bone displacement.

In conclusion, we found the combined medial-inferior wall fracture the main type of multiple wall fracture leading to traumatic enophthalmos. The combined lateral-inferior wall fracture caused by fracture of the zygomatic complex was not the main type of orbital multiple wall fracture causing enophthalmos. Enophthalmos caused by such fractures may be correlated with lateral-posterior displacement of the zygomatic complex.

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