Role of Medial Orbital Wall Morphologic Properties in Orbital Blow-out Fractures

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PURPOSE. This study compares medial orbital wall supporting structures in patients with isolated inferior and medial wall fractures.

METHODS. The morphologic properties in all consecutive patients with periocular trauma who underwent orbital computed tomography (CT) scans from January 2004 to March 2006 were reviewed. On CT scans, the size of the fracture, the number of ethmoid air cell septa, and the length and height of the lamina papyracea were measured.

RESULTS. In 118 patients without orbital wall fracture, there were no bilateral differences in the measured structures. We took measurements from the opposite site in patients with fractures in whom it was difficult to visualize the structures at the fractured site. Seventy patients with medial wall fractures and 37 with inferior wall fractures showed no differences in sex, side of impact, etiology of the trauma, association with intraocular injuries, fracture size, anterior and posterior height, anteroposterior length, or the area of the lamina papyracea. In contrast, the number of ethmoid air cell septa was significantly lower (3.09 ± 0.86 vs. 3.62 ± 0.79, $P = 0.002$) and the lamina papyracea area supported per ethmoid air cell septum was significantly higher (137.55 ± 40.11 mm^2 vs. 119.64 ± 38.14 mm^2, $P = 0.028$) in patients with medial wall fractures than in those with inferior wall fractures.

CONCLUSIONS. Patients with fewer ethmoid air cell septa and a larger lamina papyracea area per septum are more likely to develop medial wall fractures than inferior wall fractures. (*Invest Ophthalmol Vis Sci.* 2009;50:495–499) DOI:10.1167/iovs.08-2204

The type of fracture that occurs in the orbital region depends not only on the magnitude, direction, and point of impact forces involved, but also on the supporting structures of the orbital walls. "Blow-out" fractures of the orbit occur frequently in the inferior and medial orbital walls, the two thinnest areas of the bony orbit.[1]

Assessments of the relationship between the structure of the orbital walls and the orbital wall fractures[2–7] have indicated that the rigidity of these walls is proportionally dependent on the anatomic structures that support them. Although the bony septa of the ethmoid sinus air cells are thought to be the main supports of the medial orbital wall, this hypothesis has not been confirmed clinically. We therefore compared supporting structures of the medial wall in patients with isolated medial and inferior wall fractures. Our findings may help determine the role of the morphologic properties of the orbital wall in the pattern of blow-out fractures.

MATERIALS AND METHODS

Participants

The medical records of all consecutive patients with ocular trauma at the Severance Hospital (Seoul, Korea) from January 2004 through March 2006 who underwent orbital computed tomography (CT) scans were retrospectively reviewed. Patients were divided into three groups: those without orbital wall fractures, those with isolated inferior wall fractures, and those with isolated medial wall fractures. All subjects were treated in accordance with the Declaration of Helsinki.

The bony strut was used to discriminate between inferior and medial wall fractures. To sort out isolated inferior and medial wall fractured patients, we excluded patients in whom any of the three CT reviewers suspected a combined inferior and medial wall fracture. Patients with concomitant facial bone (i.e., the maxilla, mandible, and nasal bones) fractures, combined inferior and medial wall fractures, and lateral or superior orbital wall fractures were excluded because the power and direction of the trauma vector in these patients may have differed. Patients with bilateral orbital wall fractures, and those with intranasal pathologic conditions such as nasal polyps, which could obscure proper CT reading, were excluded. Patients with a history of previous orbitofacial surgery, trauma, or chronic sinusitis were also excluded because the orbitofacial anatomy can change due to these conditions. Since the ethmoid air cells do not attain adult size until puberty, we excluded patients under 16 years old.[8]

CT scan (SOMATOM Sensation 16; Siemens Medical Solutions, Erlangen, Germany) results with 3-mm axial and 3-mm coronal section thickness were stored digitally. All measurements were performed using workstation software (GE Centricity, version 2.0; GE Healthcare, Milwaukee WI). In patients without fractures, the number of ethmoid air cell septa and the length and height of the lamina papyracea were measured on both sides of the orbital wall. In patients with fractures, we measured these parameters on the opposite orbital wall. To minimize bias, all measurements were taken by two ophthalmologists and a radiologist and the mean values of the three data sets were used.

Measurement of the Lamina Papyracea Area

CT scans in the bone window setting (center, 570; width, 3077) were used. Using the coronal view, the anterior height of the lamina papyracea was determined in the CT slice with the crista galli behind the lacrimal bone, and the posterior height was determined at the pterygopalatine fossa just anterior to the sphenoid. The anteroposterior length was estimated in the axial slice transecting the optic foramen starting from the posterior lacrimal crest to the sphenoid (Fig. 1). The area of the lamina papyracea was calculated as the area of a trape-

FIGURE 1. Measurement of the area of the lamina papyracea. *Top left*: the anterior height of the lamina papyracea was measured in the coronal CT slice containing the crista galli behind the lacrimal bone. *Top right*: the posterior height was measured at the coronal slice just anterior to the sphenoid sinus showing the pterygopalatine fossa. *Bottom*: the anteroposterior length was measured in the axial slice transecting the optic foramen, starting from the posterior lacrimal crest to the starting point of the sphenoid bone (*arrow*). Area of the lamina papyracea = (anterior height + posterior height) × anteroposterior length/2.

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Number of Ethmoid Air Cell Septa

The number of ethmoid air cell septa was counted in the axial CT slice transecting the optic foramen. Each linear septum from the medial orbital wall to the nasal septum was counted as a single septum. In multiple crossing shapes, each full length septum from the nasal septum to the medial wall was counted as a single septum. Bleb-shaped septa and those of partial length were not counted (Fig. 2).

Statistical Analysis

Independent *t*-tests were used to compare the morphologic characteristics of the right and left medial orbital wall of patients without fractures and the morphologic characteristics of patients with medial and inferior orbital wall fractures. Pearson χ^2 tests were used to compare the sex, side of trauma, etiology of injury, and association with intraocular injury in patients with medial and inferior orbital wall fractures. Logistic regression analysis was performed on the factors that differed significantly in the two fracture groups. All statistical analyses were performed using analysis software (SPSS, version 12.0.1; SPSS Inc., Chicago, IL). The level of statistical significance was set at $P < 0.05$.

RESULTS

Symmetry of the Bilateral Supporting Structures in Patients without Fractures

A total of 118 patients without fractures were examined, comprising 76 males and 42 females (mean age, 34.5 years; range, 17-73 years; Table 1). There were no differences in the anterior ($P = 0.991$) and posterior ($P = 0.184$) heights of the lamina papyracea, the anteroposterior length ($P = 0.992$), the lamina papyracea area ($P = 0.556$), the number of ethmoid air
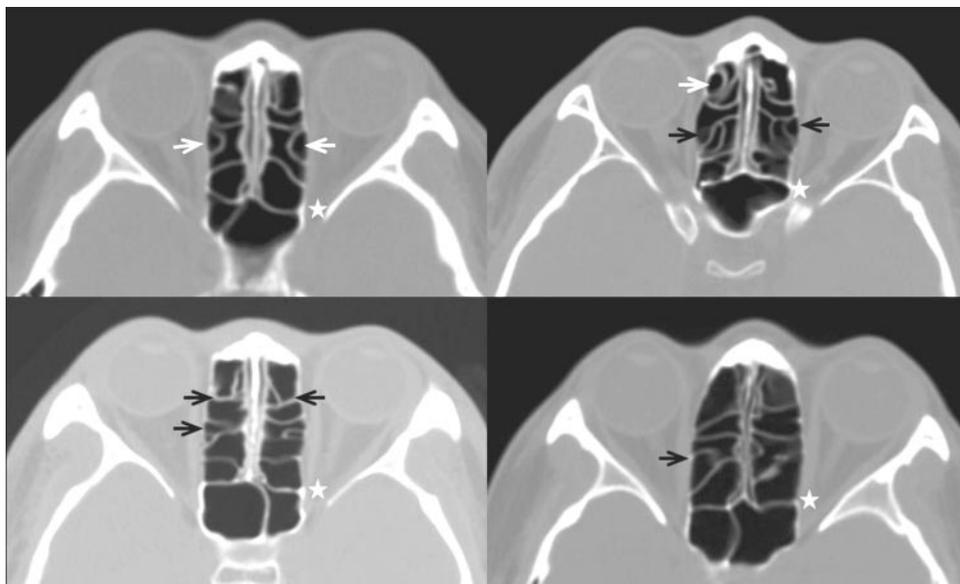
FIGURE 2. Number of the ethmoid air cell septa. In branching shapes (*black arrows*), only the septa with full linear structural support from the nasal septum to the lamina papyracea were counted as one septum. A septum with a bleb-like shape (*white arrows*) was not counted. *Stars* indicate the anterior wall of the sphenoid sinus. *Top left*: this patient therefore showed three septa in each orbit. *Top right*: multiple branching septa in the bilateral orbit: this patient had three septa in each orbit. *Bottom left*: this patient showed three septa in the right orbit and four in the left. *Bottom right*: this patient showed three septa in each orbit.

TABLE 1. Demographic Features

Factor	No Fracture (*n* = 118)	Inferior Wall Fracture (*n* = 37)	Medial Wall Fracture (*n* = 70)	*P*
Sex				
Male	76 (64.4%)	27 (73%)	46 (65.7%)	0.443*
Female	42 (35.6%)	10 (27%)	24 (34.3%)	
Age (year, mean ± SD)	34.50 ± 15.26	30.78 ± 17.57	37.67 ± 16.06	0.044†
Etiology of trauma				
Blunt blow‡	60 (50.8%)	21 (56.8%)	46 (65.7%)	0.756*
Fall	34 (28.8%)	11 (29.7%)	15 (21.4%)	
Automobile accident	6 (5.1%)	3 (8.1%)	4 (5.7%)	
Sharp object	14 (11.9%)	1 (2.7%)	4 (5.7%)	
Unknown	4 (3.4%)	1 (2.7%)	1 (1.4%)	
Concomitant intraocular injury§	Not assessed	10 (27%)	17 (24.3%)	0.756*
Laterality				
Right	39 (33.1%)	16 (43.2%)	31 (44.3%)	0.568*
Left	67 (56.8%)	21 (56.8%)	37 (52.8%)	
Bilateral	12 (10.1%)	0 (0%)	2 (2.9%)	

* Pearson Chi square tests between the isolated inferior and medial orbital wall fracture groups.
† Independent *t*-test between the isolated inferior and medial orbital wall fracture groups.
‡ Including fists, feet, and/or other blunt objects.
§ Including traumatic hyphema, commotio retina, retinal or vitreous hemorrhage, retinal detachment, retinal tear, and eyeball perforation.

cell septa (*P* = 0.936), or the lamina papyracea area/number of ethmoid air cell septa (*P* = 0.823) when comparing the right and left medial orbital wall (Table 2). We found that in each patient, the structures supporting the bilateral medial walls were symmetrical.

Morphologic Differences in the Supporting Structures between Patients with Medial and Inferior Wall Fractures

There were 37 patients with isolated inferior wall fractures and 70 with isolated medial wall fractures. The two groups showed no differences in sex, side of impact, etiology of the trauma, or association with vision-threatening intraocular injuries such as traumatic hyphema, commotio retina, retinal or vitreous hemorrhage, retinal detachment, retinal tear, or eyeball perforation (Table 1). Fracture size (*P* = 0.797), anterior (*P* = 0.225) or posterior (*P* = 0.081) height, anteroposterior length (*P* = 0.195), or lamina papyracea area (*P* = 0.279) did not differ between the two groups (Table 3). In contrast, the number of ethmoid septa was significantly higher in patients with inferior wall fractures than in those with medial wall fractures (3.62 ± 0.79 vs. 3.09 ± 0.86, *P* = 0.002; Table 3). In addition, the lamina papyracea area supported per septum was larger in patients with medial wall fractures than in those with inferior wall fractures (137.55 ± 40.11 mm² vs. 119.64 ± 38.14 mm², *P* = 0.028; Table 3).

Logistic regression analysis of the factors that differed in the two fracture groups showed that the number of ethmoid air

cell septa was the only significant independent factor in determining where a fracture was likely to occur (*P* = 0.022; odds ratio, 0.344). Age (*P* = 0.053) and area of lamina papyracea supported per septum (*P* = 0.369) were not significant.

DISCUSSION

Blow-out orbital wall fractures occur at the weakest points of the orbital wall–the lamina papyracea and the inferior wall medial to the infraorbital groove–as these are thinner than other areas of the orbital wall.[1,9] Although the lamina papyracea is only 0.2 to 0.4 mm thick, most pure orbital blow-out fractures involve the orbital floor.[1,10-12] Recently, however, the incidence of pure medial orbital blow-out fractures has increased.[13-15]

On the CT scan review, we found that the incidence of isolated medial orbital wall fractures was twice that of inferior wall fractures (70 vs. 37 patients). Similar findings have been reported in other studies from Korea,[13] where medial wall fractures (28%) were more frequent than inferior wall fractures (16.8%) in an 8-year consecutive study. Accordingly, Park et al.[15] reported that medial wall fractures were found in 37.8% of patients, whereas an inferior wall fracture was found only in 11.6%. Burm et al.[16] reported the ratio of medial fractures to inferior fractures to be 1.8:1. However, these high incidences of medial wall fractures were not supported in other studies. In a 10-year study in a single hospital in the United States involving mainly non-Hispanics, Hispanic Caucasians, and African

TABLE 2. Measurements of the Medial Orbital Wall Supporting Structures in Patients without Fractures

	Right (mean ± SD)	Left (mean ± SD)	*P**
Anterior height (mm)	15.32 ± 2.25	15.32 ± 2.33	0.991
Posterior height (mm)	10.77 ± 1.54	11.04 ± 1.55	0.184
Anteroposterior length (mm)	30.50 ± 3.14	30.50 ± 3.16	0.992
Area of lamina papyracea (mm²)	396.08 ± 52.60	400.21 ± 54.76	0.556
Number of ethmoid air cell septa	3.25 ± 0.85	3.25 ± 0.77	0.936
Lamina papyracea area/ethmoid air cell septa	131.94 ± 50.78	130.64 ± 37.83	0.823

* Independent *t*-test.

TABLE 3. Measurements of the Medial Orbital Wall Supporting Structures in Patients with Fractures

	Inferior Orbital Wall Fracture* (*n* = 37)	Medial Orbital Wall Fracture* (*n* = 70)	P†
Fracture size (mm)	15.027 ± 8.011	15.417 ± 6.230	0.797
Anterior height (mm)	15.097 ± 1.970	15.581 ± 1.945	0.225
Posterior height (mm)	10.884 ± 2.003	10.141 ± 2.108	0.081
Anteroposterior length (mm)	31.511 ± 2.174	30.846 ± 2.665	0.195
Area of lamina papyracea (mm²)	409.485 ± 61.569	396.440 ± 57.645	0.279
Ethmoid air cell septa	3.622 ± 0.794	3.086 ± 0.864	0.002
Area of lamina papyracea/ethmoid air cell septa	119.635 ± 38.144	137.550 ± 40.107	0.028

* Mean ± standard deviation.
† Independent *t*-test.

Americans, He et al.[17] reported that inferior wall fractures were the most common. Gittinger et al.[18] noted that African Americans were more prone to medial orbital blow-out fractures. They hypothesized that anatomic racial differences may underlie these discrepancies. Racial variations in the shape of the orbit or the partition of the ethmoid sinus may therefore underlie the predominance of isolated medial orbital wall fractures in Asian populations.[19]

Recent experimental studies suggest that both buckling and hydraulic mechanisms may contribute to blow-out fractures, with neither being the primary cause.[6,20] We therefore sought to determine the relationship between the innate anatomic properties and the fracture site. We compared the supporting structures of the weakest portion of the medial orbital wall in patients with isolated inferior and medial wall fractures. The lamina papyracea is supported by the bony septa of the ethmoid sinus air cells, which are shaped like a honeycomb.[1,21,22] Due to hemorrhage and edema, however, it was impossible to precisely visualize the supporting structures in the patients with orbital blow-out fractures. We therefore measured the opposite, non-fractured orbital walls in these patients. Since the ethmoid sinus has large anatomic variations, we had to show that these structures, which support the medial wall, are bilaterally symmetric. We observed significant bilateral symmetry in the number of ethmoid air cell septa and in the lamina papyracea structures in patients without orbital wall fractures. When we compared the supporting structures of the medial walls from the opposite orbit of patients with fractures, we found that patients with medial wall fractures had fewer ethmoid septa and a larger area supported per septum than patients with inferior wall fractures. This finding correlated with previous experimental results showing that the medial orbital wall was stronger if the area was smaller and the number of ethmoid cells was increased, or if the average size of ethmoid cells (surface area/number of cells) was small.[7]

Thinner CT slices may have provided more detailed information regarding the size and extent of the fracture, and the length and height of the lamina papyracea. Nevertheless, the length and height of the lamina papyracea was measured without difficulty with the 3 mm thick CT slices provided. The number of ethmoid air cell septa was counted in the axial CT slice transecting the optic foramen.

We classified patients into either isolated inferior or medial orbital wall fractured groups. We excluded patients in which any of the three CT reviewers suspected a concomitant inferomedial wall fracture. This classification was solely dependent on two-dimensional 3 mm sliced CT findings. As surgeons, we occasionally encounter cases of orbital wall fractures where the surgical findings differ from the CT findings. Since not all patients were candidates for surgery, we were unable to exclude a minor number of cases in which fractures might have extended from the inferior wall to the medial wall or lacrimal bone. However, the discrimination between isolated medial and inferior wall fractures by three observers was not difficult.

We attempted to measure the thicknesses of the lamina papyracea and of each ethmoid septum involved at the fracture site because they may have influenced the site and size of the fractures. However, these structures were too thin to measure and there were large interobserver variations.

This study did not include an analysis of the supporting structures of the inferior orbital wall. This would require examining quasi-sagittal CT slices transecting the middle of each orbit parallel to the inferior rectus muscle. Since our study was retrospective, we could not obtain these CT slices.

Although the patients with other facial bone fractures and combined orbital wall fractures were excluded, we could not ignore the effect of different trauma vectors on the size and site of blow-out fractures. However, we found no differences in the etiology of trauma between the groups of patients with medial and inferior wall fractures. Additional studies that include a larger number of patients and that perform intense analysis taking the trauma vector into account are required.

We have shown here that blow-out fractures of the orbit depend on several intrinsic factors. When similar extrinsic forces act on the periocular region, patients with fewer ethmoid air cell septa and a larger lamina papyracea area per septum are more likely to develop isolated medial wall fractures than inferior wall fractures.

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