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REVIEW

Etiology of orbital blowout fractures

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Abstract

There is still much controversy surrounding the mechanisms that produce orbital blowout fractures. Since the first report of blowout fracture, theories have evolved and experiments been conducted to elucidate and demonstrate the globe-to-wall contact, hydraulic, and buckling mechanisms. However in clinical terms, it is very difficult to identify the precise mechanism(s) involved in each case. The author has encountered some rare clinical cases in which orbital blowout fractures may have been caused by a single mechanism alone. The aim of this review is to present the theories of the three types of mechanisms underlying orbital blowout fracture and then describe cases from the author's clinic exemplifying rare situations in which the fractures may have been produced by a pure, single mechanism alone.

Introduction

Since the first report of orbital blowout fracture, there has been much debate and contention as to its etiology. Three principal mechanisms have been proposed to explain the etiology of blowout fractures : the globe-to-wall contact[1], hydraulic[2], and buckling[3] mechanisms. Based on a great deal of experimental and clinical evidence, however, it appears unlikely that a single theory is sufficient to explain the diverse range of blowout fractures seen in clinical practice. Therefore, the etiology of almost all orbital blowout fractures may involve a combination of these three mechanisms.

Recently, however, we have treated several patients in whom the orbital fracture appears to have been caused by a single mechanism alone, which is rare. In this review, we discuss the three mechanisms which usually underlie orbital blowout fractures and then describe the rarer cases of possible single mechanism blowout fracture that we have encountered.

Three etiologies of orbital blowout fractures

1) The globe-to-wall contact mechanism

First espoused by Pfeiffer[1] in 1943, the globe-to-wall contact mechanism is the oldest accepted etiological basis of inferomedial orbital fractures. According to Pfeiffer, the mechanism of internal orbital fracture responsible for posterior displacement of the eye is clearly evident : the force of the blow received by the eyeball is transmitted to the wall of the orbit, causing fracture of the more delicate portion. For many years, the theory of globe-to-wall contact had existed alongside two newer theories. However, in 1999, Erling et al.[4] supported the globe-to-wall theory on the basis of an analysis of fracture type using computed tomography (CT). They examined CT scans of blowout fractures restricted to the medial and inferomedial wall, and showed that orbital displacement exactly fitted the shape of the globe in 75% of cases. They concluded that a significant number of internal orbital blowout fractures indicate globe-to wall contact as the major mechanism of

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injury. Here, we have analyzed our own cases of medial and inferomedial blowout fractures based on the methods of Erling et al.[5] It was found that the size and shape of the displacement of the orbital wall fitted the globe exactly in 44% of cases, and all fractures occurred in the inferomedial area of the orbit.

Some authors[6)7)] have contended that such posterior movement of the globe is unlikely. However, several reports of cases of blowout fractures described traumatic displacement of the globe into the ethmoid sinus.[8-12)] These reports showed that the globes of the patients were entrapped within the ethmoid sinus by the inferomedial orbital wall ; moreover, the area of fracture of the orbit was similar to that observed in our own cases, which were due to the globe-to-wall mechanism. It is our belief that a strong, direct, blunt blow with an object smaller than the diameter of the orbit may induce posterior movement and herniation of the globe into the ethmoid sinus. Patients with such displacement of the globe represent the most severe cases of blowout fracture due to the globe-to-wall contact mechanism.

Clinical case of blowout fracture caused by globe-to-wall contact mechanism

A-53-year-old man fell and hit his right eye region on a small stake while he was playing tennis. After injury, he noticed diplopia with restricted upward and downward gaze. Displacement of the right inferomedial wall was observed by CT, and the size of the orbital wall displacement fitted the globe exactly. He was treated conservatively and his diplopia resolved within three weeks. However, enophthalmos of his right eye was still present at one month post-injury ; bone graft surgery undertaken to improve his enophthalmos was successful (Figure 1).

2) The hydraulic mechanism

In 1957, Smith and Regan[2] proposed what is known as the hydraulic mechanism of orbital fracture. They explained that when the force of blunt trauma to the eye region is insufficient to fracture the orbital rim, the soft tissue pressed into the orbital cavity penetrates the fragile orbital floor ; fluid malleability of the contents of the globe helps prevent rupture of the globe. Many cadaver and animal studies have been cited to support this theory.[6)13-18)] These experiments showed that fractures caused by hydraulic pressure are common in the weakest areas, which are the medial posterior region of the orbital floor and the lamina papyracea of the ethmoid.[13-15)] In an experimental study, Ahmad et al.[18] noted that impact directed to the globe produces large fractures located mainly in the posterior and posteromedial aspect of the orbital floor.

In a clinical report, Lee[19] described a young man who sustained orbital blowout fracture after being placed in a headlock by his friend (a headlock is a wrestling hold in which the attacker's arm encircles the opponent's head) ; the nature of this injury strongly suggested high hydraulic pressure in the orbital cavity as the cause of the blowout fracture. We previously reported another case with a similar cause of blowout fracture, which also supports a purely hydraulic mechanism.[20]

Clinical case of blowout fracture caused by hydraulic mechanism

A 56-year-old woman presented at our clinic complaining of right enophthalmos. During a quarrel, she had been pushed to the floor by her husband, who applied pressure to her right eye region with his left palm. During this attack, she heard a cracking sound in her right orbital region. Enophthalmos of her right eye was prominent immediately following injury. A CT scan revealed a right orbital floor fracture, extending from the anterior portion to the most posterior portion of the floor. An operation was undertaken 3 days post-injury, employing the trans-maxillary approach. The patient's

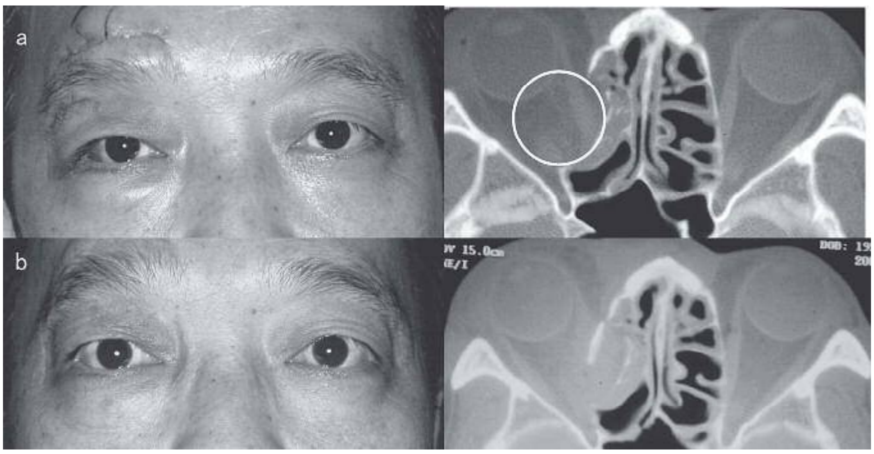

Figure 1 A 53-year-old man fell and hit his right eye region on a stake while playing tennis. A CT scan revealed displacement of the right inferomedial wall, and the size of the orbital wall displacement fitted the size of the globe exactly (shown as circle in a). After a bone graft operation, the enophthalmos showed good improvement (b).

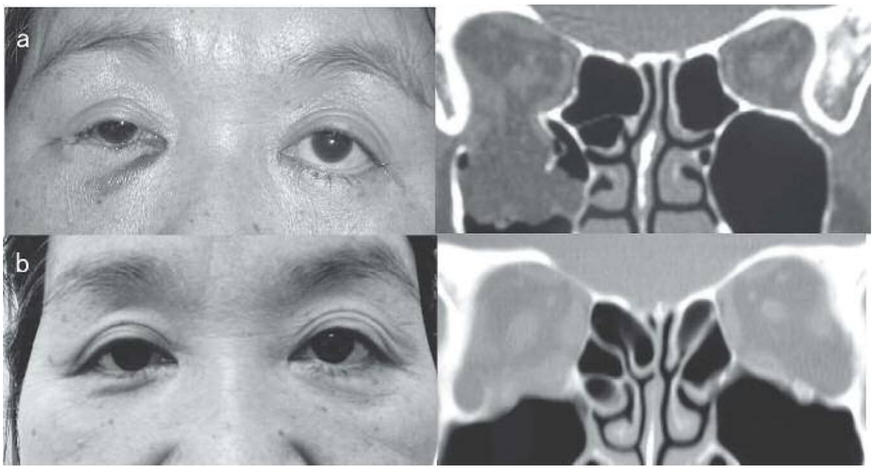

Figure 2 A 56-year-old woman was pushed to the floor by her husband who applied pressure to her right eye region with his left palm. She complained of enophthalmos of the right eye after the attack. A CT scan revealed a right orbital floor fracture extending from the anterior portion to the most posterior portion of the floor (a). An operation was undertaken 3 days after injury. The patient's enophthalmos resolved after the intervention (b).

enophthalmos was resolved after this intervention.

In this case, there was no strong blow to the orbital rim and globe. Additionally, the shape and area of these fractures coincided with the experimental results for blowout fracture due to hydraulic pressure.[18] We believe that the etiology of blowout fracture in this case was a purely hydraulic mechanism[20] (Figure 2).

3) The buckling mechanism

In 1974, Fujino[3] experimentally produced a typical blowout fracture of the orbital floor by striking the orbital rim of a dried human skull with a silicon rubber plate. He described a direct compression, or buckling force, as the cause of orbital floor fractures. Several studies have been cited to support this bone buckling theory.[15)16)18)21] Ahmad et al.[18] reported that rim-directed trauma produced fractures limited to the anterior part of the orbital floor. Nagasao et al.[21] specifically investigated various striking angles and found that fractures were distributed over a wider area of both the orbital floor and medial wall.

In a clinical analysis of blowout fracture, Burn et al.[22] noted that the most common facial fracture associated with medial wall fracture was nasal fracture. Their investigations of this finding suggested that the force causing nasal fracture is as important a causative factor of pure medial wall fracture as the buckling force from the medial orbital rim.

Kulwin and Leadbetter[23] reported a man who developed a blowout fracture of the orbital floor after trauma to the lateral orbital rim. The bony rim was intact and the direction of the blow precluded contact with the globe. Kersten[24] reported an old man who developed blowout fracture of the floor with entrapment of the extraocular muscle after isolated trauma to the rim of the orbit. He wore heavy-framed glasses, and a blow to the frame produced fracture of the floor without an associated orbital rim fracture. These two cases support the concept of a pure buckling force to the orbital rim in producing floor and medial wall fractures of the orbit. We also encountered one case of medial wall fracture of the orbit which may have been caused purely by a blow to the nose.

Clinical case of blowout fracture caused by buckling mechanism

A 62-year-old man hit the frame of his metal-framed glasses against a shelf while he was cleaning. After the trauma, he reported nasal pain and bloody nasal discharge. He noticed a swelling around his right orbital region while blowing his nose. A CT scan revealed a right orbital medial wall fracture and emphysema in the orbital soft tissue, while the nasal bone and the right orbital rim were unaffected. He reported no ophthalmic symptoms, so treatment was conservative. The blowout fracture suffered by this patient appeared to have been caused purely by a buckling mechanism (Figure 3).

Discussion

The physical mechanisms of orbital blowout fractures have been vigorously debated for many years by plastic surgeons and ophthalmologists. Three main theories have been considered, including the globe-to-wall contact and hydraulic and buckling theories.[1-3] However, it is very difficult to identify the precise mechanism(s) involved in individual clinical cases. Therefore, almost all orbital blowout fractures may be due to a combination of these three mechanisms. However, there are some reports of cases of orbital blowout fractures which appear to have arisen via a pure, single mechanism, although

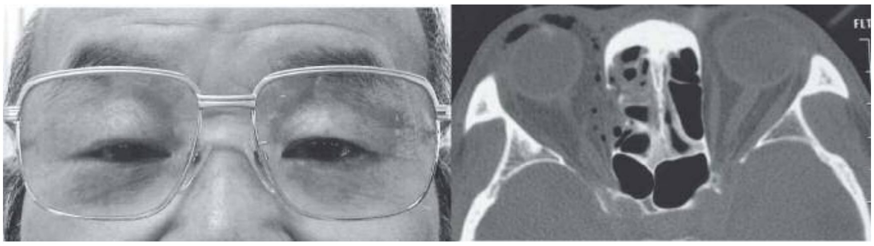

Figure 3 A 62-year-old man who wore metal frame glasses hit the frame of the glasses on a shelf. He felt swelling around his right orbital region following nose blowing. A CT scan revealed a right orbital medial wall fracture and emphysema in the orbital soft tissue. No fractures were revealed on the nasal bone or right orbital rim.

Table 1 Three etiologies of orbital fractures

Theory	Advocate and year	Mechanism	Complication
Globe-to-wall contact	Pfeiffer RL, 1943	Force transmitted by eyeball	Ocular injuries Ophthalmic nerve and cranial nerve injuries
Hydraulic	Smith B and Regan WF, 1957	Increased hydraulic pressure	Ocular injuries
Buckling	Fujino T, 1974	Buckling of orbital wall	Entrapment of extraocular muscles

they are very rare.[19)23)24)] We also have previously reported on rare cases of orbital blowout fractures due to a pure, single mechanism in patients treated at our clinic.[5)20)]. This suggested that each of the mechanisms outlined by these three theories sometimes acts independently to produce characteristic orbital fractures.

Regarding clinical symptoms, a strong association of orbital fractures and traumatically-induced ocular injuries can be anticipated with the globe-to-wall contact and hydraulic mechanisms,[25)26)] because in both mechanisms the force is driven directly to the ocular globe. Moreover, in our clinical analysis of blowout fractures caused by the globe-to-wall contact mechanism, fractures were often accompanied by more serious ophthalmic and neurological complications.[5)] In some cases, the posterior movement of the globe causes neuropathy of the optic and cranial nerves by posterior hemorrhage or direct impact between the globe and the wall.[27)] When the displacement of the globe was great, the shearing and stretching force on the optic and/or other cranial nerves was also great.[28)]

In contrast, the most noticeable complication associated with blowout fractures due to the buckling mechanism is entrapment of the extraocular muscles (Table 1). Fujino and Makino[29)] described that entrapment of the extraocular muscles in blowout fractures is due to the phase difference of the movement of solid, bony, and elastic soft orbital structures. This complication is particularly likely to accompany blowout fracture in young patients, because the elasticity of bone is more prominent in this age group.[30)] We concur with many authors who recommend early intervention to avoid muscle degeneration in patients for whom there is CT evidence of extraocular muscle entrapment.[30-32)]

In summation of this review, a more detailed understanding of the complexities of these three mechanisms will improve the effectiveness of both the diagnosis of and treatment selection for complications resulting from orbital blowout fractures.

Disclosure

The author reports no conflict of interest.

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眼窩骨折の発生機序

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眼窩骨折の発生機序に関しては、Globe-to-wall contact, Hydraulic, Buckling の 3 つの機序が広く認識されており、各々を裏付ける数多くの臨床治験、屍体や動物を用いた実験の論文が報告されている。しかしながら、眼窩骨折の個々の臨床症例においては、いずれの機序により骨折が発生したかを同定することは困難であり、ほとんどの症例では、これらの機序のいくつかが相まって骨折を形成すると解釈されている。しかし、数多くの眼窩骨折の症例を検討していると、極めてまれではあるが、これらのうちの一つの機序が純粋に作用して骨折を発生させたことを確証できる症例が存在する。今回は、独立した機序が骨折に関与したと考えられた症例を提示するとともに、各々の眼窩骨折発生機序の歴史的展開を解説する。

一方、眼窩骨折に伴う合併症は、骨折の発生機序により特徴的な病像を呈することが多い。Globe-to-wall contact, Hydraulic 機序では、眼球自体に強い外力が加わるため、眼球自体の損傷を伴うことが多い。さらに、Globe-to-wall contact 機序では、眼球後退による物理的障害や球後出血により、視神経、III、IV、VI 脳神経の重大な損傷を伴う場合がある。一方、Buckling 機序による骨折では、骨折部に外眼筋が陥頓、絞扼されることがあり、緊急的な対応が必要な場合があることを認識しておく必要がある。

眼窩骨折の骨折形態から、その主たる発生機序を推察することにより、眼窩骨折に伴う合併症の診断と、速やかな対応が可能となることをあらためて強調したい。

〈キーワード〉 眼窩骨折、Blowout 骨折、眼窩吹き抜け骨折、眼窩底骨折、眼窩