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Classifications and Theories of Orbital Fractures: A Review of Literature

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Orbital fractures occur in isolation or may even be associated with other maxillofacial injuries. The classifications of these fractures are dispersed in literature and an encompassing review of classifications is unavailable. The authors thus attempt to comprehensively review the classifications of orbital fractures while also reviewing the historical background and etiologic theories of the same.

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INTRODUCTION

Orbital fractures account for almost 40% of all craniomaxillofacial fractures and trauma[1], [2]. They can occur either in isolation or in combination with fractures of the adjacent facial bones such as orbito-zygomatic and naso-orbital-ethmoid fractures. Isolated orbital fractures constitute 4%-16% of all facial fractures while those with associated fractures account for about 30%- 55% of all facial fractures[3], [4]. Orbital fractures mainly occur medial to the infraorbital groove and canal. Floor fractures are frequently combined with medial wall fractures due to the insubstantial thickness of the bone in this area[5].

The fractures of the orbital floor, account for the majority of injuries involving the middle-third of the face, sometimes as pure blow-out and (58%) are the most common fractures, followed by a medial wall fractures (24%) and lateral wall (15%) and roof fractures (3%)[6]–[11].

Impure orbital fractures account for 76% of all orbital fractures. They are characterized by orbital rim discontinuity, large orbital wall defects with multiple-wall involvement, deep extension of defects resulting in facial disfigurement, enophthalmos with/without diplopia, restricted ocular movement, and visual impairment[12].

HISTORICAL BACKGROUND

Orbital floor fractures were first described in 1844 by **MacKenzie** in Paris[13]. The major cause of cosmetic deformity following orbital fracture was postulated to be expansion of the orbit and herniation of its soft tissue contents[14].

Lang, 1888 rightly suspected enlargement of the orbit as the cause of enophthalmos and was thoroughly proven later by **LaGrange**, 1917. In 1889, **Lang** suggested that, fracture and displacement of a portion of the orbital wall would cause an enlargement of the orbit such that the orbital fat would no longer be of sufficient quantity to adequately fill this enlarged area without sinking of the globe due to atmospheric pressure and also result in limitation of ocular movements[15], [16].

Pfeiffer, 1943 put forth seven possible mechanisms of enophthalmos which included: dislocation of the trochlea, atrophy of orbital fat, enlargement of the orbit, cicatricial contraction of the retrobulbar tissue, rupture of the orbital ligaments or fascial bands, fracture of the orbital wall and displacement of part of the orbital tissue. He surmised that the most likely cause was the increase in size of the bony cavity[17].

King, 1944 debated that dystopia of the globe was due to downward displacement of the orbital floor. Plain radiographs were used for identification of features of blowout fractures by **Pfeiffer** and **King**[14], [17].

Converse, 1944 suggested that diplopia and enophthalmos were major consequences of blow-out fractures. He described procedures for repair of fractures of the orbit and the zygoma. In 1950 and 1957 **Converse** and **Smith** reiterated the mechanism of globe displacement and put forth the management of the same by its reconstruction using bone grafting procedures[18]–[20].

Devoe, 1947 proposed a nonoperative approach. He is considered one of the earliest proponents of conservative management. He observed that simple blowout fractures with mild enophthalmos produced few delayed symptoms and that the appearance of these patients was acceptable and double vision if present, was not functionally limiting or subsided eventually[21].

Etiology and Theories of Blowout Fractures

The common mechanisms of injury include falls, high-velocity ball-related sports, traffic accidents, and interpersonal violence[22]. The most common mechanism of injury was motor vehicular accidents (30%), followed by interpersonal violence (12%) and falls (9%)[7]. While many recent studies suggest that the most frequent cause of all orbital fractures was assault (84%) followed by falls (16%)[8], [10], [11].

Hydraulic Theory

Orbital floor fractures occur as a result of nonpenetrating blunt forces to the orbital area by an object having dimensions greater than the orbit itself. The “hydraulic theory”, as postulated by **Smith et al**.(1957), **Waterhouse et al**.(1999) and **Warwar et al**.(2000) states that retropulsion of the globe causes a rise in intraorbital pressure, which is then transferred to the orbital walls to create a force large enough to cause a fracture[23]–[25].

Blunt trauma to the eye forces the soft tissues against the orbital cavity leading to penetration of the fragile orbital floor. Fluid malleability of the globe helps prevent its rupture. Cadaveric studies have demonstrated that fractures caused by hydraulic pressure are common in the weakest areas of the orbit, namely the medial posterior region of the orbital floor and the lamina papyracea of the ethmoid. It was noted that this type of impact produced large fractures located mainly in the posterior and posteromedial aspect of the orbital floor and results in extensive soft tissue prolapse and enophthalmos[24]–[28]. (Figure 1)

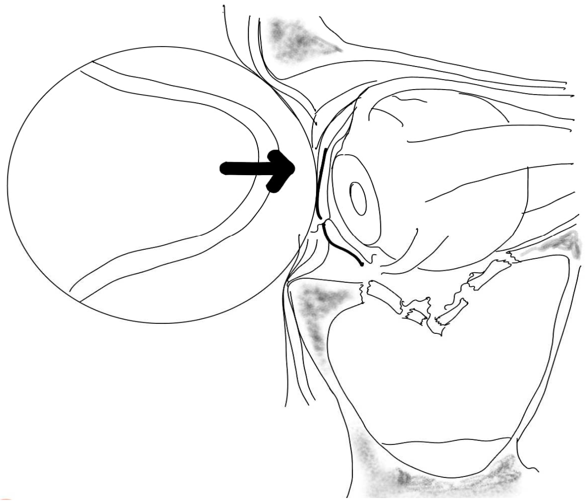

Figure no 1: Illustration of Hydraulic theory of orbital fracture

A tennis ball striking the eye will not cause a fracture but it may damage the globe. During contact, the hollow ball will undergo deformation and cause a suction effect as it bounces off the periorbital area. It may thus dampen the rise in intraorbital pressure. An impact of an object that does not undergo transitory deformation can cause fracture[26], [27].

Buckling Theory

This alternate theory was proposed by **Le Fort**, 1901 and **Lagrange**, 1917[16], [27]. It states that when force is delivered to the orbital rim, it will undergo temporary deformation or will buckle without fracturing. The backward movement of the orbital rim during that moment causes fracture along the orbital floor and/or medial wall, following which it springs back into its original position without any evidence of a complete fracture[28], [29]. (Figure 2)

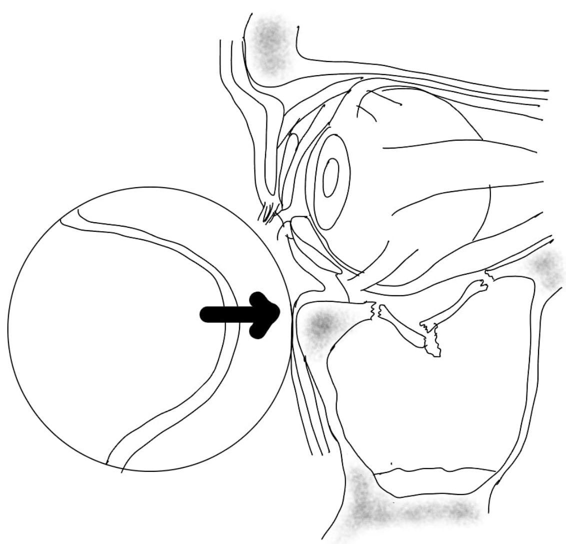

Figure no 2: Illustration of Buckling theory of orbital fractures

In 1974, **Fujino** demonstrated this theory by striking orbital rim of dried human skulls with a silicon rubber plate. It was reported that this type of impact produced fractures limited to the anterior part of the orbital floor which do not affect the medial wall, and are not accompanied by soft tissue entrapment in the bone defect area[26], [27], [29], [30].

Both these mechanisms are plausible and depend on whether the injury is caused by a large blunt object that hits the rim or if a smaller object that transmits most of the force to the globe or even a combination of both[12]. Although the hydraulic theory explains both orbital floor and medial wall fractures, it is more difficult to reserve the buckling theory to pure medial orbital wall fractures.

Globe to wall Theory

First adapted by **Pfeiffer,** 1943 the globe-to-wall theory states that the force of the impact received by the globe pushes it backwards such that the force is transmitted to the walls of the orbit, causing fracture of the more delicate portion[17], [28], [29]. It was postulated that if the globe is displaced to within 2.5 cm of the orbital apex, the globe itself fractures the orbital wall[7]. (Figure 3)

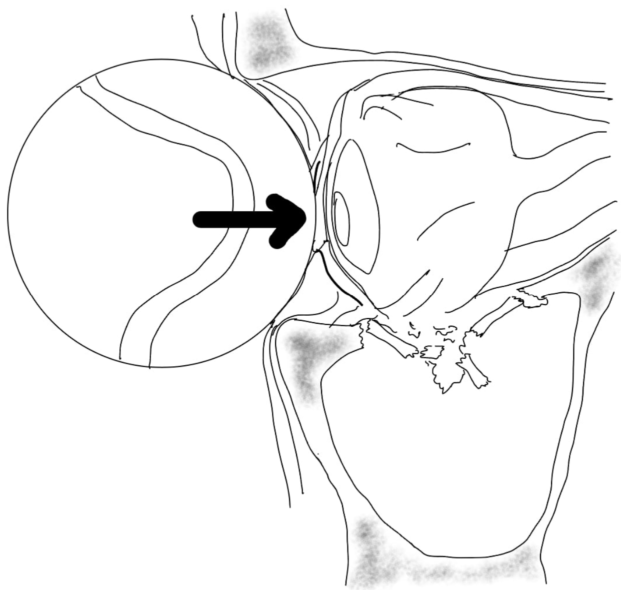

Figure no 3: Illustration of Globe to wall theory of orbital fractures

While some authors argued that such posterior movement of the globe is unlikely, **Erling et al**. (1999) reported that orbital displacement exactly matched the shape of the globe in 75% of cases and concluded that globe-to wall contact is a major mechanism of injury[29], [31].

It is presumptuous to credit a single theory to be a mechanism of all types of fractures. A strong correlation has been noted between blowout fractures and traumatic ocular injuries because force is delivered directly to the globe in both the hydraulic and globe to wall theories[12].

Classification Systems

The various classifications proposed to categorize and assess orbital fractures as described in literature are enlisted below.

Orbital fractures may be broadly classified according to the pattern of involvement of orbital walls, rims and orbital fractures associated with other facial bones[32][33].

1. Fractures limited to internal orbital skeleton (Blow out and Blow in)

Orbital floor, medial wall, or roof may be involved.

a. Trap door type of fracture – due to low velocity injuries

b. Medial blow out fractures – due to intermediate velocity injuries

c. Lateral blow out fractures – as a result of high velocity injuries

2. Fractures involving orbital rim with or without involvement of internal orbital skeleton

a. Inferior orbital rim fracture

b. Superior rim fracture

c. Lateral rim fracture

d. Rim fracture with fractures of internal orbital skeleton

3. Fractures of orbit associated with other facial fractures

a. Zygomatico maxillary fracture

b. Naso-orbito-ethmoid fracture

c. Frontal sinus fracture

d. Lefort II

e. Lefort III

4. Orbital apex fractures

Early identification is crucial due to the potential threat to structures at the superior orbital fissure and optic canal. Optic canal injuries can result in traumatic optic neuropathy.

The earliest classification was devised by **Converse and Smith,** 1950 and 1957 as follows:[8], [18], [23]

a) Pure (blow out and blow in)

b) Impure (complex and involving orbital rim fractures)

Heretofore orbital fractures were frequently missed due to diagnostic limitations until the introduction of computed tomography, which was a revolution in the domain of orbital fractures. It aided in the diagnosis of fracture patterns, localization of bone fragments, and soft tissue components and had a breakthrough impact on the management of orbital wall fractures[33].

Newer zygomatico-maxillary complex fracture classification systems were developed by **Jackson et al** (1989) which addressed the severity of the fracture. The management was based on the fracture pattern noted using CT scans. No remarks were made on orbital fractures[34], [35].

In 1989, **Antonyshyn et al** described a blow-in fracture as an inwardly displaced fracture of the orbital wall or rim that resulted in decreased orbital volume. He classified orbital blow-in fractures based on the distinguishing clinical and radiologic features, and the outcome of treatment[36].

- Pure blow-in fractures: isolated blow-in of a segment of the roof, floor, or walls
- Impure blow in fractures: disrupted orbital rim.

Manson et al (1990) proposed a CT based classification based on the consequence of energy impact on the pattern of segmentation and displacement[3], [33], [37].

- Low energy injuries: fractures with little or no displacement.
- Middle energy injuries: complete fracture of all articulations with mild to moderate displacement (comminution may be present)
- High energy injuries: comminution in the lateral orbit and lateral displacement with segmentation of the zygomatic arch.

Zingg et al (1992) classified the orbito-zygomatico-maxillary fractures based on specific anatomic points and used it as an essential guideline for their treatment but involvement of orbital fractures was not commented upon[38].

For decades, no classifications were devised with regards to internal orbital fractures. **Blotta et al** (1992) considered the orbit as a single component and proposed a classification that can define the fracture area, the displacement of the fragment, the ocular motility impairment, and the shift of the orbital content[39].

Digman classified orbital fractures into three categories:[8]

a) Fractures involving the orbital rim

b) Intraorbital fractures with no orbital rim involvement

c) Combined intraorbital and orbital rim fractures

In 1995, **Nolasco et al** formulated a classification of medial wall fractures to help predict their clinical outcome. They were divided into four categories[40]:

- Type I- confined to medial wall
- Type II- medial orbital wall and complex midfacial injuries
- Type III- medial orbital wall with floor fractures combined with malar fractures
- Type IV- medial orbital wall and complex midfacial injuries

Lauer et al (1996) described a CT based classification system for orbital floor fractures defining their anatomic location relative to the infraorbital rim and infraorbital nerve[41].

- Floor fractures without rim involvement (Blow out fractures):

Fractures located medial to the infraorbital nerve or extended on both sides of the nerve and not confined to the lateral half of the orbital floor.

- Floor fractures with rim involvement, associated with ZMC or Le Fort II or III fractures:

Fractures located either lateral to or on both sides of the infraorbital nerve and not confined to the medial half of the orbital floor.

G J Harris et al (1998) proposed a classification that reflected upon the fracture pattern and emphasized on the severity of soft tissue damage[42].

- Type I: “Trap-door" injuries wherein, bone fragments appear perfectly realigned

Subtype IA: no orbital tissue is visible on the sinus side of the fracture line

Subtype IB: radiodensity of soft tissues and orbital fat is visible within the maxillary sinus

- Type II: bone fragments are distracted and soft tissue displaced between them.

Subtype IIA: soft tissue displacement is less than or proportional to bone fragment distraction.

Subtype IIB: soft tissue displacement is greater than bone fragment distraction.

- Type III: displaced bone fragments surrounded by displaced soft tissue in all areas.

Subtype III A: soft tissue and bone moderately displaced.

Subtype III B: both markedly displaced.

Water House, 1999 described two types of orbital fractures:[24]

Type I: A small fracture confined to the floor of the orbit (mid medial floor) with herniation of orbital contents into the maxillary sinus. It occurs as a consequence of impact of force directly to the globe (Hydraulic theory)

Type II: A large fracture involving the floor and medial wall with herniation of orbital contents. It occurs if force is applied to the orbital rim (Buckling theory).

In 2002, **Manolidis et al** recapitulated the principles of orbital reconstruction and presented an integrated classification system for orbital injuries. The orbital walls are assessed independently and the severity of the injury is categorized according to the disruption of the number of walls involved. The orbital rims are evaluated separately[34], [35], [43].

- Orbital skeletal involvement:
  - Single wall involved
  - Two walls involved
  - Three walls involved
  - Disruption of all four walls
- Orbital injury classification

Grade 0: no disruption of orbital walls (minimum injury)

Grade 1: disruption of one wall

Grade 2: disruption of two walls

Grade 3: disruption of three walls

- Orbital Volume

Orbital volume was examined as an outcome of injury and was categorized as:

- Intact: unaffected

o Mild disruption: produced by injury to one wall, comminuted floor fractures and significant herniation of orbital contents or in a two-wall, minimally displaced ZMC fracture.

o Moderate disruption: three-wall injuries and in the majority of two-wall injuries involving the ZMC complex with severe comminution and displacement.

o Severe or total disruption: inferior displacement of the globe, secondary to displacement of ZMC and its lateral canthal ligament attachment. Severe orbital volume changes are encountered in all injuries involving four walls[35].

Ahmed El Degwi et al (2002) devised a classification of orbital fractures based on their three dimensional topography[44]

Type I: Isolated medial wall or floor fracture
Type II: Medial wall and floor fractures
Type III: Medial wall, floor and zygomatic fractures
Type IV: Medial wall, floor and complex fractures (maxillary, NOE and frontal fractures)

Carinci et al (2006) formulated a classification that describes the type of orbital fracture, and the associated Le Fort or pan-facial fractures. Orbital fractures are summarized with abbreviations: one for describing fractured bone wall or orbital rim, one for fragment shift, one for ocular movement impairment and one for eye position[45]. (Figure 4)

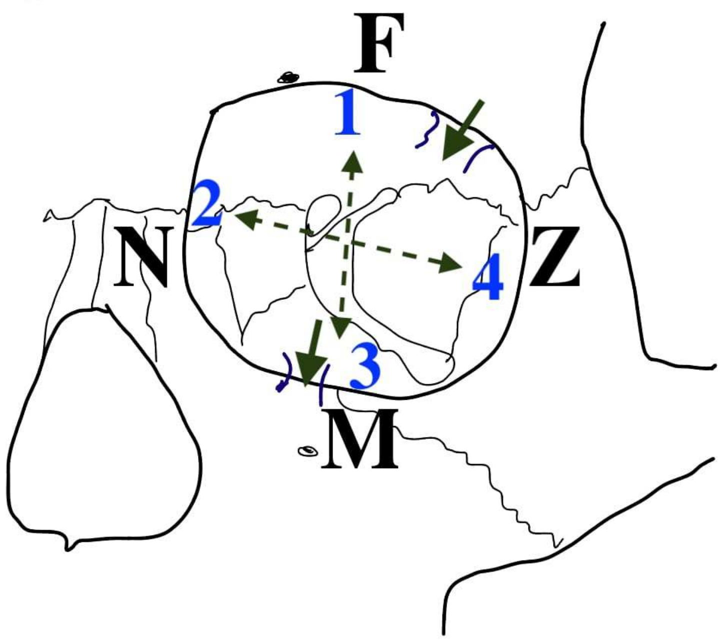

Figure no 4: Carinci's classification of Orbital fractures
-Bone fragment shifting: in, blow-in fractures; out, blow-out fractures.
-F: fracture of the orbital roof (frontal bone); M: fracture of the orbital floor (maxillary bone); Z: fracture of the zygomatic wall; N: fracture of the naso-ethmoid wall
-Ocular motility (in blue): 1, upward; 2, horizontal toward the nasal quadrant; 3, downward; 4, horizontal toward the zygomatic wall

The topographical aspect of the classification (F, N, M, and Z) has to be associated with the type of bone fragment shift. The bone fragments can break up in an outward direction or inwardly, as a result of trauma. Four letters define the site:

o F = frontal bone/ orbital roof fracture
o N = nasal bone fracture

- M = maxillary bone/ orbital floor fracture
- Z = zygomatic bone fracture

• Two acronyms describe fragment shift
- in = blow-in
- out = blow-out

Another parameter considered is the ocular motility, which is relevant from a therapeutic point of view.

• Four numbers define ocular movement impairment
- 1 = superior extrinsic muscular deficit (upward gaze)
- 2 = internal extrinsic muscular deficit (medial gaze)
- 3 = inferior extrinsic muscular deficit (downward gaze)
- 4 = external extrinsic muscular deficit (lateral gaze)

The last point to be considered is the presence of exophthalmos or enophthalmos.

• Two acronyms describe eye position
- EX = exophthalmos
- ENO = enophthalmos

A radiologic classification was proposed by **Fueger et al**, which categorized blow-out fractures into six main types, with subtypes[26], [27] (Figure 5):

• Classical blowout fracture: a low energy orbital floor fracture that occurs medial to the infraorbital canal

• Fracture involving the infraorbital canal

• Inferomedial fracture: a middle energy fracture of the inferior and medial walls.

• Total fracture of the orbital floor: High energy fracture lateral to the infraorbital canal fracturing of the entire orbital floor.

• Atypical forms of blow-out fractures:
- Rectangular fracture
- Triangular fracture
- Stellate fracture

• Linear fractures of the orbital floor without displacement of fracture fragments:
- Y shaped fracture
- Linear lateral fracture

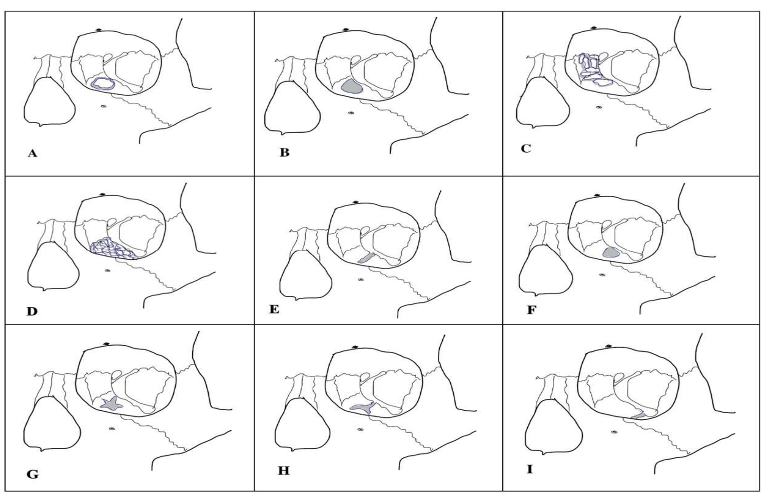

Figure no 5: Orbital floor fractures according to Fueger et al:
A: Classical fracture, limited to the orbital lamina of the ethmoidal bone and infraorbital canal. Posterior border is formed by inferior orbital fissure
B: Fracture involving the infraorbital canal
C: Inferomedial fracture
D: Total fracture of the orbital floor
Atypical and linear fractures- E: Rectangular fracture parallel to the infraorbital canal
F: Triangular fracture
G: Stellate fracture

H: Y shaped

I: Lateral linear fracture connecting the inferior orbital fissure with the infraorbital rim

Jaquiery et al (2007) categorized orbital fractures by simplification of the three-dimensional structure of an orbit by de-folding it into a two dimensional trefoil-like orbital scheme. This two-dimensional model can be used to describe and evaluate most orbital defects. Lateral wall defects were not considered in the model[46]. (Table 1, Figure 6)

Category	Description	Note
Category I	Isolated defect of the orbital floor or the medial wall, 1–2 cm^2, within zones 1 and 2	
Category II	Orbital floor and/or of the medial wall defects, >2 cm^2 , within zones 1 and 2	Bony ledge preserved at the medial margin of the infraorbital fissure
Category III	Orbital floor and/or of the medial wall defects, >2 cm^2 , within zones 1 and 2	Missing bony ledge medial to the infraorbital fissure
Category IV	Entire orbital floor and medial wall defects extending into the posterior third (zone 3)	Missing bony ledge medial to the infraorbital fissure
Category V	Same as IV with defect extending into the orbital roof	

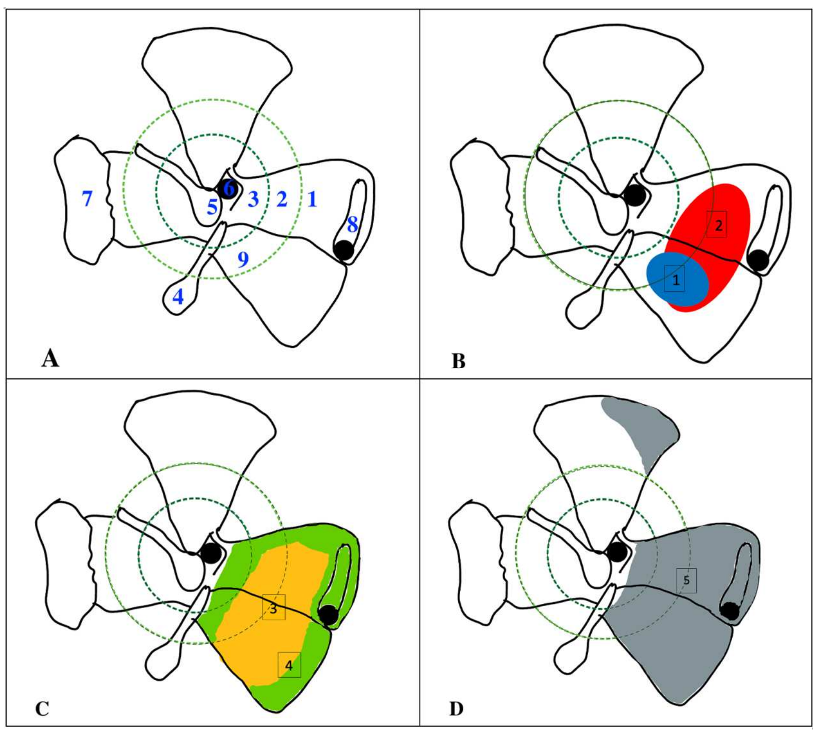

Figure 6: Jaquiery's classification of orbital wall defects

A: Sketch of the right orbit showing:

(1) orbital floor, anterior third; (2) orbital floor, middle third; (3) orbital floor, dorsal third; (4) infraorbital fissure; (5) supraorbital fissure; (6) optical nerve; (7) lateral wall; (8) naso-lacrimal duct; and (9) medial border of the infraorbital fissure.

B: Schematic depiction of category I (blue) and II (blue + red) defects

C: Schematic depiction of category III (yellow) and IV (yellow + green) defects

D: Schematic depiction of category V (grey) defect

The **AOCMF Classification Group** (2014) developed a 3-level classification system of the craniomaxillofacial region. It was a stratified classification with increasing level of complexity. Within the midface, the level 2 system (level 1 code 92), describes the location of the fractures in the central and lateral compartments including the internal orbit[33]. It is a level 3 classification system for orbital fractures which illustrates the fractures according to subregions such as orbital rims, anterior orbital walls, midorbit, and apex.

The orbital skeleton is divided into two subunits: the orbital frame and the orbital walls. Clinically, they are described as follows:[47]

• Fractures of the Orbitozygomatic region wherein the malar bone is the area of impact

• Fractures of the Naso-orbitoethmoidal region where the area of impact is the central upper midface

• Internal orbital fractures or fractures of orbital walls (blowout, blow-in), if only the orbital walls are involved which exclude the orbital frame or rim

• Combined orbital fractures which involve the entire orbital skeleton

The four walls make up a quadrangular-shaped coronal cross section in the anterior part of the orbital cavity (anterior third) and the midorbit (middle third). This configuration is pyramidal in shape in the three dimensional view (base- anterior orbital entrance and triangular shaped coronal cross-section of the apex posteriorly).

All structures around the orbit seen in the frontal view were regarded as orbital rims. The transition zone between the orbital rims and the internal orbital walls is made up of a demarcation where the orbital frame blends with the orbital walls. The important orbital landmarks include the 1) anterior loop of the inferior orbital fissure which marks the boundary of the anterior section of the orbital cavity, 2) confluence of the superior and the inferior orbital fissure delineates the posterior border of the midorbit and the entrance to the apex of the orbit[33].

This classification is the most detailed addition to literature that divides each subdivision into its respective regions and subregions while also denoting specific codes to the same. The complex anatomical structure mapping is thus very challenging and requires great effort for understanding and application. Simpler classifications mentioned previously can hence be used for ease.

This review of literature was an attempt towards compilation of all the chronologic events of importance in orbital fractures especially their classifications. The authors believe that this review will aid in better understanding of the basic concepts and will also help the reader apply the same in clinical diagnosis.

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