The Comprehensive AOCMF Classification System: Orbital Fractures - Level 3 Tutorial

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Abstract

The AOCMF Classification Group developed a hierarchical three-level craniomaxillofacial classification system with increasing level of complexity and details. Within the midface (level 1 code 92), the level 2 system describes the location of the fractures within defined regions in the central and lateral midface including the internal orbit. This tutorial outlines the level 3 detailed classification system for fractures of the orbit. It depicts the orbital fractures according to the subregions defined as orbital rims, anterior orbital walls, midorbit, and apex. The system allows documentation of the involvement of specific orbital structures such as inferior orbital fissure, internal orbital buttress, the greater wing of sphenoid, lacrimal bone, superior orbital fissure, and optic canal. The classification system is presented along with rules for fracture location and coding, a series of case examples with clinical imaging and a general discussion on the design of this classification.

Keywords
- fracture classification
- midface
- orbit
- anatomic regions

The AOCMF craniomaxillofacial fracture classification system was developed as a hierarchical three-level system with increasing level of complexity and details.[1] Within the midface (level 1 code 92), the level 2 system describes the location of the fractures within the defined regions in the central and lateral midface including the internal orbit.[2]

This article presents the level 3 classification system for individual outlining and displacement of orbital fractures and is organized in a sequence of sections dealing with the description of the classification system with illustrations of the topographical orbital subregions along with rules for fracture location and coding, a series of case examples with clinical imaging and a general discussion on the design of this classification.

Tutorial Level 3 Orbital Fracture Classification System

For surgical purposes, the bony orbit is divided into the orbital frame and the orbital walls, both subunits consisting of

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Table 1 Bones and orbital regions and subregions

Bones	Orbital regions/subregions
Frontal bone	Supraorbital rim, orbital roof, superior part of medial wall
Zygoma	Lateral rim, lateral part of the inferior rim, anterior part of the lateral wall, anterior lateral floor
Sphenoid	Greater wing (posterior lateral wall), lesser wing (posterior medial wall)
Maxilla	Medial part of the inferior rim, orbital floor
Lacrimal bone	Medial rim, anterior medial wall
Ethmoid bone	Medial wall
Palatine bone	Orbital process of palatine bone (posterior shelf)

several bony components of different anatomical origin (►**Table 1**). Thus, fractures involving the orbit may affect a changing pattern of involved bones. Under clinical aspects they are described as follows:

- *Orbitozygomatic fractures* (OZM), if the malar bone is the area of impact (see Cornelius et al[3])
- *Nasoorbitoethmoidal fractures* (NOE), if the trauma is directed to the central upper midface (see Cornelius et al[3])
- *Internal orbital fractures or orbital wall fractures* (blow-out, blow-in), if only the orbital walls and not the frame are involved
- *Combined orbital fractures*, if the entire orbital skeleton is involved

For classification of orbital fractures, the orbital walls are assessed independently from the bones that they originate from (geometric concept). In the anterior part of the orbital cavity (commonly referred to as the anterior third) and the so-called midorbit (middle third of the orbital cavity), the four walls make up a quadrangular-shaped coronal cross-section. In the three-dimensional (3D) view, this configuration is pyramidal in shape, the base of which is located over the anterior orbital entrance. To its posterior end the orbital floor blends into the medial wall resulting in the triangular-shaped coronal cross-section of the apex region (►**Fig. 1**). All structures around the orbit projecting to the external bony surface in a strictly frontal view are regarded as orbital rims. The demarcation between the orbital rims and the internal orbital walls is determined by the transition zone, where the thick bony orbital frame blends to the thin orbital walls.

An overview of the detailed topography and orbital structure is presented in ►**Fig. 2**, with descriptors being presented in ►**Table 2**. For surgical purposes it is helpful to divide the bony orbit into three basic components: the orbital rim, the orbital walls, and the orbital apex.

Special attention should be directed to the identification of important intraorbital structures as the inferior orbital fissure (IOF) (►**Figs. 3–6**), the intraorbital buttress (IOB), a tiny bony brace at the confluence of the medial orbital wall and the floor running from the anterior section to the apex (►**Figs. 4–6**) and the posterior ledge, a solid shelf in the posterior orbit also called the palatine orbital surface according to its origin (►**Figs. 4**, **5**, and **7**). Due to their importance with regard to intraorbital derangement, these structures will need closer description in the text below.

In the context with orbital wall fractures the term "displacement" needs further specification. Basically it describes the aberrance of the shape of the injured wall as compared to the uninjured orbit. Under functional aspects a displacement has to be interpreted as a defect, increasing the orbital volume or, rarely seen, the displaced wall (mainly the lateral wall) downsizes the orbital volume. Due to the thin bony walls, displacement of orbital walls is associated with fragmentation in most cases as several fracture lines (merging and independent from each other) occur.

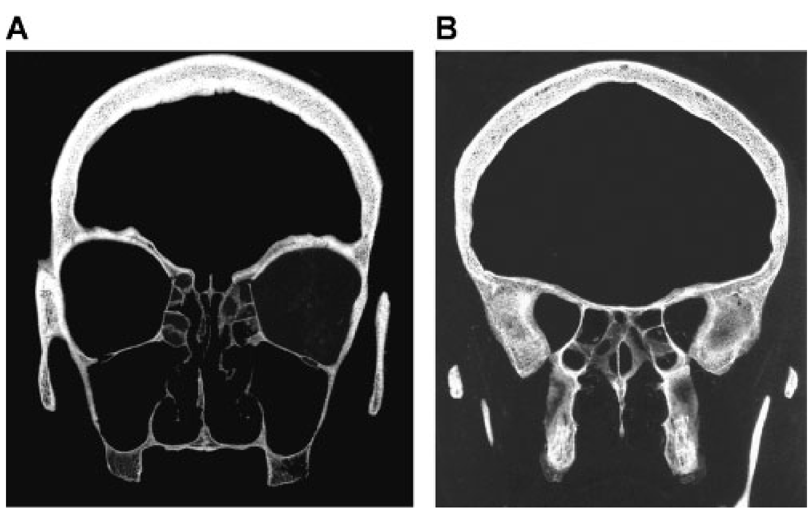

Figure 1 Shape of the anterior section (A) and the apex (B) of the orbit.

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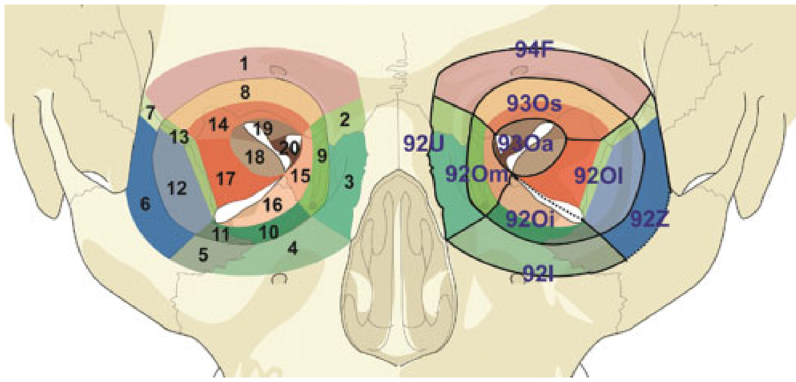

Figure 2 Orbital structure and fracture mapping. The left and right orbits show level 2 regions[2] and level 3 subregions, respectively. The numbering on the right orbit (orbital structure ID from 1 to 20) is described in ►**Table 2**. Orbital rims: Subregions 1–7 contribute to the orbital rims; orbital walls: subregions 8–12 contribute to anterior section (anterior "third"), subregions 13–17 correspond to midorbit (middle "third"), and subregions 18–20 correspond to the apex (posterior "third").

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Orbital Rims

The orbital rim is subdivided in three functional segments: the nasoethmoidal (medial rim), the zygomatic (lateral and inferior rims), and the supraorbital (superior rim) segment building the quadrangular opening of the orbital cavity. Anatomically four different bones, the frontal bone, the lacrimal bone, the maxilla, and the zygoma contribute to these segments (►**Table 1**).

Orbital Walls

The internal orbit (orbital walls and orbital apex) is divided into three sections, commonly referred to as anterior, middle, and posterior thirds; however we will hereafter preferably refer to sections instead of "thirds" due to their boundary descriptions. The middle and posterior sections correspond to the midorbit and orbital apex, respectively. The anterior loop of the IOF marks the boundary of the anterior section, the confluence of the superior and the IOF provides the posterior border of the midorbit and the entrance to the apex area (►**Fig. 3**). Injuries of orbital walls could become manifest by linear fractures, obvious bony defects or defect-like lamellar fracture patterns. Displacement of an orbital wall means a deviation from its original shape and can be due to all fracture types mentioned above.

Linear fractures (with or without displacement) show a clear fracture line which can be followed in the computed tomography (CT) scans. There may be small additional bony fragments which do not contribute to more complex fracture pattern than linear.

Orbital wall defects are characterized by missing bony support of the orbital contents by displacement of laminar pieces of the affected wall, usually the displaced bone shows no or only punctual contact with the uninjured part of the orbital wall.

Defect-like lamellar fractures may be the most difficult to detect. They may produce dents and tubs but flow smoothly in continuity with the undisplaced part of an orbital wall, however producing changes in volume. After exposure, this fracture type renders as an instable area. This fracture type contributes most to the fact that CT scans often underestimate the intraorbital fracture pattern.

The internal orbit is composed of four walls and the apex as discussed below.

Superior orbital wall or *roof* (superior wall formed by the orbital surface of the frontal bone): The orbital roof separates the orbit from the anterior cranial fossa as a thin, curved structure and belongs to the anterior skull base.[4] In a sagittal plane from anterior to posterior it first inclines upward just behind the supraorbital rim. The midportion extends posteriorly followed by a final inclination inferiorly to the apex region.

Lateral orbital wall (formed by lateral flange of the zygoma and the thin part of the greater wing of the sphenoid around the suture): The lateral orbital wall consists of the greater wing of the sphenoid and the orbital process of the zygoma. Anteriorly the small zygomaticoorbital artery perforates the bone. Because of its firm structure higher energy is necessary before a fracture occurs as compared with the other orbital walls.

Displacement of the lateral wall means a pure deviation from its alignment, whereas fragmentation is characterized by multiple bone fragments due to involvement of the zygoma (fragments anterior to sphenozygomatic suture) or involvement of the greater wing of the sphenoid (fragments posterior to the suture). As fractures of the lateral orbital wall usually are in the context with zygoma fractures or cranial base injuries, the tutorials regarding midface level 3 and skull base systems should be consulted.[3,4]

Medial orbital medial wall (formed by the lacrimal and the ethmoid bone): The medial orbital wall is a paper-thin delicate structure formed by the orbital plate of the ethmoid bone reinforced by the septae and bony cell formation of the ethmoid sinuses. Entering the orbit anteriorly the wall is in line with the optic foramen. The two ethmoid arteries perforate the bone at the same vertical level as the optic nerve enters into the orbit. Thus, they allow a reliable orientation with regard to the optic canal. The foramina can be used as a landmark, being located about 25 to 35 mm from the anterior lacrimal crest. The optic nerve lies 5 to 8 mm posteriorly to the posterior ethmoid artery (40–45 mm from the anterior lacrimal crest).

Table 2 Orbital anatomical structure mapping

Specific level 3 orbital system			Related level 1 and 2 systems				
Subdivisions	ID	Additional description	Code	Region	Subregions	Code	
Orbital rims							
Superior	1		Rs	Cranial vault	Frontal bone	94F	
Medial	2		Rm	Cranial vault	Frontal bone	94F	
Medial	3	Frontonasal maxillary processes	Rm	Midface	UCM	92U	
Inferior	4	Part of ICM	Ri	Midface	ICM	92I	
Inferior	5	Part of zygomatic body	Ri	Midface	Zygoma	92Z	
Lateral	6	Part of zygoma but not zygomatic body	Rl	Midface	Zygoma	92Z	
Lateral	7	Area of zygomaticofrontal suture	Rl	Midface	Zygoma	92Z	
Orbital walls							
Superior	8	Anterior section of orbit[a]	W1s	Skull base	Anterior	93Os	93A
Medial	9	Anterior section of orbit[a] (including the lacrimal bone)	W1m	Midface		92Om	
Inferior	10	Anterior section of orbit[a]	W1i	Midface		92Oi	
Inferior	11	Anterior section of orbit[a] (including part of zygoma)	W1i	Midface	Zygoma	92Oi	92Z
Lateral	12	Anterior section of orbit[a]	W1l	Midface	Zygoma	92Ol	92Z
Lateral	13	Area of zygomaticosphenoidal suture (greater wing of sphenoid)	W1l	Midface	Zygoma	92Ol	92Z
Superior	14	Midorbit[b]	W2s	Skull base	Anterior	93Os	93A
Medial	15	Midorbit[b]	W2m	Midface		92Om	
Inferior	16	Midorbit[b] (including the palatine bone)	W2i	Midface		92Oi	
Lateral	17	Midorbit[b] (greater wing of sphenoid)	W2l	Midface		92Ol	93M
Orbital apex[c]							
	18	Lateral wall (greater wing of sphenoid)	Al	Skull base	Middle	93Oa	93M
	19	Superior wall (lesser wing of sphenoid)	As	Skull base	Anterior	93Oa	93A
	20	Medial wall	Am	Skull base	Sphenoid bone	93Oa	93S

Abbreviations: ICM, intermediate central midface; UCM, upper central midface.
Note: ID (orbital structure ID as presented in ►**Fig. 2**).
[a]Corresponding to "anterior third."
[b]Corresponding to "middle third."
[c]Corresponding to "posterior third."

Orbital inferior wall or floor (inferior wall formed by the orbital surface of the maxilla): The IOF separates the lateral orbital wall from the floor (►**Fig. 3**). It communicates with the retromaxillary space and is crossed by several smaller arteries and is a landmark structure for dissection. Posteriorly the maxillary portion of the trigeminal nerve, the infraorbital artery and the zygomaticofacial nerve pass through. Fractures of the orbital floor with extension to the posterior section of the orbit and displacement of the posterior wall of the maxillary sinus may result in critical enlargement of the IOF. Repair of these fractures should provide complete obliteration of the fissure to prevent enophthalmos.

In the literature the transition of the quadrangular cross-section of the orbit into the triangular cross-section is often described as the "key area" due to its fundamental impact on the globe position. It has to be emphasized that the term "key area" is not synonymous with the orbital apex as the transition of cross-sections already starts in the posterior section of the medial wall.

Orbital apex: The orbital apex represents the posterior section of the internal orbit and starts where the rectangular coronal cross-section becomes more triangular in shape. The transition from the midorbit into the cone usually begins behind the posterior end of the IOF at the confluence with the

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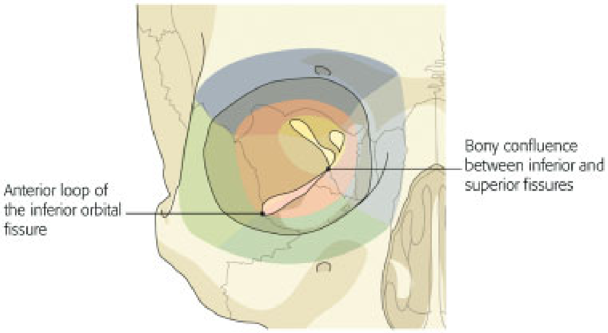

Figure 3 Orbital landmarks. The anterior loop of the inferior orbital fissure marks the boundary of the anterior section of the orbital cavity, the confluence of the superior and the inferior orbital fissure defines the posterior border of the midorbit and the entrance to the apex of the orbit.

superior orbital fissure. The optic canal and the superior orbital fissure are included in the orbital cone.

Important Intraorbital Structures

Inferior Orbital Fissure

The IOF communicates with the retromaxillary space and the anterior entrance to the infratemporal fossa. Posteriorly, it merges with the superior orbital fissure. This zone is crucial for assessment of orbital injuries as fractures of the floor extending posteriorly may result in enlargement of the fissure and the orbital volume. Usually the fissure is affected by fractures of the medial bony margins whereas involvement of the lateral boundary is rarer, mostly in combination with fragmentation of the lateral wall (►**Figs. 3–6**).

Intraorbital Buttress

The IOB is a thin bony brace at the confluence of the medial orbital wall and the floor running from the anterior section through the midorbit and merging with the posterior ledge. It is crucial for assessment of the severity of intraorbital injury. Undisplaced it can be used as an important landmark for reconstruction, which distinctively facilitates orbital repair (►**Figs. 4–6**).

Posterior Ledge

The posterior ledge, also called the palatine orbital surface according to its origin (palatine bone), is a solid shelf in the posterior orbit medially from the IOF. If present it offers a reliable and stable landmark for correct volumetric assessment and reconstruction of the posterior orbit. If absent, reconstruction of the posterior orbit needs to be performed rigidly to prevent a widening of the orbital cone.

The status of these intraorbital landmark structures can be described morphologically in level 3 using the AO comprehensive injury automatic classifier software (AOCOIAC) software solution[5] however are not highlighted in the detailed panoramic view of the orbits in the current version (►**Figs. 4**, **5** and **7**).

Fracture Coding

Fractures of the midface, skull base, and cranial vault are identified with the two digit codes 92, 93, and 94, respectively.[1] In coding the orbital fractures according to their topography in the level 3 system, orbital structures are identified by letters which stand for:

- R = rim, W = wall, A = apex
- s = superior, m = medial, i = inferior, l = lateral
- 1 = anterior section of the orbit, 2 = midorbit

The level 3 coding provides a specific orbital fracture identification to be specified separately from the overall level 2 coding. The fractures are coded in the order from outside to inside (R→W1→W2→A) with separate codes given for right and left orbits, respectively.

Case Examples

This coding system allows description of most relevant fracture patterns as illustrated in the case examples. We illustrate the coding of an orbital floor fracture with IOB involvement (►**Fig. 8**); an isolated medial orbital wall fracture with apex involvement (►**Fig. 9**); and a zygoma fracture with orbital floor involvement (►**Fig. 10**). A range of additional fracture patterns are presented in a special case appendix to this issue of the Journal.[6] Buitrago-Téllez et al[7] provide detailed information and discussion about imaging issues in this coding process.

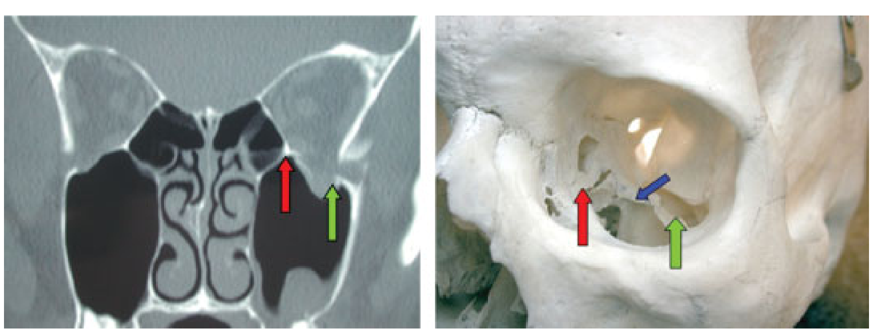

Figure 4 Intact inferior orbital fissure and internal orbital buttress. CT scan and anatomic specimen showing an intact inferior orbital fissure (green arrow) without widening (the posterior ledge is marked with a blue arrow) and an intact internal orbital buttress (red arrow).

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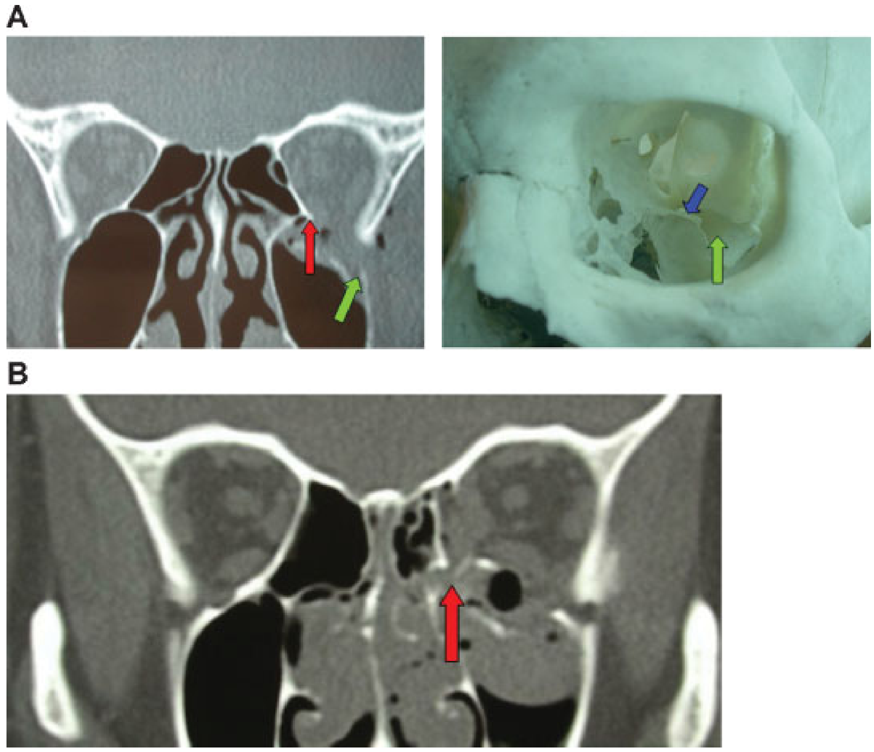

Figure 5 Involvement of inferior orbital fissure and internal orbital buttress. (A) Involvement of inferior orbital fissure with widening (green arrow), and intact internal orbital buttress (red arrow) is intact. The posterior ledge is marked with a blue arrow. (B) The internal orbital buttress is displaced an no longer a reliable landmark.

Discussion

Fractures involving the orbit are frequently observed. In more than 40% of all the facial fractures parts of the orbital rim or/ and the internal orbit are injured with a variety of fracture patterns. Commonly multiple portions of the orbit are involved: orbitozygomatic, NOE injuries and combinations thereof reveal fractures of the orbital rim and (several) internal orbital walls ranging from simple to complex comminuted fractures, the latter being responsible for the majority of unfavorable results. In simple fracture patterns as the common "blow-out" fracture, only one region of the internal orbit is involved. However, even these may not be underestimated, as the orbit is a complex 3D structure, which needs precise reestablishment after traumatic derangement.

The diagnosis of orbital fractures requires clinical and radiological examination. As orbital fractures often present a rather uniform clinical appearance, radiological assessment is of major impact for precise diagnosis. However, clinical examination may provide important hints about the severity of the trauma and indications for further diagnostic procedures and treatment. Fractures of the bony orbit are frequently associated with traumatization of the adjacent structures. Thus, clinical examination has to identify injuries of the eye globe and adnexa with the need for ophthalmologic assessment to prevent visual impairment or additional trauma to the globe by means of reconstruction of the bony orbit.

A variety of classifications has been proposed to assess orbital fractures. Most of them describe the orbit as a part of facial skeletal subunits as the zygoma or the nasoethmoidal bone emphasizing the contribution of multiple facial bones to the orbital cavity and mainly focusing on clinical aspects with therapeutic relevance and not on pure anatomic description. Former classifications of zygoma fractures[8–10] focus on the orbital frame and the degree of its displacement due to the incapacity of diagnostic intraorbital assessment and attempts have been made to even simplify these categories for practical use.[11] The majority of OZM fracture classifications describe four basic fracture patterns according to the degree of displacement and fragmentation.[11–13] New aspects were introduced by the classification proposed by Jackson[12] relating on the severity of the fracture, not the direction of displacement, thus emphasizing the impact of a fracture pattern-related treatment. So far orbital wall fractures were noted to be a part of a "more serious" facial injury and often missed due to diagnostic limitations. The introduction of CT has revolutionized the diagnosis of intraorbital fracture patterns, localization of bone fragments, and soft tissue components and showed impact on the assessment and treatment of orbital wall fractures. In 1995 Nolasco and Mathog proposed a classification of medial wall fractures in four categories to associate and predict clinical outcome.[14] Lauer et al described a classification system for orbital floor fractures based on their anatomic location, relative to the infraorbital rim after assessment of 24 fractures by axial and coronal CT scans.[15] In 2002 Manolidis et al summarized the principles of reconstruction of the orbital skeleton and introduced a unified classification system for orbital injuries,[16] pulling together three different classification systems referred to frontal sinus, NOE, and orbitozygomatic fractures. The orbital walls were

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A

B

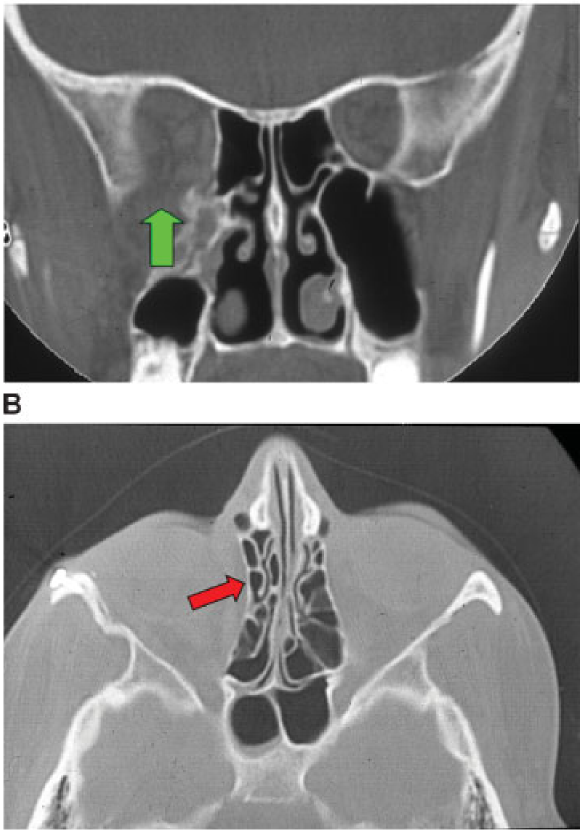

Figure 6 Lack of landmarks after involvement of inferior orbital fissure and internal orbital buttress. (A) The inferior orbital fissure shows severe widening (green arrow) resulting in an increased orbital volume. (B) Coronal aspect of a secondary orbital deformity due to malalignement of the lateral orbital wall and displacement of the internal orbital buttress (red arrow).

A

B

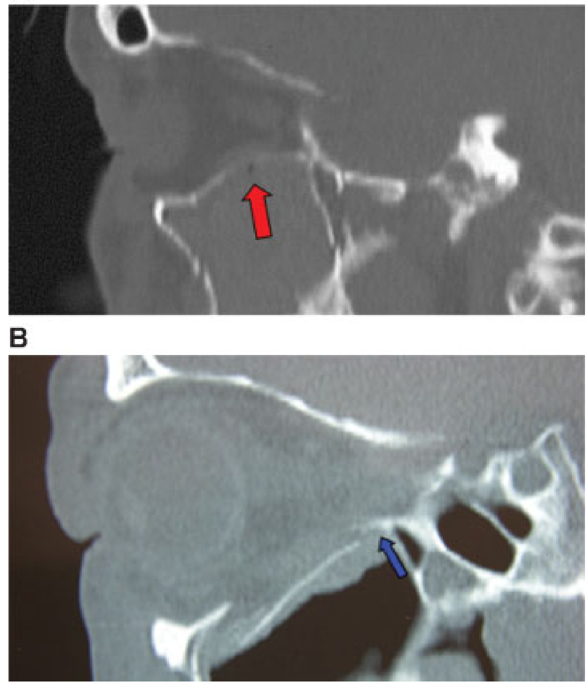

Figure 7 Assessment of intraorbital landmarks. (A) The intact retrobulbar constriction (red arrow) has important impact on the position of the globes, (B) Blow out fracture with displacement of the orbital floor (the posterior ledge is marked with a blue arrow).

examined as four walls, each comprising one entity and the severity of the injury graded according to the disruption of the number of walls involved. The orbital rim was examined separately and its components graded according to injury. The zygomaticomalar complex was assessed according to four levels of injury (Jackson[12]) representing an increasing amount of skeletal disruption. The NOE region was graded according to the comminution and the relation of the medial canthal ligament to the central fragment (Markowitz et al[17]). The frontal region was classified according to the frontal sinus into five levels and a total score assigned to each injury. The authors concluded that orbital fractures can be analyzed by two components, first the orbital rim, comprising the zygomaticomallar complex, the NOE and frontal region and second the four orbital walls.

The NOE area is the most demanding area to classify, due to its complex 3D anatomy and the presence of highly important soft tissue structures (lacrimal system, medial canthal ligament) with essential impact on facial esthetics. Although there is a high variety of fracture patterns, Markowitz et al[17] describes three basic types of injury, essentially differing in the size of the canthal ligament bearing fragment, which has impact on the algorithm of the surgical approach. The classification is based on the status of the medial tendon, the tendon-bearing bone fragment and the fracture pattern, parameters which, beneath radiological assessment, require meticulous clinical examination of the medial canthal soft tissues. A pure radiological description may be misleading as the "central" bone fragment is difficult to identify or can be invisible in the scan.

For internal orbital fractures there was no classification existing for decades. Blotta[18] proposed a staging which considered the orbit as a single unit and the classification can be applied to all orbital parts. It defines the fracture area, the displacement of the fragment, the ocular motility impairment, and the shift of the orbital content. An approach to classify fractures of the orbital walls based on their localization and the range of the fracture pattern has been proposed by Jaquiéry et al.[19] Carinci et al[20] presented a classification strictly for orbital fractures that describe the fracture type, but also match with the classical clinical description like Le Fort or pan-facial fractures because the single element composing the system can be grouped. A special classification for blow-in fractures of the orbit describing the distinguishing clinical and radiological features of this type of injury was presented by Antonyshyn et al.[21]

Injuries with major disruption of the orbital skeleton (frame and walls) result from combinations of fracture patterns (OZM, NOE, and internal orbital fracture), which need an integrative assessment. A systematic approach enhances interpretation of the fracture pattern as supported by the development of the AOCOIAC software solution.[5]

The classification presented is based on an anatomical structure outlining, which takes into consideration

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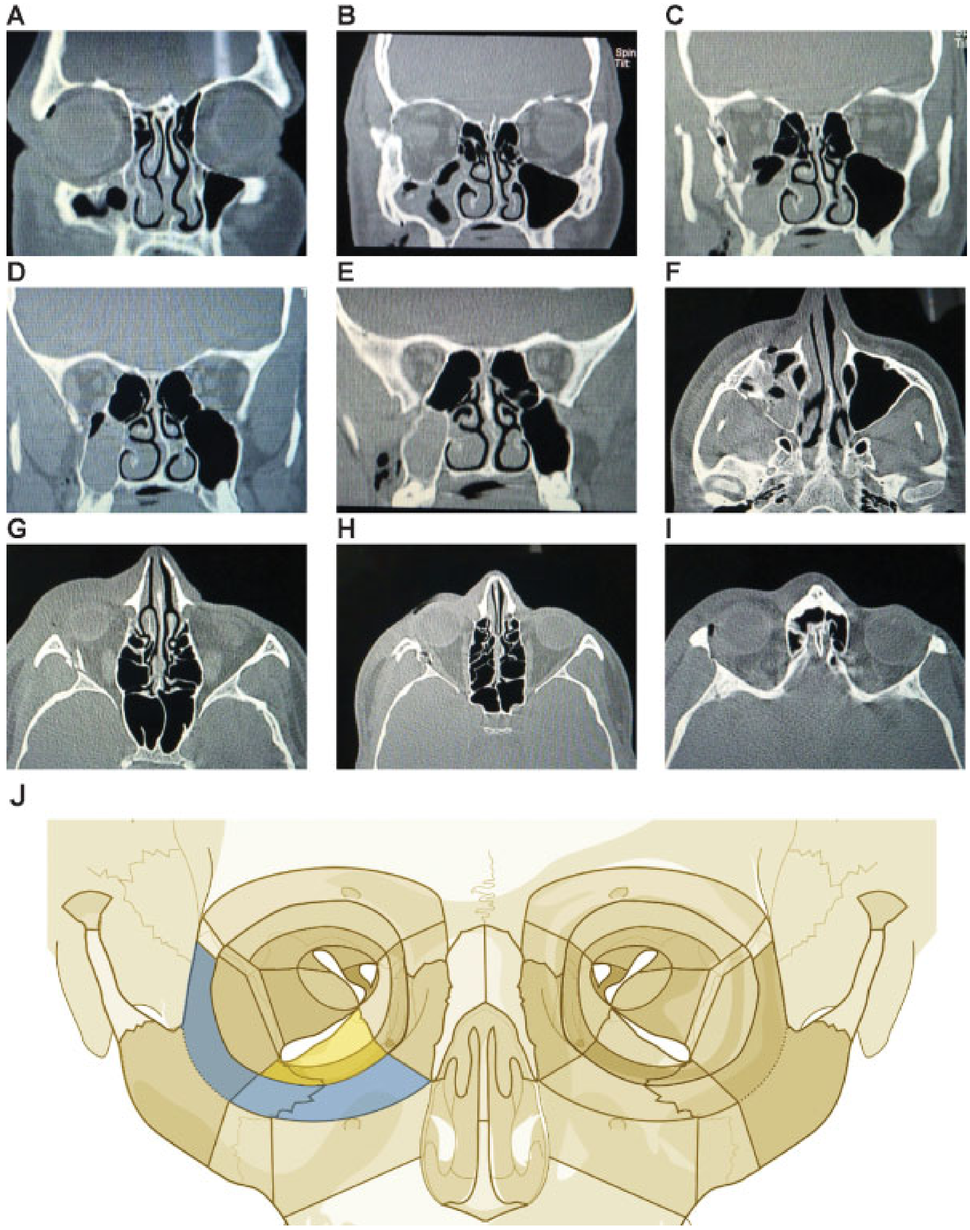

Figure 8 Orbital floor fracture with intraorbital buttress involvement. Imaging: CT scan coronal view (A–E) and axial view (F–I). Description: Fracture of orbital floor anterior and middle section (W1i, W2i). Fracture of lateral wall; involvement of inferior rim and lateral rim IOB stable, IOF not widened. (J) Level 3 code: 92 ZIi.Ii.Oi.m, Orbit (right): R(Ii).W1(i)2(i). This case example CMTR-92-201 is made available electronically for viewing using the AOCOIAC software at www.aocmf.org/classification.

topographical divisions of the orbit. Due to the unambiguous assignment to clearly defined sites the base for authentic communication and reflection of the true injury status of the patient is set. Therapeutic relevance deduced from the classification can be further documented, in particular if the assessment of the complex orbital soft tissue content (not yet included in this proposal) is correlated with the bony injury.

As for every image-based classification system, limitations may occur with decreasing quality of the imaging, as the level 3 system allows meticulous description of an orbital fracture pattern and only clearly visible fracture lines contribute to the recording. Beneath diagnosis of orbital wall defects the CT scans allow assessment of important features of orbital fracture patterns.[7] A widened IOF, a possible reason for enlargement of the orbital volume, can be detected in the coronal plane. The axial scan allows the assessment of the posterior orbital cone with regard to the presence or absence of a bony ledge providing support to bone grafts or orbital plates. If this posterior ledge is lacking, rigid reconstruction is highly recommended.

However, under certain circumstances evaluation of CT scans may be misleading and results in underestimation of the fracture patter. For instance, detection of linear fractures creating orbital wall instability and enlargement is sometimes difficult and the size of orbital wall defects is difficult to be correctly assessed. Often defects are larger than they appear on CT scans.

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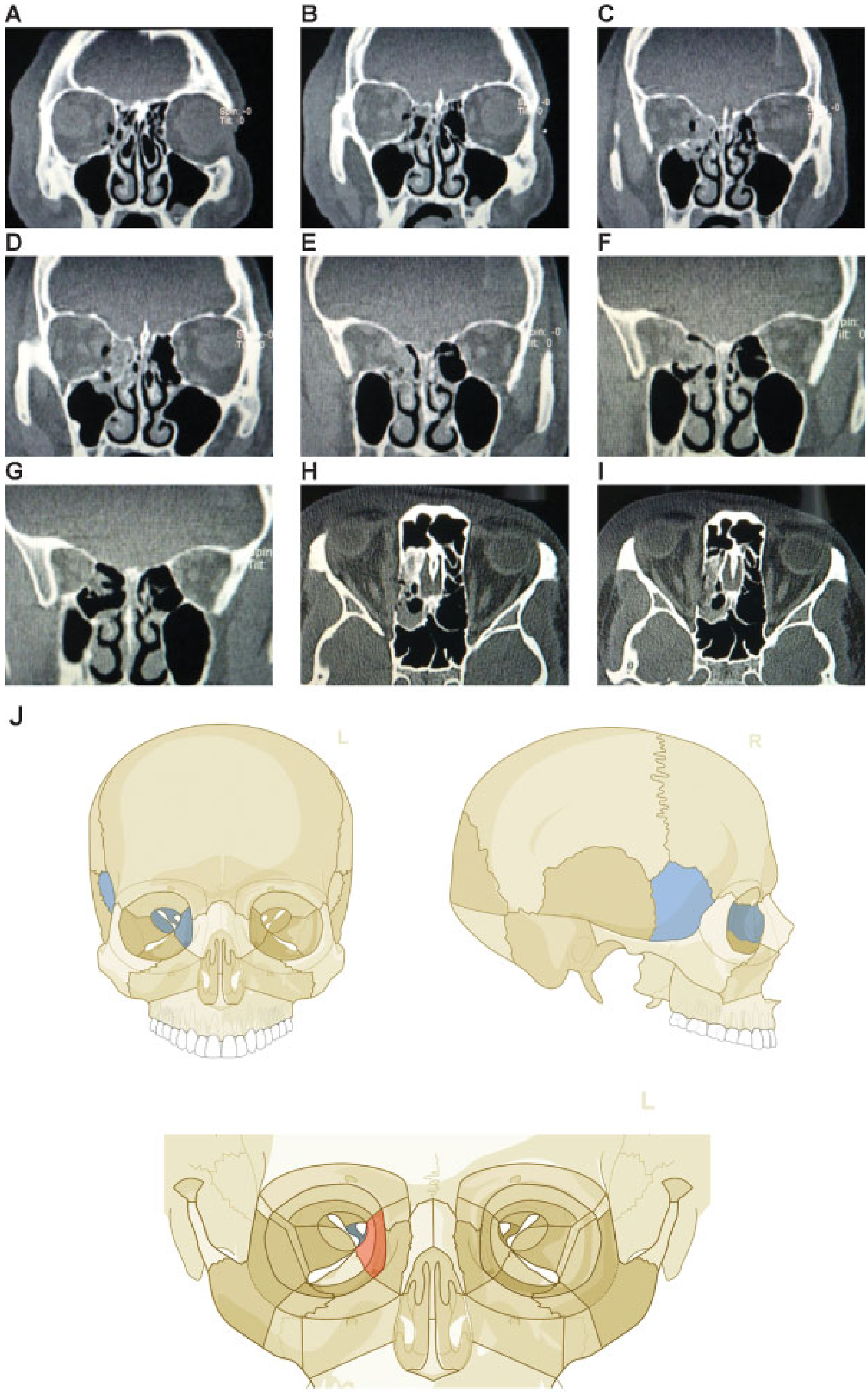

Figure 9 Isolated medial orbital wall fracture with apex involvement. Imaging: CT scan coronal view (A–G), axial view (H–I). Description: Isolated medial orbital wall fracture middle (W2m) and posterior section (Am), IOB stable, IOF not widened. (J) Level 3 code: 92 Om.m- 93 S.Oa.m, Orbit (right): W1(m)2(m).A(m). This case example CMTR-92-202 is made available electronically for viewing using the AOCOIAC software at www.aocmf.org/classification.

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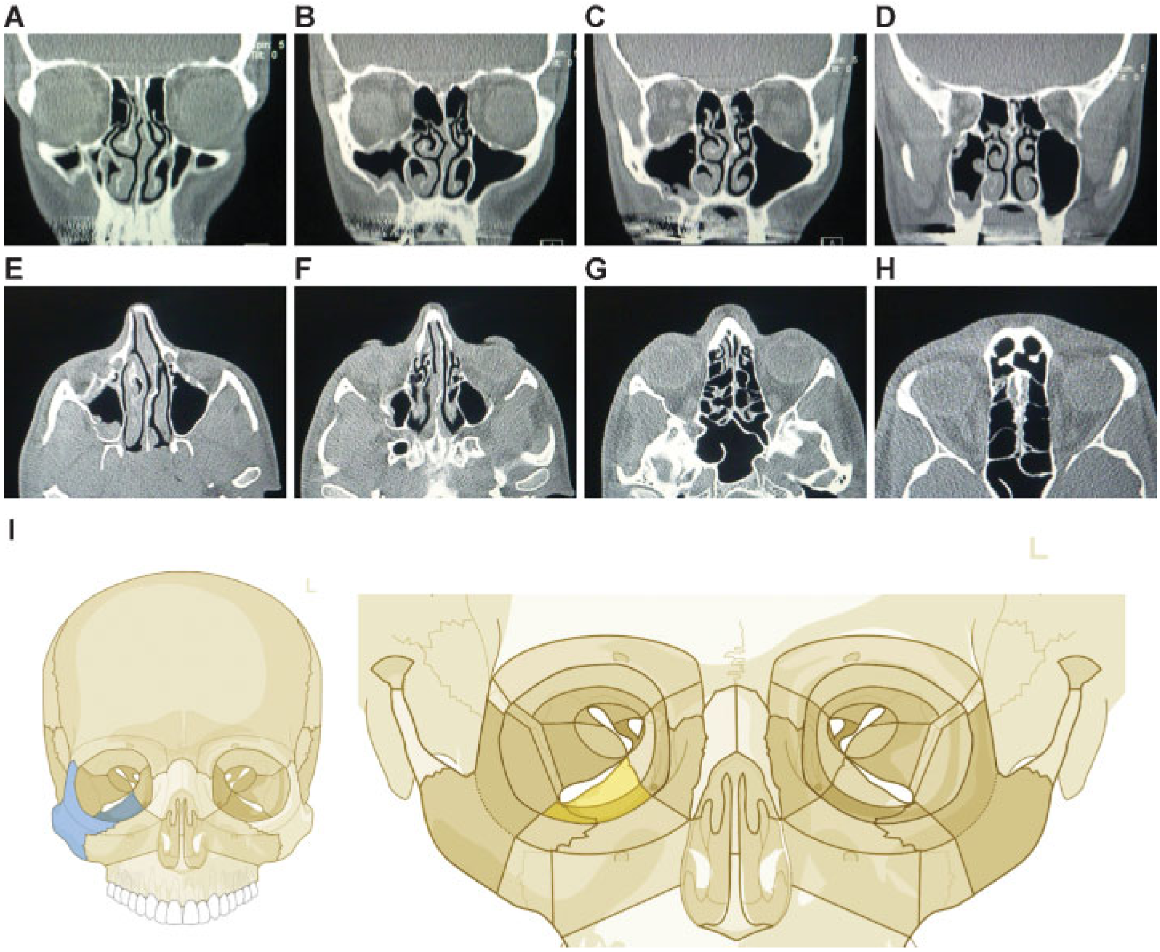

Figure 10 Zygoma fracture on the right side. Imaging: CT scan coronal view (A–D), axial view (E–H). Description: Zygoma fracture (Z) on the right side with fracture of the orbital floor in the anterior and middle portion (W1i, W2i). The internal orbital fissure (IOF) is widened, and internal orbital buttress (IOB) is stable. (I) Level 3 code: 92 Z.Oi.m, Orbit (right): W1(i)2(i). This case example CMTR-92-203 is made available electronically for viewing using the AOCOIAC software at www.aocmf.org/classification.

Conclusion

The AOCMF classification system offers a structured orbital fracture assessment tool, which is simple enough for daily routine; however it allows description of complex fractures. It is based on anatomical, functional regions, and subregions that are generally accepted in literature.

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