Classification and epidemiology of orbital fractures diagnosed by computed tomography

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Abstract
Purpose. *To characterize cases of orbital fractures diagnosed by computed tomography (CT) during a time period of one year at our Imaging Department.*
Materials and Methods. *A cross-sectional descriptive study was performed. All cases of orbital fracture diagnosed during a period of one year (from June 2011 to June 2012) were identified. The analyzed variables were: patient age and sex, mechanism of fracture production, fracture location, and need for surgical management. EpiDat 3.1 was used for the data statistics processing.*
Results. *Orbital fractures were diagnosed in 25 of the 167 patients who underwent orbital computed tomography during that period: 5 female (20%) and 20 male (80%). The mean age of the injured patients was 31 years (range 1 to 63 years). The fracture mechanisms were: falls (32%), physical aggression (44%), car accidents (8%), and other causes (16%). Fifteen cases (60%) required surgical management. As regards fracture distribution, 10 of them (40%) were isolated (just one orbital wall involved), while 15 (60%) were combined (2 or more orbital walls involved). Right orbital fractures were found in 11 cases (44%), while left and bilateral fracture locations were detected in 12 (48%) and 2 cases (8%), respectively.*
Conclusion. *The most common types of isolated orbital fractures found in our study were those of the orbital floor and the medial orbital wall, which could be associated with their known anatomical weakness. Mean age and gender distribution of lesions were consistent with those reported by other studies.*
Keywords. *Orbital fracture. Classification. Epidemiology. Computed tomography.*

Introduction

Facial trauma currently constitutes a social and public health problem of relevance because of its frequency and magnitude as well as for its close association with car accidents and episodes of violence and insecurity [1]. Potential consequences include injury of orbital structures, which may lead to significant functional impairment when not diagnosed and managed in a timely and efficient manner. Although the eyeball represents only 0.3% of the total surface area on the human body, loss of vision in one or both eyes has been classified as a 24% or 85% disability, respectively [2].

Orbital fractures are a consequence of middle third facial trauma and occur as a result of the application of forces that overcome the resistance of bone structures forming the orbital cavity. These fractures are very frequently associated with damage to the surrounding soft tissue and they sometimes damage the orbital cavity contents or communicate the orbit with adjacent structures (cranial cavity, paranasal sinuses or nasal cavity).

Orbital fracture management aims at the early and correct restoration of fragments through reduction and internal fixation of the fractured area in order to avoid a defective repair with subsequent resorption and loss of the original bone volume [3].

Even if in the initial management of a poly-trauma patient orbital trauma is not a priority in itself, the evaluation performed after hemodynamic compensation has been achieved, should include a comprehensive assessment of the risk for orbital structures involvement. In this respect, given its high sensitiv-

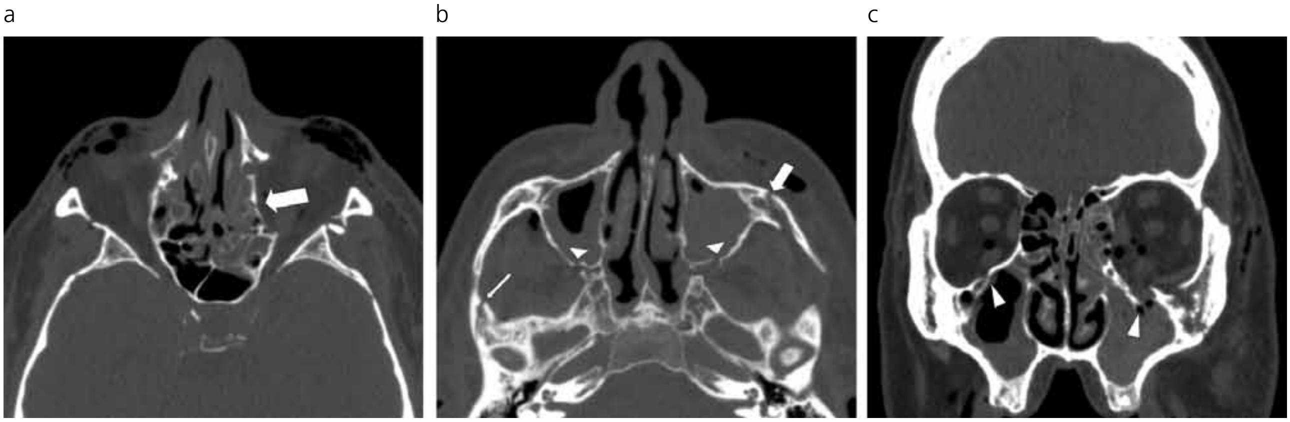


Fig. 1: Multislice CT scan in a 61-year-old male patient who was a victim of a car accident. (a).Axial slice in bone window. The arrow indicates fracture and depression of the left lámina papirácea orbital plate with occupation of ethmoidal cells. (b) Most caudal slice in bone window. Occupation of both maxillary sinuses with multiple bilateral fractures. Note fractures of the posterior maxillary sinus wall (arrowheads), of the left malar bone (thick arrow) and of the right zygomatic arch (thin arrow). (c) Coronal slice in bone window. Fractures of both orbital floors (arrowheads) with inferior displacement towards maxillary sinuses. On the left side, the fracture line involves the infraorbital nerve canal, a finding of great functional and therapeutic importance in this specific case.

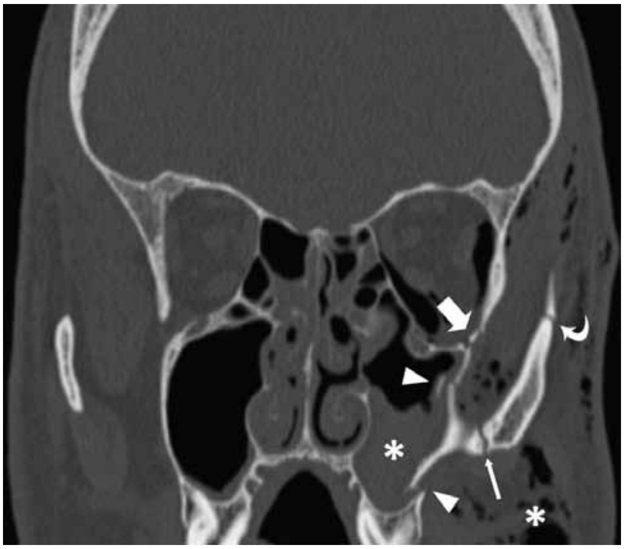


Fig. 2: Multisclice CT in a 38-year-old male patient who was victim of physical aggression. Coronal slice in bone window. Left orbital floor fracture (thick arrow), associated with a displaced double fracture of the maxillary sinus lateral wall (arrowhead), and fracture of the maxillary and temporal processes of the malar bone (thin and curved arrows, respectively). The scan also shows left maxillary sinus hemorrhage and soft tissue (asterisk) and intraorbital emphysema.

ity [2,4,5], the computed tomography (CT) scan is considered the imaging method of choice in the diagnosis of mid-face fracture and other potential consequences of facial trauma.
In addition, knowledge of facial trauma epidemiology may be a relevant tool for clinical suspicion and targeted screening for orbital injury.
The aim of this study is to characterize, according to epidemiology criteria and CT findings, the cases of orbital fractures diagnosed by CT during a time period of one year at our Imaging Department.

Materials and methods

A cross-sectional descriptive study was performed. All orbital (spiral and multislice) CT scan requests entered into the database of our Imaging Department from June 1st, 2011 to June 1st, 2012 were reviewed. Relevant electronic medical records, digital images and their corresponding reports were subsequently reviewed to identify cases of orbital fracture diagnosis. The analyzed variables were: patient age and sex, mechanism of fracture production, fracture location (including injury side), and need for surgical management. Depending on their location, fractures were classified according to a three-category qualitative scale into: isolated (when only one orbital wall was involved), combined or mixed (when more than one orbital wall was involved) or orbital apex fracture. Data collected on the above-mentioned variables was entered into a matrix table previously created using Microsoft Excel 2007. For statistical processing of data, the EpiDat 3.1 software was used.
Orbital CT scans ordered during the specified period were performed using a helical (GE HiSpeed) CT scanner or a 16-detector row multislice CT scanner (Phillips Brilliance). According to current protocols, sagittal scanograms were ob-

Table 1: Absolute and relative frequency distribution according to fracture mechanisms.

Fracture mechanism	Absolute frequency	Relative frequency
Falls	8	32%
Physical aggression	11	44%
Traffic accidents	2	8%
Others	4	16%

Table 2: Absolute and relative frequency distribution of orbital fractures according to type and side involved.

Type of fracture	Right side	Left side	Total
Isolated	5 (20%)	5 (20%	10 (40%)
Combined	8 (32%)	7 (28%)	15 (60%)
Orbital apex	0 (0%)	0 (0%)	0 (0%)
Total	13 (52%)	12 (48%)	25 (100%)

Table 3: Absolute and relative frequency distribution of isolated orbital fractures according to the wall and side involved.

Type of fracture	Right side	Left side	Total
Superior wall	1 (10%)	0 (0%)	1 (10%)
Lateral wall	0 (0%)	0 (0%)	0 (0%)
Medial wall	3 (30%)	1 (10%)	4 (40%)
Inferior wall	1 (10%)	4 (40%)	5 (50%)
Total	5 (50%)	5 (50%)	10 (100%)

tained, with slices from the beginning of the frontal sinus to the floor of the maxillary sinus. With the helical CT scanner, acquisition included 3-mm thick axial and coronal slices at 3-mm intervals, while with the multislice CT scanner, 1-mm axial slices were performed at 0.5 mm with subsequent multiplanar reconstruction. In both cases, acquisitions were performed using the soft tissue protocol and then reconstructions were performed with the bone algorithm.

Results

During the study period, orbital CT scans were ordered from 167 patients; 25 were diagnosed with fracture: 5 were fe-

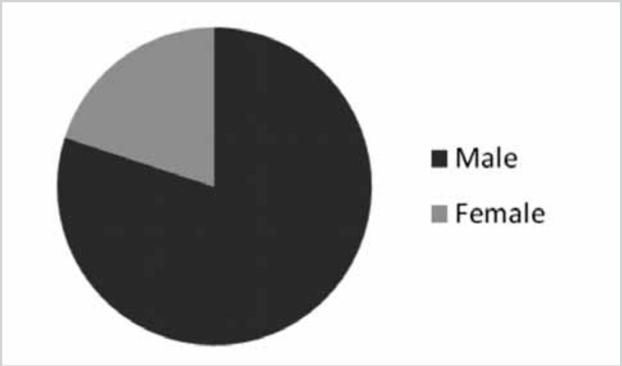


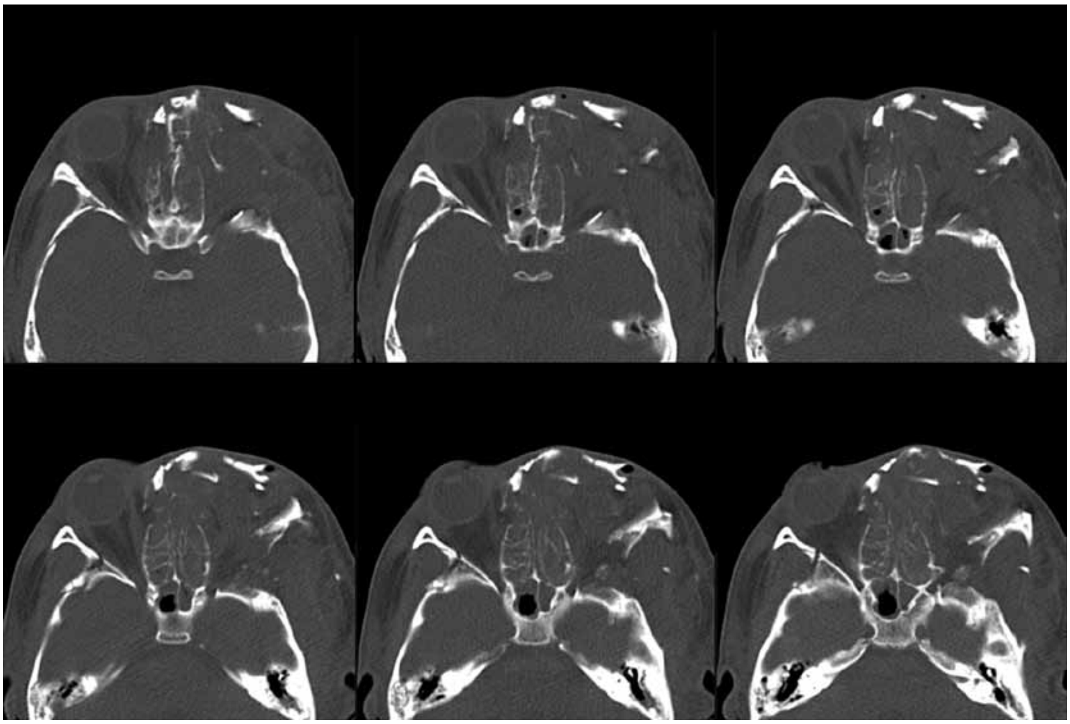
Chart 1: Distribution according to gender of patients with orbital fractures.

male (20%) and 20 were male (80%) (Chart 1). The mean age was 31 years, with an age range from 1 to 63 years.
Frequency distribution according to fracture mechanisms is shown in Table 1, while Tables 2 and 3 summarize frequency distribution according to the type of fracture and the side involved on the one hand, and to the orbital wall involved, on the other.
The need for surgical management of fractures was confirmed in 15 cases (60%).
Figures 1 to 5 show some of the cases reviewed.

Discussion

Although orbital fractures are not themselves life-threatening, they may be associated with intracranial or ocular injuries that require emergency management [6]. They are usually part of complex mid facial trauma and can be managed by different specialists [5]. CT scan is currently the gold standard for assessing orbital fractures (Figs. 1 – 5) and imaging specialists have a key role in the assessment of the extent of bone and soft tissue damage, characterization by different criteria and identification of potential causes of post-traumatic complications [7].
Orbital fractures have been reported to occur more commonly among adult and adolescent males [6] (these data are consistent with our findings). Thus, in a retrospective study of 92 adults with orbital fractures, 72% of cases were male and the mean age was 32 years [8]. Furthermore, in our country, Tomich et al. [9] reported that out of 78 patients with fractures due to maxillofacial trauma, 66% were male and the highest rate of patients with fractures (68%) had an age range between 15 and 35 years. Rodríguez-Perales et al [1] have also reported a mean age of 33 years for the occurrence of orbital fractures, with an age range of 17 to 87 years.

a



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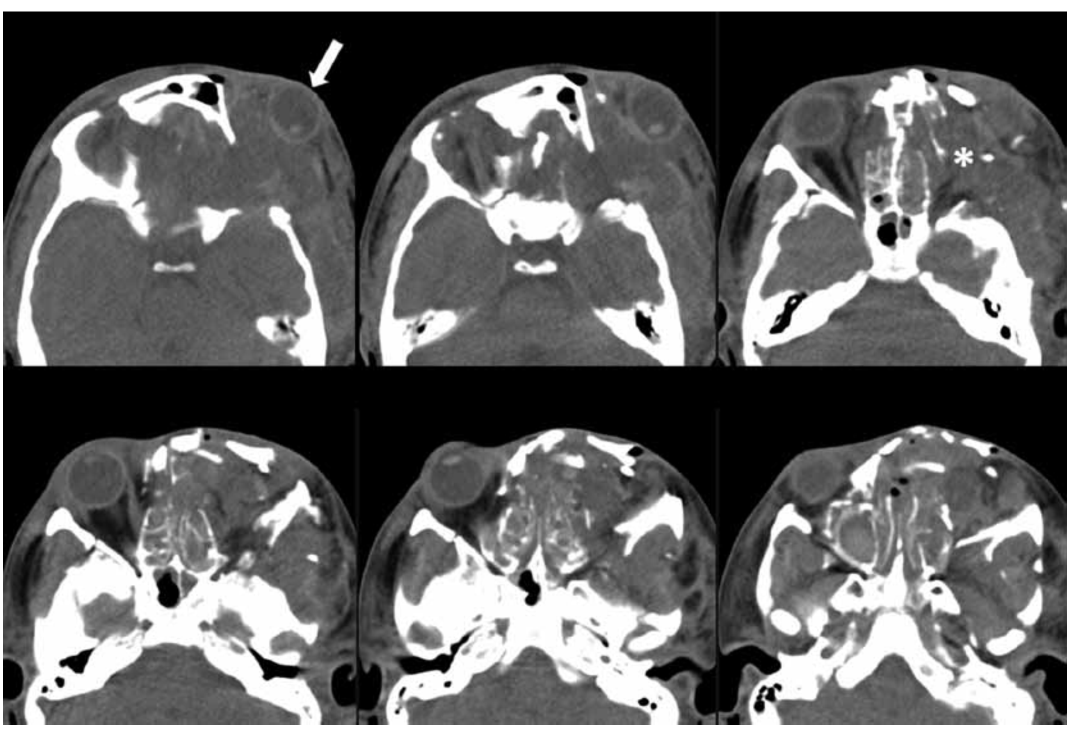

Fig. 3: Helical CT in a 14-year-old male polytrauma patient with severe cranioencephalic trauma, caused by a boat propeller. (a) Axial slices in bone window showing a comminute, extensive and complex fracture, predominantly on the left side. On this side, morphological distortion is severe and disturbs the three-dimensional arrangement of the orbital pyramid. Fragments of the lateral wall of the orbit are anteriorly and medially displaced. (b) Axial slices in soft tissue window. Note the extrusion of the left globe (arrow) and replacement of intra- and extra-conal structures (asterisk).

Fig. 4: Multislice CT of a 53-year-old male patient with facial trauma as a result of a sports accident. (a) Coronal slice in bone window. Evidence of fracture and depression of the left orbital floor, with involvement of the infraorbital nerve canal (arrow). (b) and (c) Coronal and sagittal slices in soft tissue window. Abnormal density of intra- and extra-conal soft tissue (asterisks) due to soft tissue hemorrhage and swelling. Note the thickening of the inferior rectus muscle (arrowheads) and herniation of orbital fat adjacent to the floor towards the left maxillary sinus (arrows). (d) Axial slice in soft tissue window. Anterior protrusion of the globe (thin arrow) with optic nerve elongation (curved arrow).

According to Cruz et al, in most countries, traffic accidents are the leading cause of orbital fracture [5]. This data is consistent with findings reported by Tomich et al. in Argentina. In their study, the most common causes associated with the presence of fracture were traffic accidents (58%), injuries from fights (24%) and sport-related injuries (15%) [9].

Nevertheless, the causes of facial trauma and potential orbital fractures would be largely determined by the socioeconomic context of each population. In this respect, Rodríguez-Perales et al. report that the leading cause of facial trauma and orbital fracture is robbery on public roads, probably related to the local urban reality and problems of alcohol and drug abuse, and the use of weapons [1]. In our study, physical aggression (a category including fights and sport-related injuries) was the most frequent mechanism of fracture, while car accidents had a 5.5-fold lower frequency. This finding would be closely associated with the characteristics and habits of the target population of our hospital, located in an area of the Greater Buenos Aires suburbs. This hospital receives a large number of patients at weekends and on holidays, and it is within easy reach of many sport and recreational facilities.

In agreement with previously reported cases, medial wall and orbital floor fractures were the most common types of isolated fractures found in our study (reflecting the greater a b c

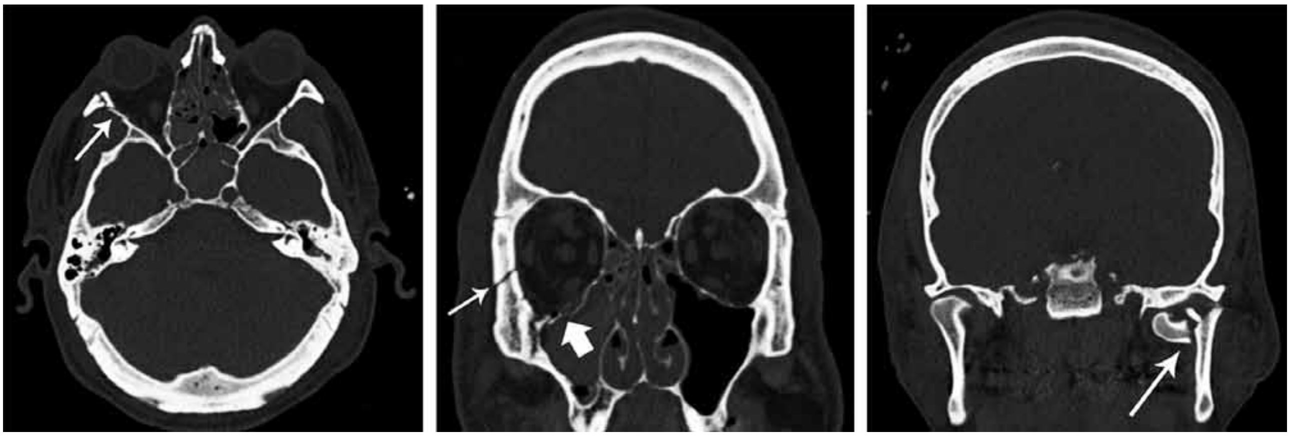

Fig. 5: Multislice CT of a 31-year-old male patient who was a victim of physical aggression. (a) and (b) Axial and coronal slices in bone window. Fracture of the right lateral wall of the orbit (thin arrows) and of the ipsilateral orbital floor (thick arrow), with depression of the floor. (c) Coronal slice in bone window. Evidence of fracture with associated dislocation of the left maxillary condyle (arrow).

structural weakness of these walls).

A special type of fracture of the orbital floor is the blow-out fracture (Figs. 4 and 5). The term was coined by Smith and Regan in 1957 to describe the loss of continuity of the orbital floor or medial wall generated by a direct impact that increases intraorbital pressure causing bone rupture and displacement of orbital contents to the maxillary or ethmoid sinus while the orbital rim remains intact [10,11]. With the subsequent decrease in intraorbital pressure, herniated orbital tissue moves backward and becomes entrapped in between the fractured fragments, causing restrictive strabismus [12].

Since the first description of blow-out fractures, there has been controversy over the exact mechanism causing these injuries and various theories have been proposed. There are three main theories: the first one, known as the hydraulic theory (proposed by Smith and Regan in their original study), postulates that when orbital pressure is increased, the orbital content decompresses through the weakest bone walls; the second one is the globe-to-wall contact theory, which states that when the globe becomes displaced posteriorly, it strikes the wall causing a fracture; and the third theory is the hypothesis of buckling, which states that it is the posterior movement of the orbital rim that causes fracture [2].

Anyway, for Ahmad et al, efforts to separate potential mechanisms of fracture have been misplaced, as in an experimental study conducted in intact cadavers, this group of researchers from London quantified intraocular pressure, forces and their distribution on orbital bone structures and concluded that both buckling and hydraulic mechanisms can cause blow-out fractures, but with different and specific characteristics [13].

Even if orbital fractures may occur in isolation, they commonly occur in multiple walls and they are also usually associated with the involvement of extraorbital bone structures. In a study conducted by Manolidis et al, of the orbital walls, four walls were involved in 5% of cases, three walls in 17% and two in 30 [8]. Lee et al. have reported, in turn, that 62% of cases (of a total of 73 patients with head trauma) had orbital fractures involving multiple sites [4]. In agreement with these findings, in our study, we found that the frequency of fractures involving more than one orbital wall was higher than that involving only one wall (Table 2).

It is thought that the clinical evaluation of ocular injury in an emergency should include at least the two most important ophthalmologic functions: visual acuity and extraocular muscle motility. However, as the assessment of these capabilities may sometimes be difficult due to the severity of the head injury, the extent of soft tissue edema, and/or inadequate cooperation of patients, CT has become a key tool for the initial evaluation of the orbit and its adjacent structures in acute trauma patients [4]. For this reason, the imaging specialist has a key role not only in the correct acquisition and evaluation of images, but also in the timely and efficient communication with the healthcare professionals involved in making decisions on potential therapeutic strategies. Thus, it is important that the radiologist should use a language that is sufficiently understandable for all other specialists involved in the management of a patient with facial and ocular trauma, mainly taking into account that the classification of orbital fractures varies widely and there is often no local consensus on this issue. In fact, Digman classifies orbital fractures into three categories: a) fractures involving the orbital rim; b) intraorbital fractures with no orbital rim involvement; and c) combined (intraorbital and orbital rim) fractures [3], while Manson has proposed a classification of orbital fractures into three groups, depending on whether they were the consequence of low, middle or high energy impact, based on the

comminution and displacement observed on CT. Converse and Smith, in turn, divide fractures into pure (blow-out and blow-in) and impure (complex and involving the orbital rim).
From this perspective, and in order to optimize the report of imaging findings, we think that classification of injuries should be agreed upon among the different members of the group of treating physicians and, if possible, it should be simple, understandable and easy to implement. In our case, we decided to classify the fractures found according to orbital wall location and the number of walls involved, as we considered that this division met the aforementioned requirements and provided the necessary information for all specialists involved in patient management. As regards the potential involvement of the orbital apex (not found in our series), we established a separate category because of the markedly high risk of secondary injury to the optic nerve [(8, 14)].
As we have previously stated, CT is an essential tool for a proper evaluation of orbital fractures and it should include a detailed imaging of the area involved in at least two planes: axial and coronal slices [(15)]. According to Rothfus [(7)], the nature of fracture itself is an important piece of information for clinicians, as it may have prognostic significance. Sharp margins and acute angles of focal fractures or of fractures with marked displacement are highly suggestive of entrapment or incarceration of orbital contents. For orbital floor defects, special attention should be paid to the shape and position of the inferior rectus muscle on coronal CT scan. If the rectus has a normal shape and position, damage to the fascial sling of the globe is unlikely, while if the rectus is round and inferiorly displaced, the fascial sling should be assumed to be disrupted with prolapse of conal contents into the orbital floor defect [(14)]. In addition, in the event of trauma, analyses of CT scans should not overlook indirect sings of fracture, which include, but are not limited to, air-fluid levels, fluid collections within the paranasal sinuses, abnormal density, emphysema and facial soft tissue asymmetry.
Nevertheless, the role of radiologists is not limited to the identification and characterization of orbital fractures; instead, knowledge of the most common post-traumatic orbital injuries and their imaging correlates is also necessary to make a rapid and accurate diagnosis that may help to choose adequate treatment options. As a guide to a comprehensive radiological assessment, Kubal [(16)] provides a classification of post-traumatic orbital injury patterns that includes: a) anterior chamber injuries, b) injuries to the lens, c) open-globe injuries, d) ocular (retinal and choroidal) detachments, e) intraorbital foreign bodies, f) carotid cavernous fistula, and g) injuries to the orbital apex (mainly optic nerve injuries). On the basis of this classification, the author also proposes an image evaluation checklist for a comprehensive evaluation of the orbit and its contents, which is worth reading.

Conclusion

In agreement with previous studies, the most common types of isolated orbital fractures found in our study were those of the orbital floor and the medial orbital wall (which could be associated with their known anatomical weakness). Furthermore, the mean age and gender distribution of patients were consistent with those reported by other studies.
The high proportion of combined fractures and fractures secondary to physical aggression detected by CT scan is a relevant finding that should be considered in the systematic image evaluation and in the management of patients with maxillofacial trauma.

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Conflicts of interest

The authors declare no conflicts of interest