Frequency and types of fractures in maxillofacial traumas. Assessment using Multi-slice Computed Tomography with multiplanar and three-dimensional reconstructions.

Gabriela Tomich, Patricio Baigorria, Nicolás Orlando, Mariano Méjico, Cecilia Costamagna, Roberto Villavicencio

Resumen

Introducción. Los traumatismos maxilofaciales (TMF) representan un motivo de consulta común en los servicios de Urgencias. La compleja anatomía del macizo facial requiere de métodos de imágenes multiplanares para su correcta evaluación.

Objetivos. Describir la frecuencia y tipos de fracturas en una serie de pacientes con TMF evaluados mediante tomografía computada multislice (TCMS) con reconstrucciones multiplanares y tridimensionales.

Materiales y Métodos. Se revisaron en forma retrospectiva las tomografías de macizo facial, solicitadas por TMF a través del servicio de Emergencias durante el periodo junio 2008-diciembre 2009. Se recabaron los siguientes datos: edad, sexo, causa del traumatismo, presencia y tipo de fracturas. Los pacientes fueron evaluados utilizando un TCMS de 8 filas de detectores. En todos los casos se realizaron reconstrucciones multiplanares con ventana de alta resolución para hueso y con ventana para partes blandas, así como reconstrucciones tridimensionales.

Resultados. Fueron realizadas 137 tomografías por TMF, de las cuales 78 (57%) presentaron 131 fracturas. De estos 78 pacientes, 52 (66%) eran hombres y 26 (34%) mujeres. Edad promedio: 33 años (rango: 14-90 años). Causas: 58% accidentes de tránsito; 24% lesiones por enfrentamientos o peleas; 13% lesiones deportivas; y 7% causas varias. Tipo y frecuencia de fracturas: 18.3% fueron de piso de órbita, 16% de senos maxilares, 15.3% de nasales, 13% de mandíbula, 9.2% de las fracturas del complejo zigomático-malar, 9.2% fueron de fracturas Le Fort tipo II-III.

Conclusions. Fractures were more common in males, in the age range from 15 to 35 years old. Most fractures, and the most complex ones, were caused by traffic accidents. The most common fracture, either isolated or associated with other fractures, was the orbital floor fracture.

Palabras clave. Fracturas maxilofaciales. TCMS.

Abstract

Frequency and types of fractures in maxillofacial traumas. Assessment using MDCT with multiplanar and 3D reconstructions.

Introduction. Maxillofacial trauma (MFT) is a common reason for attendance at Emergency Departments. The complex anatomy of the facial bones requires multiplanar imaging techniques for a proper evaluation.

Objectives. To describe frequency and types of fractures in a series of patients with MFT evaluated by multi-slice computed tomography (MDCT) with multiplanar and 3D reconstructions.

Materials and Methods. Facial bone CTs ordered for MFT by the Emergency Department from June 2008 to December 2009 were retrospectively reviewed. The following data were obtained: age, gender, cause of trauma, presence and type of fractures. Patients were evaluated with an 8-channel MDCT. Multiplanar reconstructions were performed in all cases using high resolution bone window and soft tissue window, as well as 3D reconstructions.

Results. One-hundred and thirty-seven CTs were performed for MFT: 78 (57%) showed 131 fractures. Of these 78 patients, 52 (66%) were males and 26 (34%) were females; mean age 33 years old (range: 14-90 yrs.). Causes: 58% were injuries from traffic accidents; 24% were injuries from fights; 13% were sport injuries; and 7% were due to miscellaneous etiologies.

Type and frequency of fractures: 18.3% were orbital floor fractures, 16% were maxillary sinus fractures, 15.3% were nasal fractures, 13% were jaw fractures, 9.2% were orbital fractures, and 12.3% were fractures of the zygomatic-malar complex; two cases of Le Fort II-III fractures were also observed.

Conclusions. Fractures were more common in males, in the age range from 15 to 35 years old. Most fractures, and the most complex ones, were caused by traffic accidents. The most common fracture, either isolated or associated with other fractures, was the orbital floor fracture.

Keywords. Maxillofacial fractures. MDCT.
fractures and/or soft tissue damage require immediate therapy and/or preoperative planning with multiplanar imaging techniques for a proper assessment.

**OBJECTIVES**

To describe the frequency and types of fractures in a series of patients with MFT evaluated by MDCT with multiplanar and 3D reconstructions.

**MATERIALS AND METHODS**

One-hundred and thirty-seven facial bone CTs ordered for MFT by the Emergency Department from June 2008 to December 2009 were retrospectively reviewed. The following data were collected: age, gender, cause of trauma, presence and type of fractures.

Patients were evaluated with an 8-row multi-slice CT scanner (GE Brightspeed) by the following protocol: using a sagittal scout view and bone algorithm slices were programmed from the top of the frontal sinus to the chin, inclusive, with a 1.25-mm thickness at 1.25-mm intervals. Multiplanar reconstructions were performed in all cases using high resolution bone window and soft tissue window, as well as 3D reconstructions.

Fractures found were classified into the following groups: nasal fractures, nasoethmoidal fractures, fractures of the zygomatic-malar complex, orbital floor fractures, maxillary sinus wall fractures, frontal sinus fractures, jaw fractures, Le Fort fractures and other sort of fractures.

**RESULTS**

Of the 137 CTs for MFT reviewed: 78 patients (57%) had 131 fractures. Of these 78 patients, 52 (66%) were males and 26 (34%) were females. The mean age of patients with fractures was 33 years old (range: 14-90 yrs.). Sixty-eight percent of patients with fractures were in the age group between 15 and 35 years old, while only 10% were older than 55. The most common causes were injuries determined by traffic accidents (58%); fights (24%) and sport injuries (13%). The type and frequency of fractures are shown in Table 1.

**DISCUSSION**

Anatomically, the face is divided into five regions: nasal, orbital, zygomatic, maxillary and mandibular. The nasal region is comprised of the nasal bones, lacrimal bones, frontal process of the maxilla, nasal septum and ethmoid cells. The orbital region is composed of seven bones: the maxillary, zygomatic and frontal bones comprise the external orbital skeleton, while the internal orbit includes the lacrimal, palatine, ethmoid and sphenoid bones. The zygomatic region is comprised of the zygomatic process of the frontal bone, the zygomatic bone and the zygomatic process of the maxilla. The maxillary region includes the alveolar process and the bony components of the hard palate. Finally, the mandibular region is composed of the mandible and the temporomandibular joint, and is notable for being the only portion of the facial skeleton that is mobile.

Functionally, these structures are supported by eight pillars or buttresses, and forces directed toward the face are distributed along these buttresses. Four of these pillars are vertical: the nasomaxillary buttress (connections between the maxilla and nasal bones), the zygomaticomaxillary buttress (from the maxilla to the zygomatic region), the pterygomaxillary buttress (from the maxilla to the pterygoid process) and the posterior or mandibular buttress (ascending ramus of the mandible). The four horizontal buttresses include the frontal, zygomatic, maxillary and mandibular buttresses.

The characteristics of fractures resulting from trau-

**Table 1**: Frequency and type of fractures in patients with MFT.

<table>
<thead>
<tr>
<th>TYPE OF FRACTURE</th>
<th>NUMBER (n)</th>
<th>PERCENT (%)</th>
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<tbody>
<tr>
<td>Orbital floor fracture</td>
<td>24</td>
<td>18.3%</td>
</tr>
<tr>
<td>Maxillary sinus wall fractures</td>
<td>21</td>
<td>16%</td>
</tr>
<tr>
<td>Nasal fractures</td>
<td>20</td>
<td>15.3%</td>
</tr>
<tr>
<td>Jaw fractures</td>
<td>17</td>
<td>13%</td>
</tr>
<tr>
<td>Fractures of the zygomatic-malar complex</td>
<td>16</td>
<td>12.3%</td>
</tr>
<tr>
<td>Orbital wall fractures</td>
<td>12</td>
<td>9.2%</td>
</tr>
<tr>
<td>Nasoethmoidal fractures</td>
<td>9</td>
<td>7%</td>
</tr>
<tr>
<td>Frontal sinus fractures</td>
<td>5</td>
<td>3.7%</td>
</tr>
<tr>
<td>Le Fort fractures</td>
<td>2</td>
<td>1.5%</td>
</tr>
<tr>
<td>Other fractures</td>
<td>5</td>
<td>3.7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>131</strong></td>
<td><strong>100%</strong></td>
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ma are determined by a dynamic factor (given by the force and energy of the impact) and by a static factor (given by the anatomic characteristics of the bone involved). A small impact area results in a localized fracture, whereas a large impact area leads to more extensive indirect fractures, because the force is being transmitted over a larger area of bone.

The most common causes of maxillofacial trauma are traffic accidents, injuries from fights, sport accidents or falls. The combination of traffic accidents and injuries from fights account for 80% of maxillofacial fractures.

Facial fractures are classified into central midface fractures, lateral midface fractures and mandibular fractures. Central midface fractures include: nasal, nasoethmoidal, orbital wall, maxillary sinus and Le Fort I and II fractures. Lateral midface fractures include fractures of the zygomatic-malar complex, zygomatic arch fractures and orbital floor fractures, while Le Fort III fractures are combined central and lateral midface fractures. In a series of multi-trauma patients with over 7,000 facial bone fractures, 24.3% affected the mandible and 71.5% affected the central and lateral midface. In our series of patients, the distribution of fractures—according to facial regions—can be observed in Graph 1. Almost one third of fractures simultaneously affected more than one area of the face.

Orbital fractures, because of the complex anatomy of the region, are often associated with maxillary, zygomatic and/or nasal fractures, either in their internal or external region.

Orbital floor fractures were the most common in our series (Fig. 1a), associated in most cases with fractures of the maxillary sinus walls. One of the mechanisms of this fracture is the blow out, first described by Pfeiffer in 1943. This occurs when the force of a direct impact on the eye ball is absorbed by the orbital rim (which remains intact) and is transmitted to the orbital floor, which shatters (usually in the middle third, near the infraorbital canal). The eyeball usually remains undamaged. The presence of an air-fluid level or the complete occupation of the maxillary sinus is common (Fig. 1b); instead, the presence of orbital emphysema is infrequent. Fat protrudes through the fracture line (sign of the pending drop or tear) (Fig. 1c). Herniation of inferior rectus muscle and inferior oblique muscle may also occur and can be associated with diplopia (Fig. d). Muscle entrapment and acute enopthalmos are indications for immediate surgery. Less often, fracture segments can herniate upward into the orbit, which is called blow-in fracture. When there is orbital rim involvement in fractures of the orbital floor, these fractures should be considered separa-
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tely from blow-out fractures, in which, by definition, orbital rims remain intact. Orbital rim involvement has implications for the surgical therapy technique, and therefore it is important to differentiate both types of fractures. Fractures of the orbital floor are clearly seen, mainly on coronal reconstructions from MDCTs (Fig. 1 a, b, c, d).

Other orbital fractures had a frequency of approximately 9%, generally associated with fractures of the ipsilateral maxillary sinus. The most common orbital wall fracture is that of the internal wall, which occurs either as an isolated fracture or in association with other fractures. In 50% of cases it is associated with nasal fractures, suggesting a similar causative mechanism, and in one-third of cases, it is associated with orbital floor fractures. This fracture is more common in males (5:1) and most injuries involve the left orbit, with the most frequent cause being fist fights (Fig. 2 a and b). It is very frequently associated with orbital emphysema from ethmoid cells fractures (Fig. 2 c).

Lateral wall fractures (Fig. 2 d) have been reported to occur at a frequency of approximately 30% in

Fig. 2: Orbital wall fractures (a) MDCT axial slice. Fracture of the internal wall of the left orbit (arrows) involving anterior and middle ethmoidal cells. (b) MDCT axial slice (soft tissue window) of the same patient, showing involvement of the internal rectus muscle (line arrows) and marked soft tissue swelling in the left nasoorbital region (arrows). (c) MDCT axial slice. Fracture of the internal wall of the left orbit with involvement of the internal rectus muscle and small bubble of air at the level of the fracture line (circle) with occupation of ethmoidal cells (asterisk). (d) MDCT axial slice. Fracture with displacement of the external wall of the right orbit with small bubble of air (circle).

Fig. 3: Fracture of the orbital roof (a) MDCT coronal reconstruction. Fracture of the right orbital roof (arrow) and bilateral fracture of the orbital floor (arrowheads) in a patient with serious craniofacial trauma. (b) MDCT sagittal reconstruction. Fracture of the orbital roof with displacement of bone fragment into the orbit (circle). (c) MDCT sagittal reconstruction showing fracture of the orbital roof (circle in 1) with extension to the apex (arrow in 2).
various series. Fractures of the orbital roof (Fig. 3a and b) are rare (occurring at a frequency of 1 to 5%, according to various reports) and the most common causes are traffic accidents. It is associated with skull base fractures (70%) and frontal sinus fractures (50%). When these fractures are secondary to direct impacts, the supraorbital rim is fractured; instead, if the impact force comes through the frontal bone, the thin plate forming the orbital roof is fractured, and the supraorbital rim remains intact. These fractures may extend to the orbital apex and affect neurological structures entering the orbit (Fig. 3c).

Nasal fractures are the most common facial fractures, accounting for 50% of isolated fractures of the face. The nose is the most prominent region of the face, and therefore is frequently affected by traumatic injuries. The extent of disruption of the nasal bones depends on the direction and intensity of the impact. Sixty-six per cent of nasal fractures result from a lateral force and 13% are the result of a frontal impact. A lateral blow to the nose usually causes nasal cartilage depression or fracture of the ipsilateral nasal bone (Fig.
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4 a), while a frontal blow is more commonly associated with fractures of both nasal bones (Fig. 4 b) and of the nasal septum (Fig. 4 c). Furthermore, lateral blows may damage the nasal cartilage (Fig. 4 d and e). This injury may initially go undetected because of the presence of edema and hemorrhage—which may impair physical examination—and, if not adequately treated, it may result in deformity and functional impairment. Rohrich and Adams have devised a classification of nasal fractures that is summarized in Table 2.

In our series, isolated nasal fractures account for approximately 15% of the total, being the third most frequent type of fractures after orbital floor fractures and maxillary sinus fractures. However, probably a large number of nasal traumas were excluded for not having been evaluated by CT. Generally, nasal fractures are apparent on clinical examination and radiographic examination is performed to confirm the diagnosis (CT is performed only upon a maxillofacial surgeon’s request) (7). However, one study demonstrated that 25% of nasal fractures require surgical reduction, despite a negative plain film examination.

Nasoethmoidal fractures (Fig. 5 a and b) occurred at a frequency of 7%. These fractures most often result from a frontal blow over the bridge of the nose, and the nasal pyramid is displaced posteriorly, fracturing the nasal bones, frontal processes of the maxillae, lacrimal bones, ethmoid sinuses, cribriform plate, and nasal septum. They are often clinically associated with hypertelorism and telecanthus, as well as with damage to the lacrimal duct with epiphora. In the floor of the anterior cranial fossa, the dura is firmly adhered to the bone; therefore fractures in this region are related to tearing of the dura with cerebrospinal fluid rhinorrhea and the development of an intracranial pneumocephalus or infection. In one series, 70% of these fractures were caused by traffic accidents, and in over 50% of patients had associated severe nonfacial injuries. Nasoethmoidal fractures are clinically classified according to the integrity of the central bone fragment (Table 3).

Fracture of the zygomatic-malar complex (trimalar or tripod) is the second most common isolated facial fracture and generally result from a direct blow to the lateral midface. The principal lines of fracture involve the three processes of the malar bone (orbital, zygomatic and maxillary). (Fig. 6 a) extending from the lateral orbital wall, down the postero-lateral wall of the maxillary sinus through the zygomatic arch, separating the zygoma and maxilla (Fig. 6 b and c). Clinical signs and symptoms include cheek depression, infraorbital nerve paresthesia, globe entrapment (when there is orbital floor involvement) decreased visual acuity and / or ophthalmoplegia (with orbital apex involvement) and trismus when fracture of the zygomatic arch compresses the temporalis tendon. The presence of significant displacement of fragments,

<table>
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<th>TABLE 2: Classification of nasal fractures.</th>
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<td><strong>TYPES OF FRACTURE</strong></td>
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<tr>
<td>TYPE I</td>
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<td>TYPE II</td>
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<td>TYPE III</td>
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<td>TYPE IV</td>
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<td>TYPE V</td>
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<th>TABLE 3: Classification of nasoethmoidal fractures.</th>
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<tr>
<td><strong>TYPES OF FRACTURE</strong></td>
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<tr>
<td>I</td>
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<td>III</td>
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trismus, entrapment and/or orbital apex involvement are indications for surgery. They are classified according to the direction and magnitude of displacement and bony integrity of the zygoma. This classification was originally described by Knight and North in 1961, using plain films: type 1 (nondisplaced fractures), type 2 (isolated zygomatic arch fracture), type 3 (depressed, nondisplaced fractures), type 4 (medially displaced fractures), type 5 (laterally displaced fractures) and type 6 (complex or comminuted fractures). It is now generally accepted that all displaced fractures require open reduction and fixation. More recently, a new classification system was devised for these fractures (Table 4). In our series, 9.2% of fractures were trimalar fractures and we also observed 4 isolated zygomatic arch fractures. Fractures of the maxillary sinus walls were the second most common fractures (16%). Except for 2 patients who had isolated fractures of the maxillary sinus walls, all other cases were associated with other fractures involving the central midfacial region. Isolated fractures of the maxillary sinus (Fig. 7 a and b) are uncommon and generally consist in depressed fractures of the anterior wall of the maxillary sinus. Mandibular fractures are classified according to the anatomic region involved into: symphyseal fractures, alveolar process fractures, fractures of the body or horizontal ramus, fractures of the angle, fractures of the ascending ramus, coronoid process fractures and fractures of the mandibular condyle. Their rate of occurrence, based on different series, is shown in Table 5. Condylar fractures are subclassified into intra- and extracapsular. Intracapsular fractures are amenable to medical treatment, while extracapsular fractures require surgical treatment; therefore their exact localization has important therapeutic implications. The most common causes of mandibular fractures are traffic accidents and injuries from fights or falls. Knowledge of the mechanism of trauma and the magnitude and direction of the force involved helps to determine the type of injury. The most common signs and symptoms include pain, trismus, difficulty chewing, malocclusion, swelling and hematoma in the mandibular region. Lost and fractured teeth should be accurately evaluated. Any change in occlusion is highly suggestive of mandibular fracture. Ecchymosis in the floor of the mouth is a diagnostic sign of a horizontal ramus or symphyseal fracture.

In our series, mandibular fractures accounted for 13% (n=17) of the total: 3 symphyseal/parasymphysial fractures (Fig. 8 a), 4 fractures of the horizontal ramus (Fig. 8 b and c), 4 fractures of the ascending ramus (Fig. 8 d and e) and 1 fracture of the angle (Fig. 8 f); all other patients had complex mandibular fractures.

Table 4: Classification of fractures of the zygomatic-malar complex.

<table>
<thead>
<tr>
<th>TYPES OF FRACTURE</th>
<th>CHARACTERISTICS</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>Fracture involving only one of the three processes of the malar bone; zygomatic arch, external orbital rim or infraorbital rim.</td>
</tr>
<tr>
<td>B</td>
<td>Displaced trimalar fracture</td>
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<tr>
<td>C</td>
<td>Comminuted trimalar fracture</td>
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Fig. 5. Nasoethmoid fractures (a) MDCT axial slice. Bilateral fracture of nasal bones (arrows), fractures of the ethmoid cells (curved arrow), occupation of the left sphenoid sinus (asterisk) and fracture of the sphenoid bone (hollow arrow). (b) MDCT axial slice (soft tissue window) of the same patient, showing fracture of ethmoid cells (white arrow), fracture of the sphenoid bone (black arrow), fracture of the external wall of the left orbit (circle); pneumocephalus is also observed.
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Table 5: Frequency of mandibular fractures according to their location.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>FREQUENCY (*)</th>
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<tbody>
<tr>
<td>Body or horizontal ramus</td>
<td>30 – 40%</td>
</tr>
<tr>
<td>Angle</td>
<td>25 – 31%</td>
</tr>
<tr>
<td>Condyle</td>
<td>15 – 17%</td>
</tr>
<tr>
<td>Symphysis</td>
<td>7 – 15%</td>
</tr>
<tr>
<td>Ascending ramus</td>
<td>3 – 9%</td>
</tr>
<tr>
<td>Alveolar process</td>
<td>2 – 4%</td>
</tr>
<tr>
<td>Coronoid process</td>
<td>1 – 2%</td>
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(*) According to different series of the literature reviewed (3,13).

fractures with double or triple fracture lines and simultaneous involvement of the various bone regions.

Bilateral or multiple fractures account for up to 50% of mandibular fractures and often respond to coup-countercoup injuries (10). Common coup-countercoup patterns include: angle and contralateral body (Fig. 9), bilateral angle, and angle and contralateral condyle (3). Imaging methods should determine the presence, number and exact location of fractures, as well as the dislocation of bone fragments, as such data are essential for a proper therapeutic management. Isolated mandibular fractures may be evaluated by an orthopanoramic radiograph; however, this method is inadequate to evaluate nondisplaced symphyseal fractures or fractures of the posterior region of the mandible and of the condyle, because of structures overlapping (3,13). Six of 7 unrecognized mandibular fractures are located in the posterior region and the most common fracture is of the condyle (13).

It was found that CT scan was 100% sensitive in detecting fractures of the mandible, whereas orthopanoramic radiograph and conventional x-rays had a sensitivity of 86% (3). This is the method of choice to assess mandibular fractures and should be performed in all patients with suspected mandibular fractures and not only in selected cases (3,13). MDCT is a valuable tool in the diagnosis of mandibular fractures, as the integration of axial imaging with multiplanar and 3D reconstructions reveals the details of the injury anatomy, leading to a correct diagnosis in the vast majority of cases (13,14). Imaging on sagittal plane are very useful in the evaluation of condylar fractures (3). Three-dimensional reconstructions are very helpful to plan surgical treatment, particularly in cases of fractures with multiple fragments and/or displacement of bone fragments (13,14,20). These results, together with the possibility of manipulating perspective in 3D images, reinforce the importance of its use in the surgical planning and evaluation of treatment in all mandibular fractures (Fig. 10), and especially in condylar fractures (17).

The objectives of treatment are to stabilize and repair facial anatomy, restore the chewing mechanism, relieve acute symptoms and prevent secondary late complications: pseudoarthrosis, mandibular osteomyelitis, ischemic necrosis of the condylar head and posttraumatic injury of the articular disc (3). Magnetic resonance imaging (MRI) is the method of choice to detect these complications (5) and it is also the best imaging tool in the evaluation of the temporomandibular joint, before and after surgical treatment (13).

In 1901, Le Fort published his original work, describing three patterns of facial complex fractures. Le Fort outlined three lines of fracture reflecting the relative areas of weakness within the facial skeletal structure. Le Fort’s original description regarded symmetric fractures extending back to and involving the pterygoid plates.

In Le Fort type I or Guérin’s fracture, the fracture runs transversely with involvement of alveolar zygomatic arch, the internal walls of both maxillary sinuses, the vomer and the internal pterygoid plates. This results in a separation of the hard palate from the facial bones with dislocation and displacement of the hard palate (2). This fracture results from a blow delivered over the upper lip (3).

Le Fort type II fracture (Fig. 11 a, b and c) is also called pyramidal fracture because the central portion of the face becomes separated as a pyramidal fragment. The fracture line runs across the nose bridge, through both lacrimal bones, the internal wall and floor of both orbits, obliquely across the anterior maxillary sinus, extending posteriorly to the lower pterygoid plates (2). It often results from a broad blow over the central facial region and it is one of the most severe central midfacial fractures (4).

Le Fort type III fracture causes the separation of the entire facial skeleton from the skull base. The fracture line runs bilaterally from the nose bridge to the lacrimal bone, the orbital internal wall and floor to the inferior orbital fissure; at this point, one portion of the fracture line extends across the lateral orbital wall to end near the zygomatico-frontal sutures, while a second fracture line extends from the orbital floor to the lower portion of the pterygoid plates. The zygomatic arches also are fractured, thereby completing the separation of the facial skeleton from the skull base (5).

The main difference between Le Fort type II and III fractures is that the latter include the lateral orbital wall and zygoma (5). In our series, only 2 patients had fracture patterns consistent with those described above: one Le Fort type II fracture in a 22-year old male, caused by a traffic accident and a combined Le Fort II/III fracture in a 29-year old male patient who, after loosing consciousness, fell from a height of several meters. Some Le Fort fractures pears are as follows: 1) all Le Fort fractures involve pterygoid plates; 2) any combinations of Le Fort I, II and III patterns can occur; and 3) a displaced unilateral Le Fort fracture is possible only with a sagittal and parasagittal hard palate fracture (6).
Although not technically part of the facial skeleton, the frontal bone is particularly prominent and often injured in patients with maxillofacial trauma. These fractures are the result of either direct trauma or an extension of a skull fracture. Sixty-seven percent are limited to the anterior table, 28% involve both the anterior and posterior sinus walls and only 5% are limited to the posterior sinus table, generally as an extension of a skull fracture. Complex fractures of both the anterior and posterior frontal sinus tables usually are
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Fig. 8: Mandibular fractures (a) MDCT axial slices (right) and three-dimensional reconstruction, (left) lower view. Right symphyseal/parasymphyseal mandibular fracture involving the alveolar process of the mandible (arrows). (b) MDCT axial slice. Fracture with double line of the left horizontal ramus of the mandible (arrows) with soft tissue swelling in the floor of the mouth and narrowed oropharyngeal lumen (asterisk). (c) MDCT VR reconstruction. Fracture of the left horizontal ramus with involvement of the alveolar process and lost tooth (circle). (d) MDCT coronal reconstruction. Fracture of the right ascending ramus of the mandible with displacement (arrow). (e) MDCT coronal reconstruction. Fracture of the left ascending ramus at subcondylar location with lateral displacement of the proximal fragment. (f) MDCT sagittal reconstruction. Subcondylar fracture of the ascending ramus of the mandible (arrow). (g) MDCT VR reconstruction, slightly oblique view. Fracture with no displacement of the left angle of the mandible.

Fig. 9: Mandibular fracture by coup-countercoup injury mechanism: MDCT three-dimensional reconstruction. Double-line fracture of the mandible secondary to coup-countercoup injury mechanism: fracture of the right angle and of the left horizontal ramus.

associated with other midfacial or skull fractures (45). Fractures of the anterior table are the least serious injury and often do not require treatment (Fig. 12 a and c). Fractures involving the anterior and posterior tables are more serious, because they are associated with skull fractures and involvement of the central nervous system (Fig. 12 b). Posterior table fractures are often associated with pneumocephalus (Fig. 12 d). The simplest classification scheme for frontal sinus fractures requires a description of both tables and the patency of the nasofrontal duct (Table 6) (46). Frontal sinus fractures occurred at a frequency of approximately 4% in our patients and the most common injury was the isolated anterior table fracture (only one patient had fracture of the anterior and posterior tables associated with orbital and maxillary sinus fractures). We did not observed isolated posterior table fractures. Approximately 10% of patients with frontal sinus fracture experience com-
Complications: headache, chronic pain, postoperative infections and posttraumatic deformity.

Clinically, maxillofacial fracture can be suspected in a patient with trauma for the presence of certain clinical signs, although such signs may be initially concealed by overlying edema, hemorrhage and soft tissue swelling. Imaging studies are required for fracture confirmation and characterization.

At present, computed tomography (CT) is the most widely accepted method in the evaluation of patients with maxillofacial trauma, as it makes it possible to identify and quantify fractures, recognize their true extent and if there are bone displacements or not, as well as to assess soft tissue injuries. MDCT provides high-quality imaging in the three planes and excellent 3D reconstructions. The latter are particularly useful to assess bony architecture in large comminuted, displaced, and complex fractures involving multiple planes. Furthermore, they are an excellent communication tool with the surgeons, as in the case of complex fractures, they allow an adequate visualization and easy interpretation of the fracture segments and their relationship to one another. This is very helpful when deciding on the most suitable preoperative planning for each patient. Essentially, they recreate the surgeon’s complex mental process of visualizing fractures in preoperative planning.

Fox found that 3D imaging was more rapidly and effectively interpreted by clinicians and surgeons than 2D imaging. Reuben et al. showed that non-radiologists specialists preferred 3D reconstructions to 2D CT images in patients with MFT. Patients incur no additional risks and experience no overexposure to radiation, as 3D images are obtained by reformatting the original 2D images.

Imaging evaluation of facial injuries cannot be postponed and multi-trauma patients undergoing CT of the head should be examined for facial injuries at the same time. The speed of MDCT permits CT examination of patients who, would otherwise not tolerate it (such as critical or elderly patients). Early diagnosis and treatment of maxillofacial traumas prevent potential immediate and/or late complications, including but not limited to chronic pain, functional deficits and cranial nerve palsy.

The role of MRI in the evaluation of MFTs is limited in critical patients because of longer image acquisition times and less definition of cortical bone than CT scans; however, MRI provides valuable information about soft tissue injuries, patients with neurological deficits, visual or extraocular muscle impairment, and fractures with a high probability of associated intracranial injuries.

In our series, other injuries associated with facial fractures included: skull base fractures associated with Le Fort II fracture and temporal bone fracture associated with complex fracture of the ipsilateral orbit. According to various series, 1 to 10% of patients with facial trauma had cervical spine injuries, most of which were asymptomatic. Therefore, routine workup of these patients should include at least one CT of the upper cervical spine. In addition, 50% of patients with MFT have intracranial injuries. Fractures of the upper face are associated with increased likelihood of lower cervical spine injuries and intracranial injuries; unilateral midface injuries are associated with basilar skull fractures; unilateral mandible injuries are associated with upper cervical spine injuries, and severe facial injuries are associated with severe basilar skull fractures. Knowledge of these patterns should lead to extend the examination to the skull and cervical spine in patients being scanned by CT for MFT, whenever this is possible depending on the patient’s condition and available resources.

**Fig. 11:** Le Fort type II fracture (a) MDCT coronal reconstruction. Bilateral fracture of the orbital floor and inferior rim (arrows) associated with fracture of the nasofrontal suture (hollow arrow) and fracture of anterior walls of both maxillary sinuses (arrowheads). (b) MDCT axial slice. Bilateral fracture of anterior and posterolateral walls of maxillary sinuses (circles). Note that both zygomatic processes are intact (arrows). (c) MDCT coronal reconstruction. Bilateral fracture of pterygoid plates (circles).
**Frequency and types of fractures in maxillofacial traumas**

**Table 6: Frontal bone fractures: clinical significance.**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>CLINICAL SIGNIFICANCE</th>
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</thead>
<tbody>
<tr>
<td>Isolated anterior table fracture</td>
<td>If displacement is greater than width of anterior table, requires open reduction</td>
</tr>
<tr>
<td>Posterior table fracture</td>
<td>By definition, compound skull fracture, requires antibiotic treatment at a minimum. Consider possible cerebrospinal fluid leak.</td>
</tr>
<tr>
<td>Nasofrontal duct involvement</td>
<td>If involved, requires operative intervention.</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

In our series, fractures were more common in males, in the age range from 15 to 35 years old. Most fractures, and the most complex ones, were caused by traffic accidents. The most common fracture, either isolated or associated with other fractures, was the orbital floor fracture. At present, MDCT is the method of choice in the evaluation of maxillofacial traumas, as it does not only allow determination of the presence, location and extent of fractures, but also a simultaneous assessment of soft tissues and adequate preoperative planning when necessary. For the latter purpose, 3D reconstructions are highly valuable, as they allow the surgeon to have direct and real visualization of fractured segments and their relationship to one another.

**Bibliography**