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Radiographic Diagnosis of Maxillofacial Trauma

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Abstract: ***Background**: Maxillofacial traumas (MFTs) are gradually becoming common reason for presenting at emergency room. Nowadays, these traumas formed a social disease because of an increasing frequency and magnitude of traffic accidents, as well as the growing incidents of violence in urban. In initial phase of trauma, an efficient imaging assessment of patients with MFT is crucial. Once patient compensation has been achieved, to detect fractures and/or soft tissue damage requires immediate therapy and preoperative planning with required imaging techniques for a proper assessment. **Aim**: The study aims to highlight perspectives on current imaging modalities used for maxillofacial trauma and to provide an insight into the influence, both technologic and external, on future developments and applications. **Conclusion**: Correct imaging acquisition, systematic analysis and interpretation according to the anatomic and surgical relevant structures in the maxillofacial regions are essential for an accurate, reproducible, and comprehensive diagnosis in maxillofacial trauma.*

Keywords: Maxillofacial fracture, CT Scan, MRI, AOCMF, Midface level

1. Introduction

Injury to the face can occur to include the dentition or maxillofacial skeleton in isolation, or in combination with neck, multisystem, or cranial fractures. The maxillofacial region is the most exposed part of the body and is more vulnerable to trauma. Trauma is one of the major causes of death among people under 40 years of age. [1, 2]Major causes for maxillofacial fracture as reported worldwide are interpersonal violence, traffic accidents, falls and sports injuries. [3]Road traffic accidents (RTA) contribute significantly to mortality and morbidity throughout the world and in large numbers in developing countries. Reports reveal that 20% to 60% of all road traffic injuries involve some form of maxillofacial injury, and 62% involve motorcycles. The prevalence of maxillofacial injuries varies from 17% to 69%, and this large difference might be due to various environmental factors, socioeconomic conditions, cultural reasons, and traffic rules. In the present study, RTA accounted for 73.8% of injuries, and MTW were the major (90.9%) cause in injuries that involved skids and falls in collisions with other vehicles, including riders, pillion riders, and pedestrians.[4]

While our diagnostic capabilities for assessing and quantifying the effects of facial trauma have improved since the 1940s, the increasing complexity of involvement places additional demands to provide comprehensive assessment to assist in treatment planning of surgical repair. Until a few years ago, clinical evaluation assisted by conventional X-rays was the imaging standard for cranio cerebral and facial trauma. Today, however, computed tomography (CT) has become the primary imaging method, along with significant technical improvement, especially with the development of multi-sclice CT.[5]

Conventional X-rays are relatively sensitive to cranial vault fractures, but insensitive to fracture of skull base and facial skeleton. CT enables a precise diagnosis of all kind of fractures of the facial skeleton and skull base, and additionally delivers information about intracranial bleeding and injuries to cerebrum. In the panfacial trauma patients, CT can be extended to the cervical spine as well as trunk if necessary. Thus, conventional X-rays of the skull are no longer used in the case of head trauma or poly-traumatized patient.[6]

Maxillofacial traumas (MFTs) are one of the most frequently encountered emergencies in emergency department. Clinically, maxillofacial fractures can be conjectured in a trauma patient for the presence of certain clinical signs, though such signs may be primarily obscured by overlying edema, bleeding and soft tissue swelling. [7] Accuracy in detection of injuries in MFTs has significantly improved due to rapid progression in diagnostic imaging. The main objective of diagnostic imaging is to detect site and number of facial fractures. This review article aims in providing conventional imaging, multiplanar imaging techniques and 3 reconstructive methods which are beneficial for understanding the pattern of fractures and for better clinical and surgical management.

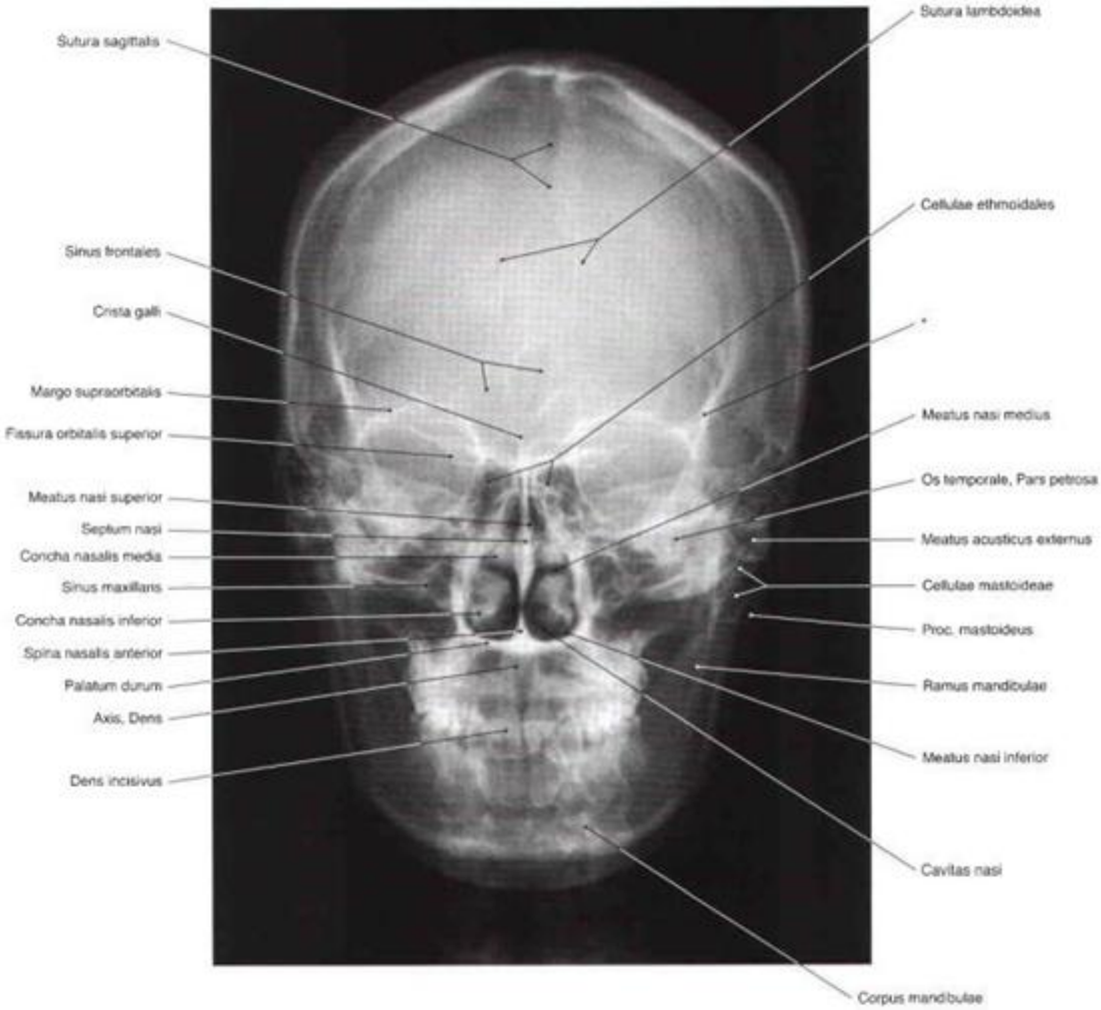

Figure 1: Facial radioanatomy[8]

Maxillofacial Anatomy

The maxillofacial anatomy is divided into upper, middle, and lower thirds. The upper third of the face consists of the frontal bone (including the frontal sinuses) and is outlined from the middle third by the superior orbital rims and walls. The middle third of the face extends superiorly from the superior orbital rims to the maxilla inferiorly and thus includes the orbits, the nasal cavity, and all paranasal sinus except frontal. The middle third of the face is delineated posterolaterally by the zygomaticotemporal posteromedially by the pterygoid the midface to the calvaria and later connects it to the skull base. The lower third of the face includes the mandible and TMJ. [8]

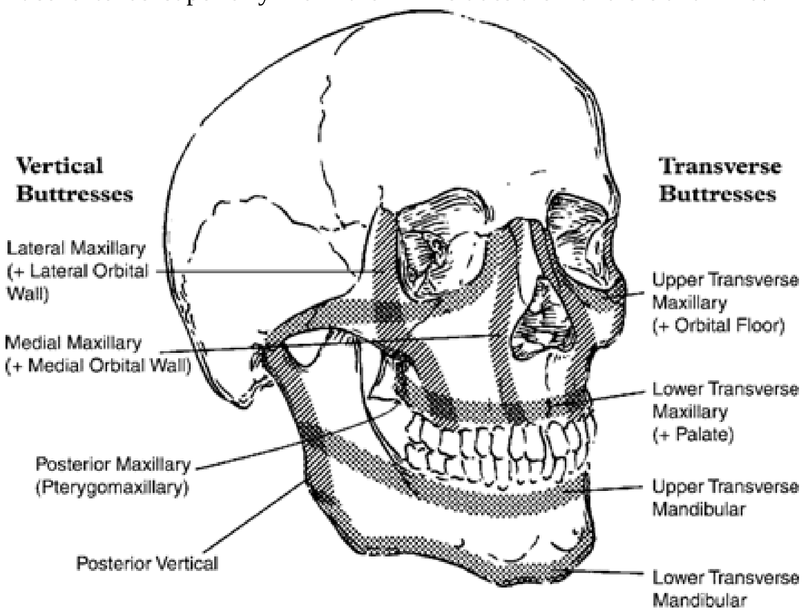

Figure 2: Drawing of the adult skull shows the four paired vertical buttresses and the four transverse buttresses, all of which exist in areas of relative increased bone thickness[9]

The facial skeleton contains four paired vertical buttresses: the lateral, medial, and posterior maxillary, and posterior vertical mandibular buttresses and four paired vertical buttresses: the upper maxillary, lower transverse maxillary, upper mandibular, and lower transverse mandibular buttresses. Disruption of these rigid structures may produce the midface instability and potential facial deformity associated with Le Fort fractures (**Figure 2**).[9]

Imaging Modalities in Maxillofacial Trauma

Computed Tomography

Plain radiography is less helpful in pediatrics than in adults particularly in mid face region where poorly developed sinuses and tooth buds occupy space and obscure skeletal anatomic landmark. Here CT scan become the gold standard of care for imaging paediatric maxillofacial trauma victims. CT is the modality of choice for the evaluation of complex facial fractures, especially those involving the frontal sinus, nasoethmoidal region and the orbital. The 3-D CT as most useful in imaging comminuted fracture of the middle third of the face and zygomaticomaxillary complex (ZMC). These 3-D CT scan altered or cancelled surgical procedures, particularly in nasoorbito-ethmoid (NOE) fractures. CT provides the highest accuracy for not only for the identification of fractures involving disruption of the orbital rim, but also in soft tissue assessment in orbital blow-out and blow-in fractures. Axial and coronal CT are adequate for diagnosis of medial orbital wall fractures. [10]

In the evaluation of the location of bone chips (**Figure 3-4**), 2D reconstruction revealed the highest sensitivity in imaging of bone chips within the orbital walls, as well as superior and medial wall of the maxillary sinus. Two-dimensional reconstructions and transverse imaging turned out to be equally sensitive and specific in imaging of free, dislocated bone chips within the posterior wall of frontal sinus, and the lateral wall of the maxillary sinus. They were also much more advantageous than the 3D imaging. The 3D imaging is the most precise in visualizing free bone chips in the anterior wall of the frontal sinus, anterior wall of the maxillary sinus, and condylar process, branches and body of the mandible, zygomatic arch, nasal bones, and zygomatic bones, in fractures of 'tripod' type. It turned out to be useless in the evaluation of the medial wall of the maxillary sinus.[11]

In the evaluation of the fracture fissures, 2D reconstructions revealed the highest sensitivity for most of the locations. This was especially true for fractures within the inferior orbital wall and the superior wall of the maxillary sinus. The highest sensitivity of imaging in the transverse plane was observed for fractures in the anterior wall of the maxillary sinus and in the lateral wall of the maxillary sinus (**Figure 5**). The highest sensitivity of 3D reconstructions was observed for fractures in the maxillary bone, zygomatic arches, nasal bones, as well as body and branches of the mandible (**Figures 6-7**). Three-dimensional reconstructions turned out to be useless in the evaluation of fractures within the medial orbital wall and in the medial wall of the maxillary sinus.[11]

Figure 3: MPR coronal reconstruction. Fracture of the anterior wall of the right frontal sinus. Frontal sinus filled with liquid[11]

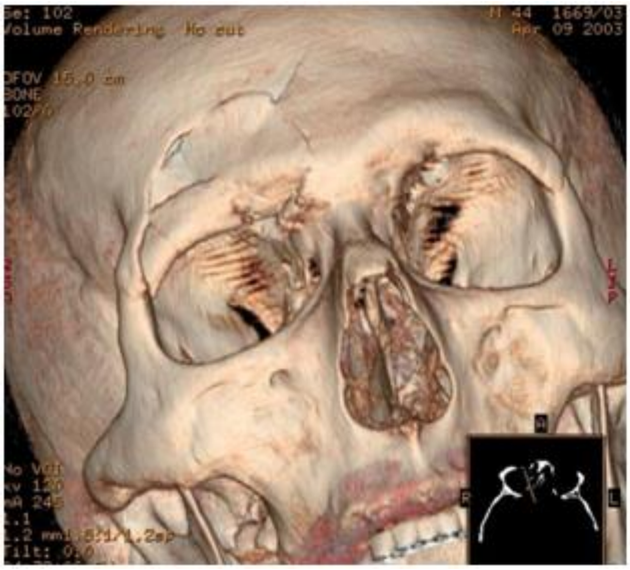

Figure 4: 3D reconstruction of CT examination. Fracture of the anterior wall of right frontal sinus and upper margin of right orbit[11]

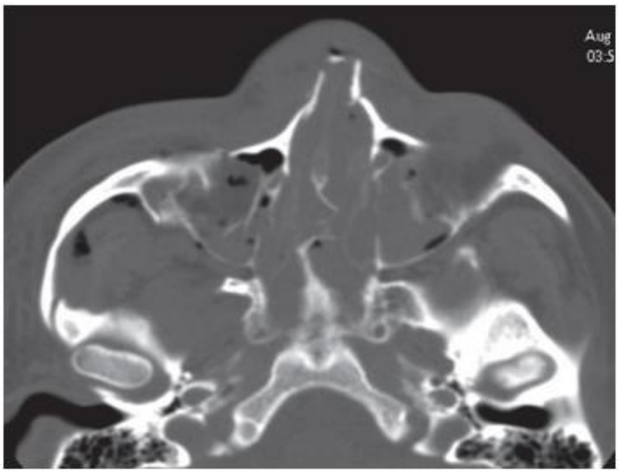

Figure 5: Axial CT scan. Multiple fractures of nasal bones, maxillary sinuses, orbits and nasal septum. Liquid in maxillary sinuses[11]

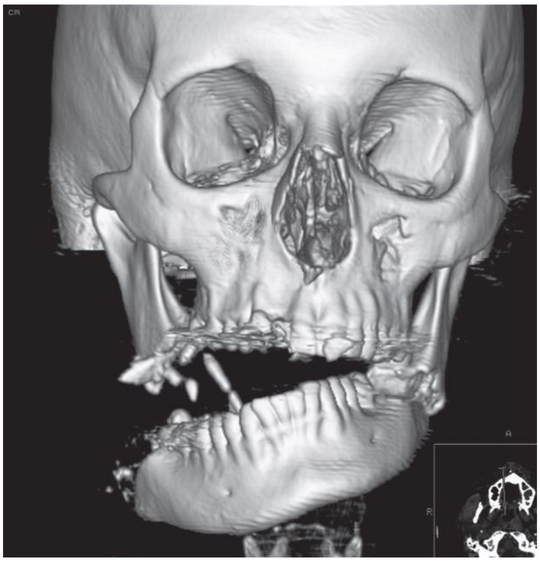

Figure 6: The 3D reconstruction of CT examination. Multifocal fracture of mandible[11]

A CT of head is obligatory if the patient has sustained a loss of consciousness due to trauma. The major drawback of CT is the exposure of the patient to ionizing radiation as well as its higher cost. So the use of CT for postoperative follow-up examinations has to be confined to certain cases, where information about fine structures such as optic nerve is needed[9].

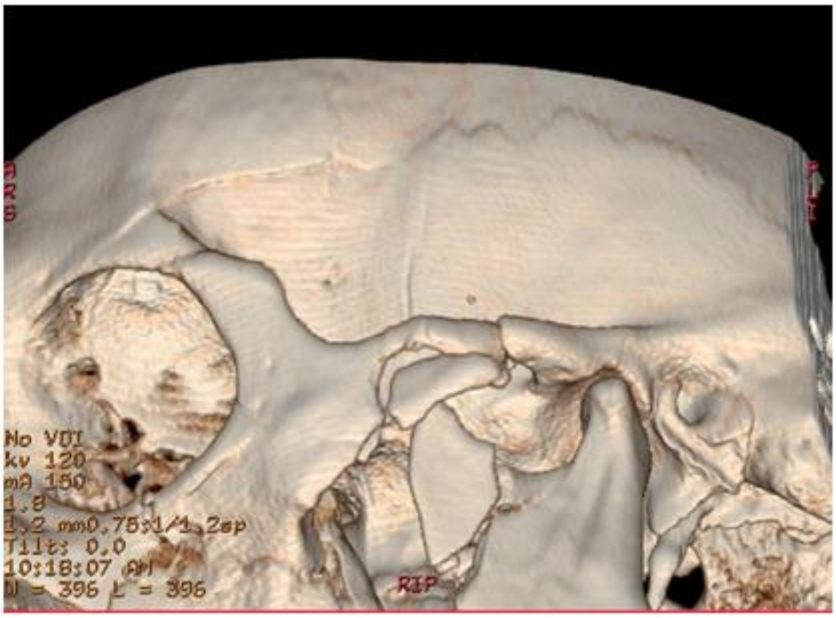

Figure 7: 3D reconstruction of CT examination. Fracture of the left zygomatic arch. A fracture fragment is seen[11]

Ultrasonography (USG)

Recently, USG has been proposed as a complementary diagnostic procedure to augment CT in the assessment of patients with midfacial fracture as ultrasonography is easy and quick to be performed; it is noninvasive and free of any risks. However, its use is restricted to fractures of the orbital margin and nasal bone, zygomatic arch, and the anterior wall of the frontal sinus. In addition, it is unable to provide true coronal scans and unable to detect non-dislocated fractures.[12, 13]

In maxillofacial surgery, it is relatively a new diagnostic aid. The USG examination has been used to evaluate various masses in the neck and cysts, tumors, swellings, and similar processes in soft tissues of the cranio-facial region. It offers potential advantage because it can be performed noninvasively, repeatedly, and easily, even at the bed side. With the aid of high-resolution transducer, ultrasound shows the internal muscle structures more clearly than does CT. USG is an effective diagnostic tool to confirm abscess formation in the superficial facial spaces and is highly predictable in detecting the stage of infection (Figures 1, 2 and 3). It has the ability to pinpoint the relation of the abscess to the overlying skin, accurately measure the dimensions of the abscess cavity, and its precise depth below the skin surface.[14, 15]

The principle of USG is based on the fact that, there are large differences in the impedance for ultrasound waves between soft tissue and air, and between soft tissue and bone. Bone and air are absolute barriers to an ultrasound beam, this means that no image within or behind bony or air containing structure can be produced by ultrasound. Therefore some regions of maxillofacial field cannot be evaluated by ultrasound, such as the retropharyngeal region and paranasal sinuses. No echoes are returned by fluids and thus USG is very sensitive in detecting fluid collections as in case of maxillofacial infections.[16]

Friedrich et al[17] found that the sonography is a reliable method as an imaging modality in cases of suspected midfacial fractures. Also, the displaced fracture of orbit zygomatic arch and malar bone were better seen in sonography than undisplaced fractures. They found that the major difficulty in the use of sonography in the diagnosis of midfacial fractures; was the verification of nondisplaced fractures without the presence of a step-like structure or dislocation, there is always the danger that the fracture may remain unnoticed.[17] The sensitivity and specificity of ultrasound in detecting orbital fractures were 56–100% and 85–100%, respectively, whilst that of nasal fractures were 90–100% and 98–100%, respectively. Sensitivity and specificity of ultrasonography in detecting zygomatic fractures were >90%. For mandibular fractures, the sensitivity and specificity was 66–100% and 52– 100%, respectively. Much evidence justifies the use of diagnostic ultrasonography in maxillofacial fractures, especially fractures involving the nasal bone, orbital walls, anterior maxillary wall and zygomatic complex. The sensitivity and specificity of ultrasonography is generally comparable with CT.[18]

Magnetic Resonance Imaging (MRI)

MRI is an imaging method that uses radiowaves rather than X-rays, M R scanning is more time consuming than CT and is much less effective in imaging bone than CT. MRI is the technique of choice in the evaluation of TMJ pathology. Its excellent soft tissue contrast resolution makes it ideal for the detection of internal derangement of the joint, and it can be used to show joint effusion, synovitis, erosion and associated bone marrow edema. It has an adjunctive role to CT in the assessment of orbital soft tissues and in particular blow out fractures 43. It can also be used to look for cerebrospinal fluid (CSF) leak after skull base injuries. A rare complication of skull base trauma is a carotid – cavernous sinus fistula. In this case MRI and MR angiography are helpful in making diagnosis. In addition, cardiac pacemakers and other implanted electronic devices are contra indications for MRI[10, 15]

Classification in Maxillofacial Injuries

The AOCMF Classification Group developed a hierarchical three-level CMF classification system with increasing level of complexity and details. The basic level 1 system differentiates fracture location in the mandible (code 91), midface (code 92), skull base (code 93), and cranial vault (code 94); the levels 2 and 3 focus on defining fracture location and morphology within more detailed regions and subregions. This system was developed for use in patients with a mature skeleton, whose trauma is not older than 10 days at the time of imaging studies. One of the pillars of proper interpretation of imaging modalities evaluating craniomaxillofacial (CMF) fractures is the knowledge of indirect and direct radiographic fracture signs in the CMF area.1 These signs are equally important to be considered in the evaluation of conventional X-ray studies as well as CT and MRI. Indirect fracture signs include soft tissue swelling, paranasal sinus opacifications or air/fluid levels, and localized air collections (soft tissue emphysema). Direct fracture signs refer to disruptions of cortical bone, abnormal linear densities (especially in plain films), cortical duplication, absent bone structures, abnormal angulation of anatomic structures, and displaced bone segments. Specific CMF regions also need anatomic definitions of relevant structures to rule out fractures. Thus, anatomic knowledge of key structures in the mandible, midface, skull base, and cranial vault are very important for adequate evaluation of different fracture signs.[19]

Mid face fractures can be divided into:

a) Central mid face fracture

It includes nasal, naso orbito ethmoid (NOE) fractures, isolated maxillary fractures and the Le Fort fractures. The classical Le Fort fractures are uncommonly seen in pure form. Fractures of the nasal bone are the commonest fractures in the maxillofacial region and are adequately assessed clinically or by plain radiographs while extensive NOE fracture require CT. The OMV150 view was chosen as it does not superimpose the orbital floor on the petrous ridge. Single-view screening was found to be sufficient to exclude a fracture in 83% of cases, with no fractures missed. Thus single-view radiographic screening of midfacial injuries maintains high diagnostic efficacy and reduces radiation exposure whilst achieving significant economic benefits.

b) Lateral mid face fracture

It includes the second commonest facial fracture, zygomatic complex fractures (trimalar or tripod fracture), orbital blow out fractures and less common isolated zygomatic arch fracture, zygomaticomaxillary fractures and zygomaticomandibular fractures.

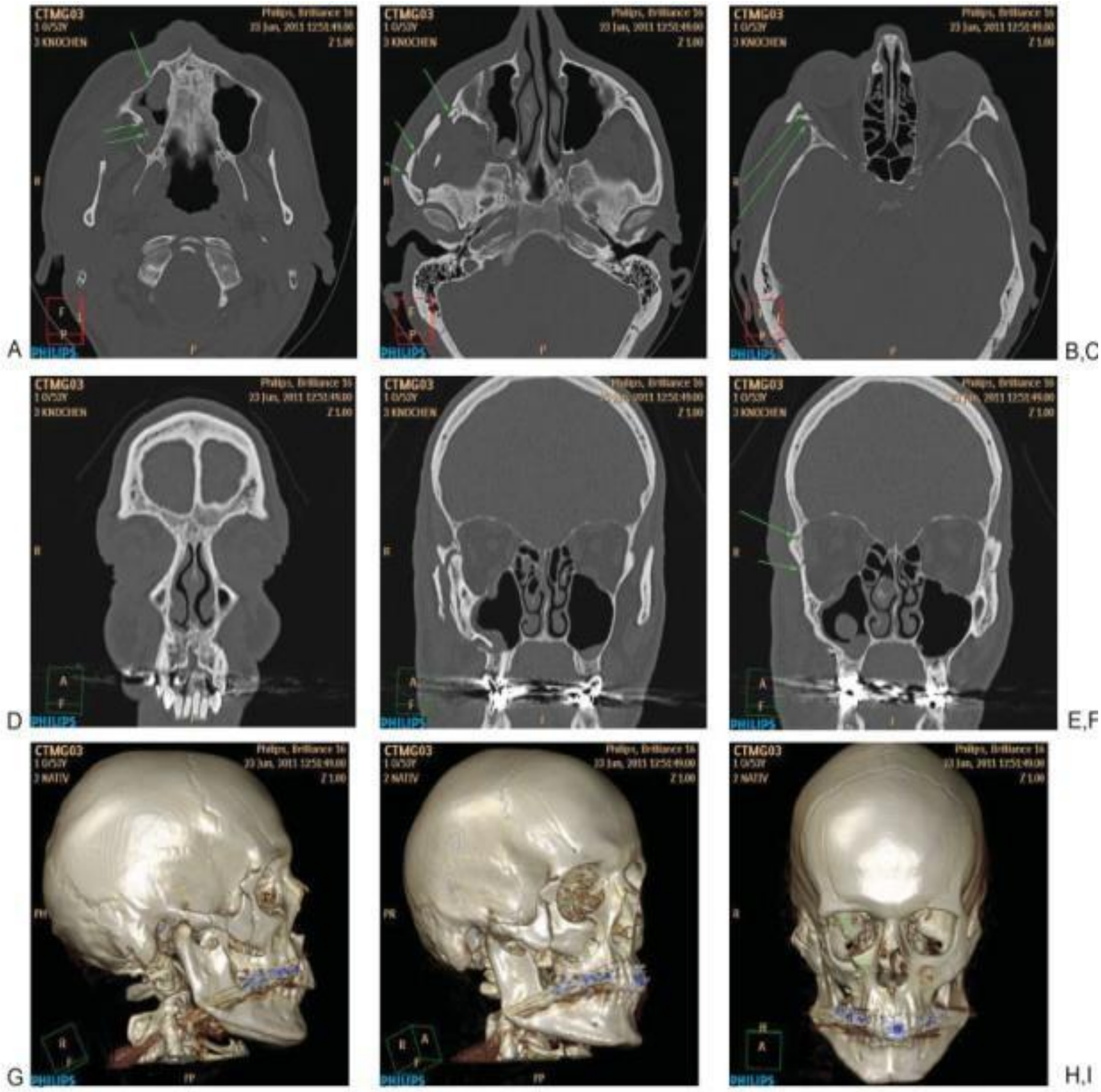

Figure 8: Systematic analysis of a midfacial fracture. (A) Axial slice: evaluation of the lower central midface with fracture of the zygomatic alveolar crest, anterior and dorsolateral maxillary sinus wall (arrows). (B) Axial slice: Involvement of the zygomatic arch with multiple fractures (arrows). (C) Axial Slice: Fracture of the anterior part of the lateral wall (arrows). (D) Two-dimensional coronal reconstruction at level frontogygomatic buttress (no fracture). (E, F) Two- dimensional coronal reconstruction with the fractures at the zygoma and anterior part of the lateral orbital wall and fronto-zygomatic suture (arrows). (G–I) Three-dimensional reconstruction showing the involvement of the right zygoma, intermediate and lower central midface and orbit[19]

Level 1

The radiological issue for level 1 system is the presence or absence of a fracture in the midface, for which conventional plain films are a minimal requirement. They are less used when the occurrence of midfacial trauma is obvious by clinical examination, but play a role in the screening of patients when fractures are only suspected.3 The routine midfacial trauma series consists of the Waters view (occipitomental), the Caldwell view (occipitofrontal), and the lateral facial view.1 The Waters view demonstrates the maxillary sinuses and anterior facial structures adequately, including nasal bones, inferior orbital rims, anterior orbital floors (inferior wall), and zygomas. The Caldwell view demonstrates the nasal sinus and orbit adequately, including orbital walls, frontal sinus, ethmoidal cells, and posterior third of the orbital floor and apex. The lateral facial view is helpful in the detection of fractures of the anterior and posterior walls of the frontal and maxillary sinus and for the evaluation of the pterygoid plates. Additional views include the submentovertex view, which requires neck hyperextension, however it is often not feasible in the acute trauma setting. An underexposed submentovertex projection ("jug-handle" projection) may be used when an isolated fracture of the zygomatic arch is suspected. For nasal fractures an underexposed lateral projection of the nasal bones may be performed.[19]

Level 2

Level 2 classification of midface fractures requires the fracture identification within the following regions: zygoma/ zygomatic arches as well as upper, intermediate, and lower central midface, palate, pterygoid plates, and orbits. For the purpose of the classification, multidetector CT with 2D multiplanar reconstructions is the basis for evaluation.

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Analogue to the mandible multidetector CT technique with narrow slice thickness should be obtained, for example, 16 0.75 on a 16- slice CT or 64 0.625 on a 64-slice CT scanner. In general, at least 1 mm axial slices should be generated for multiplanar evaluation. Bone and soft tissue windows should be assessed using 2D multiplanar coronal reconstructions. The clinical usefulness of 3D CT reconstructions has been well investigated18–20 providing useful information for surgical planning. For instance, slight displaced horizontal fractures for example, at the Le Fort I level are well detected by 3D CT reconstructions. However they provide less accuracy in comparison to 2D coronal reconstructions for the evaluation of orbital floor and medial wall fractures. [19]

Systematic evaluation of the midface in CT begins with the evaluation of axial slices from caudal to cranial (**Figure 8A-C**) to detect direct fracture signs, especially in the lower centralmidface (including alveolar process, caudal part of nasomaxillary buttress), intermediate central midface (including anterior sinus walls), upper central midface (including frontal process maxilla, lacrimal bone and nasal bones). In the axial plane the zygoma and zygomatic arch are evaluated with all its relationships to the central midface. Subsequently, the orbital rims as well as lateral and medial orbital walls are assessed. In a second step coronal 2D reconstructions (**Figure 8E-F**) are checked for the integrity of the nasomaxillary buttress in the lower and intermediate central midface regions, the frontal process of the maxilla and the nasal bones in the anterior coronal reconstructions (**Figure 9**). The integrity of the palate and the pterygoid plates should also be checked in the coronal plane, which ideally should be perpendicular to the palate. Furthermore the medial orbital walls, the orbital floors and orbital roofs are well detected in the coronal plane. The orbital apex regions are search for integrity, especially of the optic nerve canal. Additional 2D reconstructions for the orbital floor through the axis of the intraorbital nerve may be useful in detecting displaced fractures with muscle entrapment or retrobulbar hematoma. 3D CT reconstructions may not add significant information for level 2 classification (**Figure 8G– I**).[19]

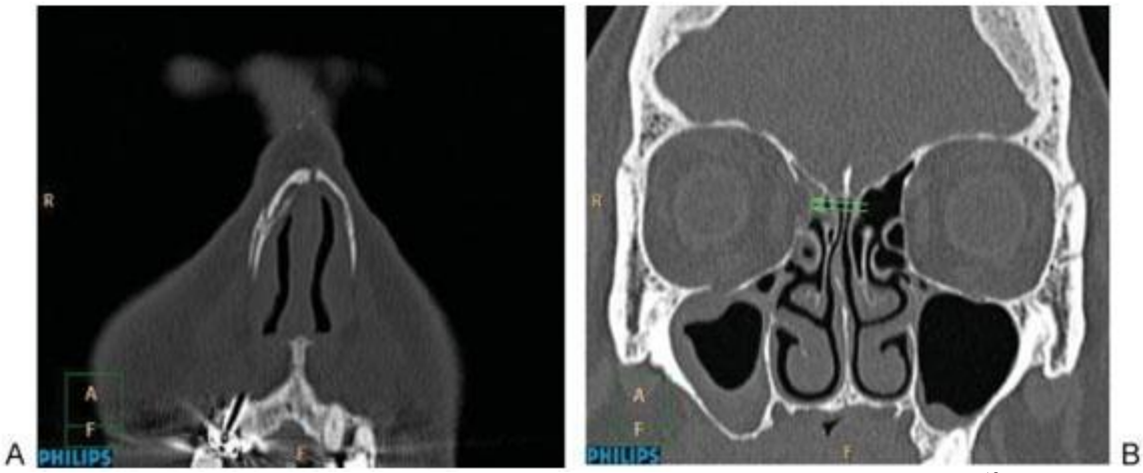

Figure 9: Systematic analysis of a midfacial fracture in coronal reconstruction[19]

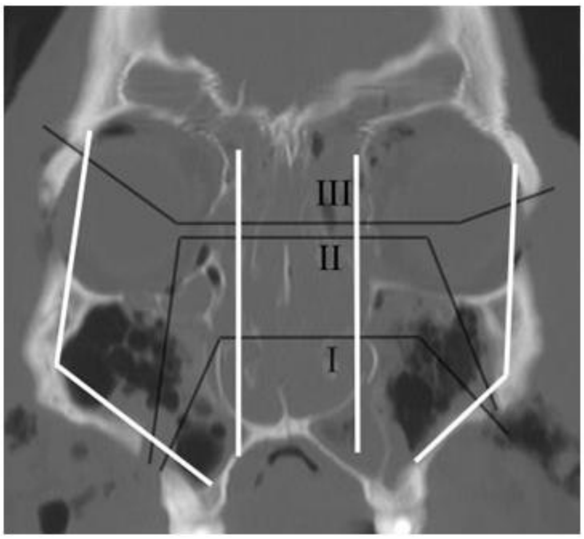

Figure 10: Le Fort fracture patterns. The lateral and medial maxillary buttresses (white lines) are fractured inferiorly and superiorly (junctions of white lines and black lines). To confirm the diagnosis, pterygomaxillary disjunction and fractures of the zygomatic arches would need to be observed on axial images[9]

Maxillary Fracture

Maxillary fractures occur less commonly than mandibular fractures. They generally are caused by mechanisms of injury involving greater amounts of force, involve more facial edema, and likely are associated with other midface fractures. The Le Fort classification classically has been used to describe maxillary fractures (**Figure 10**). Le Fort fractures are complex facial fractures that result from a high-force impact on the midface structures and were first described in the early 20th century by French surgeon Rene Le Fort. Le Fort fractures constitute a subset of injuries that result in discontinuity of the midface, a structure comprised of the maxilla, inferiolateral orbital rims, sphenoids, ethmoids, and zygomas. [9, 20]

Le Fort I

Le Fort I fractures are horizontal fractures of the anterior maxilla that occur above the palate and alveolus and extend through the lateral nasal wall and the pterygoid plates. These fractures result in mobility of the tooth-bearing maxilla and hard palate from the midface and are associated with malocclusion and dental fractures (**Figure 11**). [20, 21]

Le Fort II

Le Fort II fractures are pyramidal in shape and involve the zygomaticomaxillary suture, nasofrontal suture, pterygoid process of the sphenoid, and the frontal sinus. These fractures cause disruption of the medial, lateral, upper transverse, and posterior maxillary buttresses and produce discontinuity of the inferomedial orbital rims. Involvement of the orbit seen in such fractures may lead to the development of complications including extra-ocular muscle injury, orbital hematoma, globe rupture or impingement, and optic nerve damage. Furthermore, damage to the medial maxillary buttress has been associated with epistaxis, cerebral spinal fluid (CSF) rhinorrhea, lacrimal duct and sac injury, medial canthal tendon injury, and sinus drainage obstruction (**Figure 12**). [20, 22]

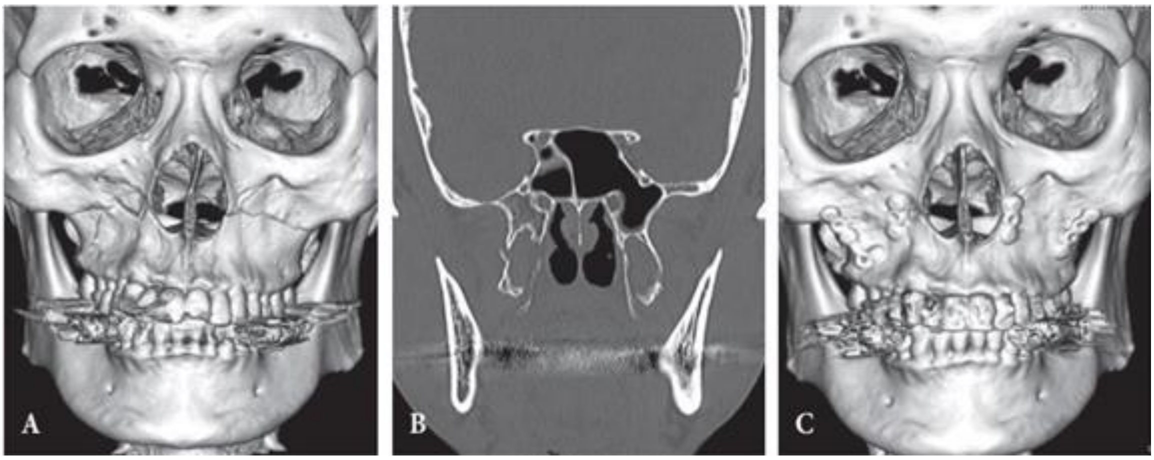

Figure 11: (A) Preoperative computed tomography (CT) showed a Le Fort I fracture. (B) Fracture of both pterygoid plates. (C) Postoperative CT 3.5 months after the surgery[21]

Le Fort III

Le Fort III fractures involve the nasal bones, medial, inferior, and lateral orbital walls, pterygoid processes, and zygomatic arches, which results in complete separation of the midface from the cranium. These fractures affect the medial maxillary, lateral maxillary, upper transverse maxillary, and posterior maxillary buttresses. Similar to Le Fort II fractures, they can be associated with orbital complications and CSF rhinorrhea (**Figure 13),** [20, 23]

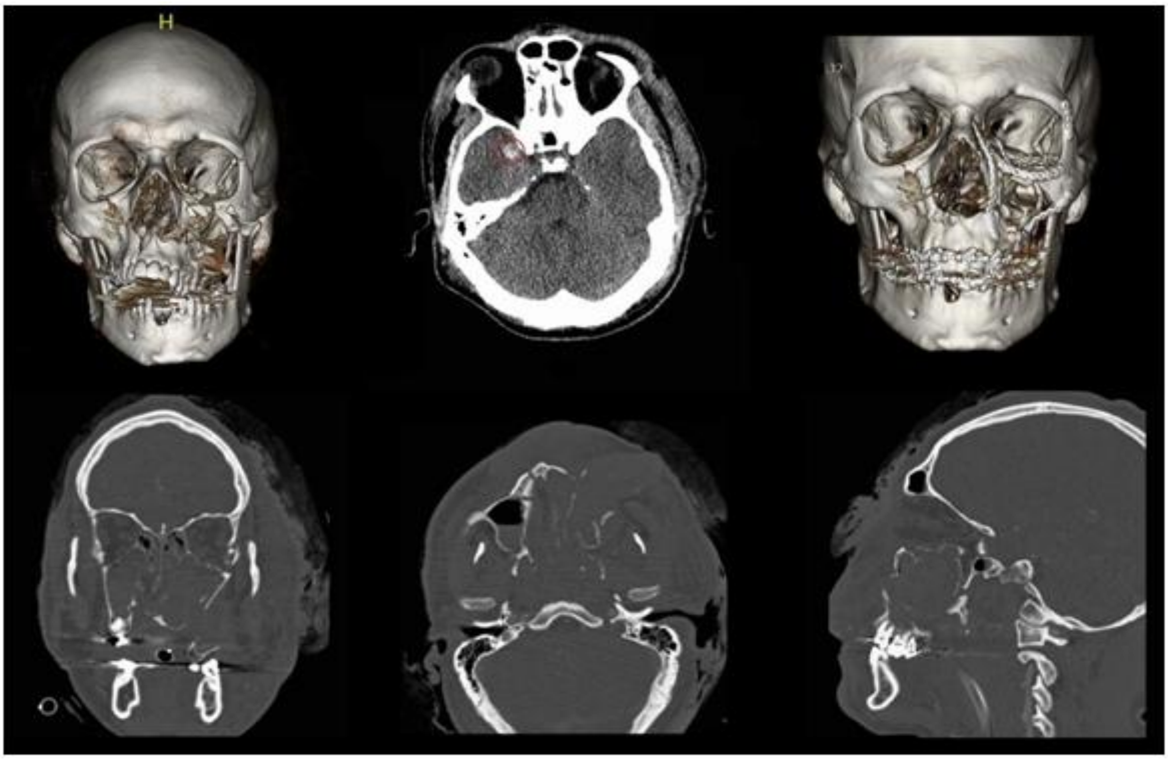

Figure 12: *Top Left*, Complex midface fractures included Le Fort II, left zygomaticomaxillary complex, and left inferior orbital floor fractures; *Top Middle*, Midface trauma was associated with concomitant diffuse axonal injury and intraparenchymal hemorrhagic contusions in the left temporal (circled) and bilateral frontal lobes; *Top Right*, After intraventricular catheter placement to reduce the intracranial pressure, the midface was reconstructed using maxillomandibular and plate fixation; *Bottom Row*, Coronal, axial, and sagittal views of the Le Fort II, zygomaticomaxillary, and orbital floor fractures[22]

Zygomatic-Maxillary Complex (ZMC) Fracture

It results from a direct blow to the lateral mid face. Fracture of the orbital wall, to the postero-lateral wall of the maxillary sinus through the zygomatic arch, separating zygoma and maxilla. The presence of significant displacement of fragments, trismus, entrapment and/or orbital apex involvement is indications for surgery (**Figure 14**). [24]

Facial CT images of fracture and non-fracture patients were imported into the “Dextroscope”, a virtual reality, three-dimensional image analysis modality. Following three-dimensional reconstruction of the skull, the anteroposterior (A-P), mediolateral (M- L), and superoinferior (S-I) axes were established to facilitate a standardized measurement of malar eminence displacement. The A-P axis was first delineated along the palatine plane by creating a line from the anterior nasal spine (ANS) to the posterior nasal spine (PNS; Figure 15 (A): The ANS-PNS axis has been shown to roughly approximate the Frankfurt plane within 1.0 ± 3.5 degrees. The M-L axis was next established by creating two lines perpendicular to the A-P axis, extending laterally in either direction from the PNS (**Figure 15B**). Finally, the S-I axis was established by creating another line perpendicular to the A-P axis, extending superiorly from the PNS in the midline (**Figure 16**) [25]

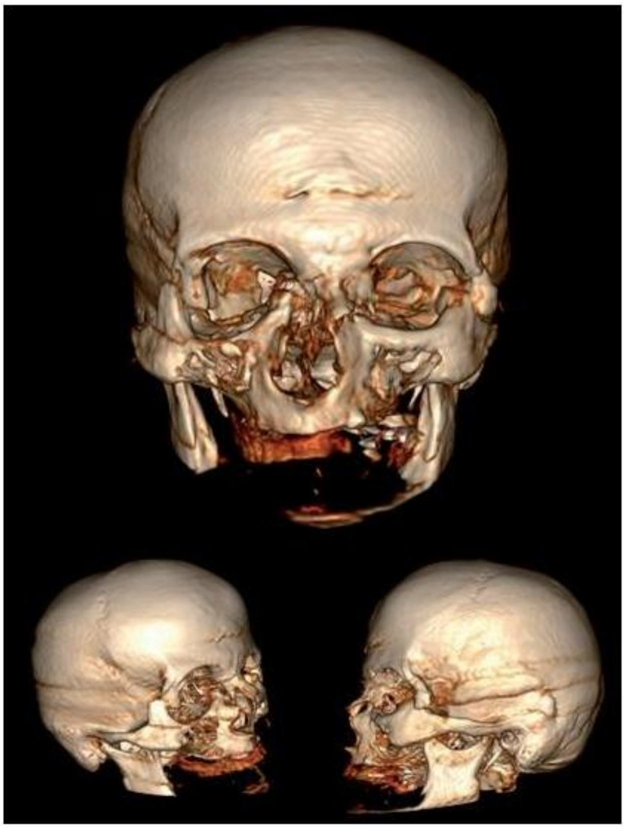

Figure 13: The three dimensional CT imaging reconstruction with typical finding of Le Fort type 3- skull fracture[23]

Figure 14: Three-dimensional reconstruction from computed tomography images of right- sided zygomatic-maxillary fracture. (A) Frontal and (B) base views.[24]

The malar eminences were located bilaterally as the point of intersection between a vertical arc from the zygomatic process of the frontal bone to the maxilla superior to the first molar, and a horizontal arc from the inferior orbital rim along the superior aspect of the zygomatic arch (**Figure 17**). In fracture patients, the malar eminence on the fractured side was designated by inferring the location of the intersecting arcs on the displaced zygoma. A series of measurements was made to compare the positions of the right and left malar eminences in the non-fracture subjects and the positions of malar eminences on the fractured and non-fractured sides in the ZMC fracture patients. The measurements, performed in each of the three axes, were calculated from compressed, two-dimensional snapshot images captured with the Dextroscope and analyzed using image analysis software. [25]

Manson and Markowitz in 1990 classified ZMC fractures as low, middle and high energy fractures and who advocated which group had a role to play in open reduction and fixation. Low energy injuries are characterised by no or minimal displacement including incomplete separation which are easily reduced and tend to stay in position with no or minimal stabilisation. These fractures account for 18% of injuries. Middle energy injuries account for the bulk of injuries sustained (77%) with displacement ranging from mild to marked with complete separation at all four sutures (**Figure 18-20**). [25, 26]

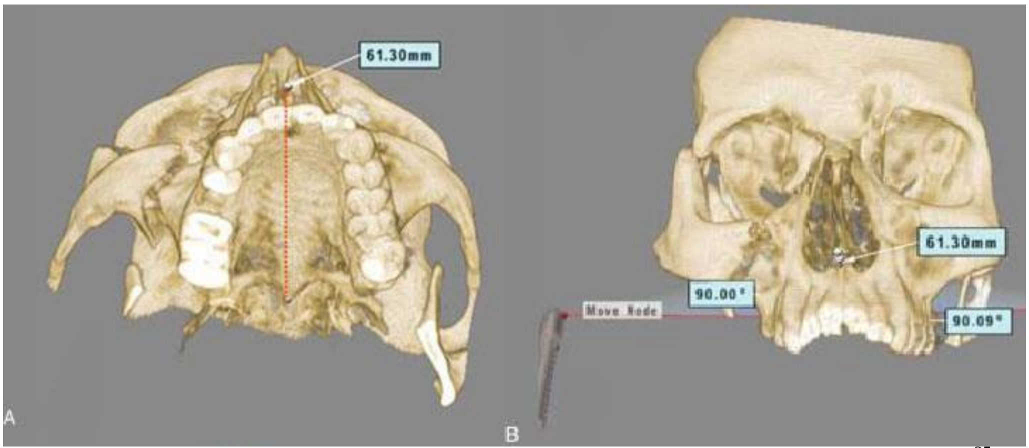

Figure 15: Determination of planes of reference. (A) Anteroposterior; (B) Mediolateral[25]

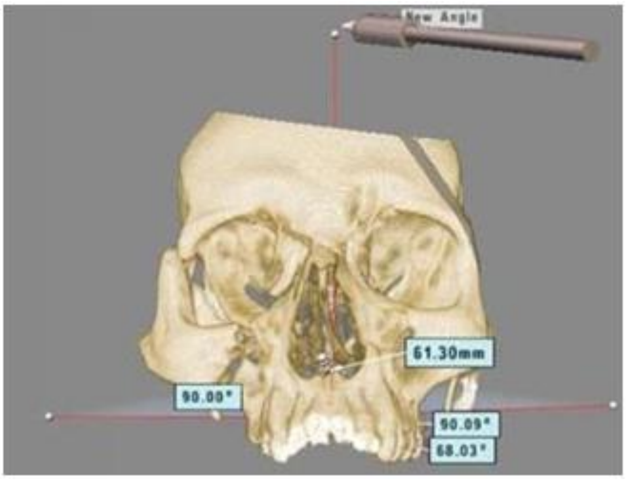

Figure 16: Determination of planes of reference in the superoinferior axis[25]

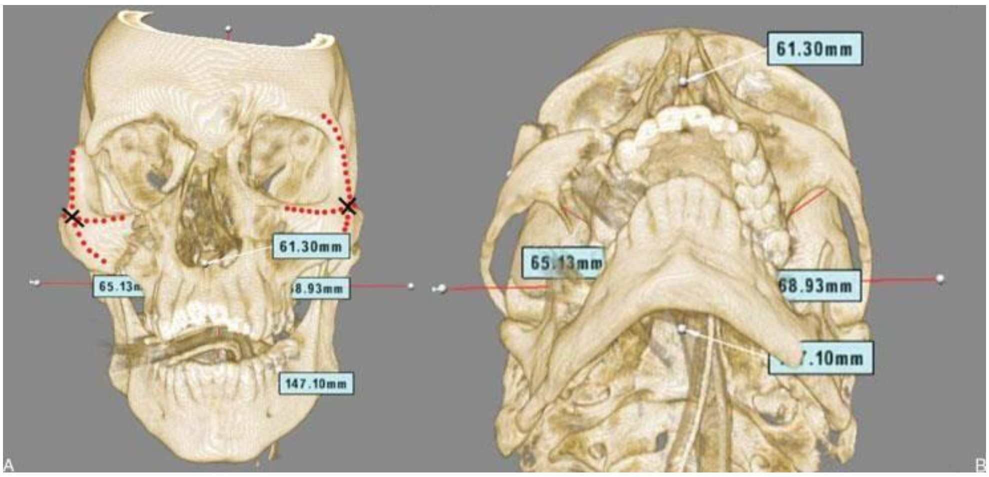

Figure 17: The malar eminences are designated as the point of intersection between a vertical arc from the zygomatic process of the frontal bone to the maxilla superior to the first molar, and a horizontal arc from the inferior orbital rim along the superior aspect of the zygomatic arch. Lines were drawn extending from the central point at the posterior nasal spine to the malar eminences on both sides[25]

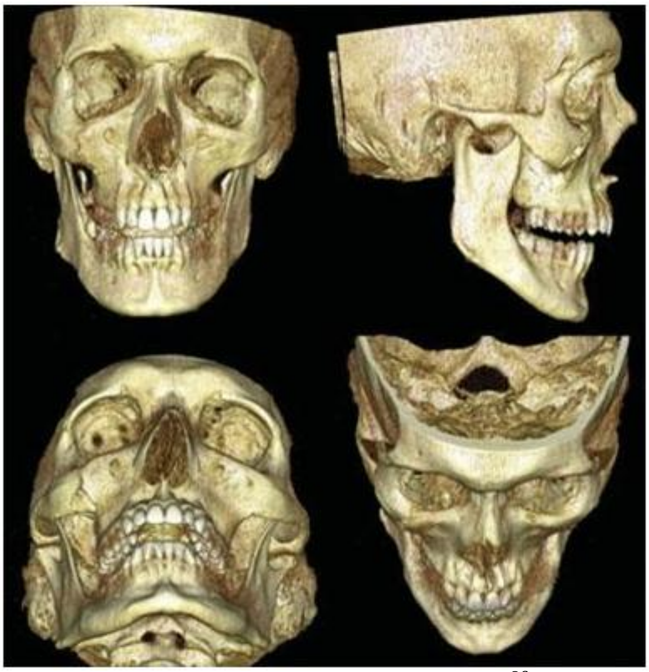

Figure 18: ZMC-non displaced type[26]

Figure 19: ZMC-displaced type[26]

Figure 20: ZMC-comminuted type[26]

Figure 21: Sagittal view of frontal sinus fracture[27]

Figure 22: Posterior table frontal sinus fracture[27]

Frontal Sinus Fractures

Fractures of the upper third of the face typically affect the wall of the frontal sinus. Fractures may involve only the anterior sinus wall or extend into the posterior wall. A fracture along posterior wall creates a communication between the frontal sinus and the anterior cranial fossa which lead to complications like CSF rhinorrhea and intracranial infection. A fracture involving the medial aspect of the frontal sinus may extend into the nasofrontal duct, can cause a mucocele that obstructs sinus drainage and requires surgical correction.

The gold standard in diagnosis and classification of frontal sinus fractures is a computed tomography (CT) scan of the face, head, and neck. Plain radiographs can be used to diagnose frontal sinus fractures, but do not sufficiently characterize the extent of fracture or detect nasofrontal involvement. Reconstruction of CT images in both axial and sagittal orientations is often helpful (**Figure 21-22**). Clinicians should look for obstruction, complex anterior ethmoid cell fracture, or frontal sinus floor fracture as evidence of nasofrontal outflow tract injury.[27]

Figure 23: Pediatric trapdoor fracture. Note: (A) coronal view; (B) sagittal view[28]

Orbital Fracture

Fracture of orbital floor is the most common orbital fracture and is caused by blow-out. The mechanism of blow-out fracture is force of direct impact is applied on the eye ball which is absorbed by the orbital rim and is transmitted to the orbital floor. Usually eyeball remains intact. Air-fluid level or complete opacification of the maxillary sinus is commonly seen. Orbital fat protrudes through the fracture line (tear drop sign) due to herniation of inferior rectus and inferior oblique muscles diplopia can occur. Coronal sections of CT clearly demonstrate the fractures of the orbital floor (**Figure 23**).[28]

In general, CT is the primary imaging modality in orbital trauma. The sensitivity of CT for fractures is higher than that of radiography, and three-dimensional reformations after image acquisition can sometimes help to guide subsequent surgical treatment. For orbital trauma, the optimal protocol is thin-sliced CT scan with 1–2 mm cut through the orbit performed with a helical CT. The advantages of the high resolution orbital helical CT over conventional CT include (1) much shorter scanning time (<30 s compared with >5 min with traditional protocol), (2) reduced motion artifact, (3) much lower radiation exposure, (4) much more sensitive in detecting soft tissue entrapment especially in pediatric patients. [28]

The superiority of coronal CT in the diagnosis of fractures of the orbital floor, blow- out fractures was confirmed, especially in patients who develop diplopia or enophtalmos (**Figure 24**). Generally, the original coronal images may be better for diagnosing orbital floor fracture detection, for adequate assessment of the cribiform plate, orbital roof, orbital floor and planum sphenoidale. 3D-CT scanning presented sensitivity of 78.9%. On the other hand, the diagnostic value of axial images was considered limited for orbital fractures region, with sensitivity of 44.2%. Both 2D-CT and 3D-CT techniques presented similar sensitivity for the diagnosis of fractures in the mandibular region, though 3D-CT imaging allowed a better visualization. 3D images provided an easy detection of specific characteristics of facial asymmetries, midface defects and skull vault defects, and a clear localization of fractures associated with extensive bone displacement. [10]

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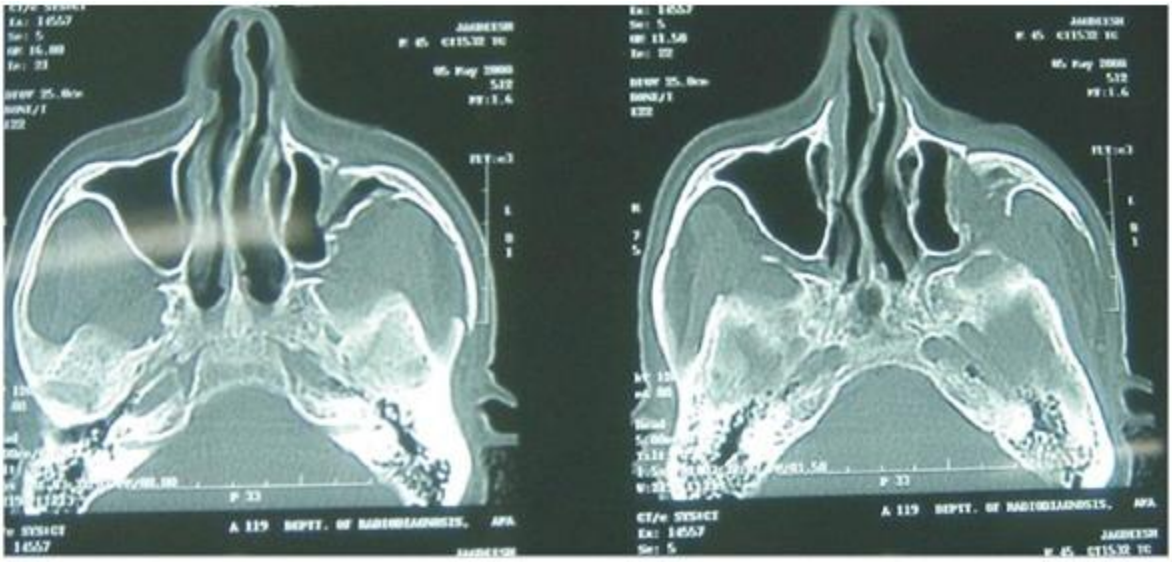

Figure 24: Axial CT cuts of midface showing left lateral wall of orbit (left) and floor of left orbit fractures (right)[10]

Nasal Fracture

Nasal bone fractures are the most common of maxillofacial skeletal injuries because of its superficial location and the relative thinness of the bone. This fracture typically result from blunt force directed from either an anterior or a lateral direction. According to the anatomic plane it is classified as follows: Type 1: fractures do not involve the nasal septum and extends from the caudal tip of the nose to the anterior nasal spine; Type 2: fractures involve the septum as well as the anterior nasal spine; and type 3 fractures involve orbital bone as well as the nasal bone and septum. A fracture that extends into the nasal cartilage may disrupt the perichondrium resulting in septal hematoma and with resultant septal perforation it can lead to impaired nasal breathing, abscess formation, and necrosis.[29]

CT is superior to conventional radiography for the detection of nasal bone fractures, assessment of the type of nasal bone fracture, for combined injuries, and for decision- making in therapeutic planning. However, although conventional radiography is not the first choice as a diagnostic tool, it may be useful for the detection of transverse and non-depressed nasal bone fractures. Thus, combined use of reformatted CT and conventional radiography is necessary to detect all types of nasal bone fractures (**Figure 25**).[29, 30]

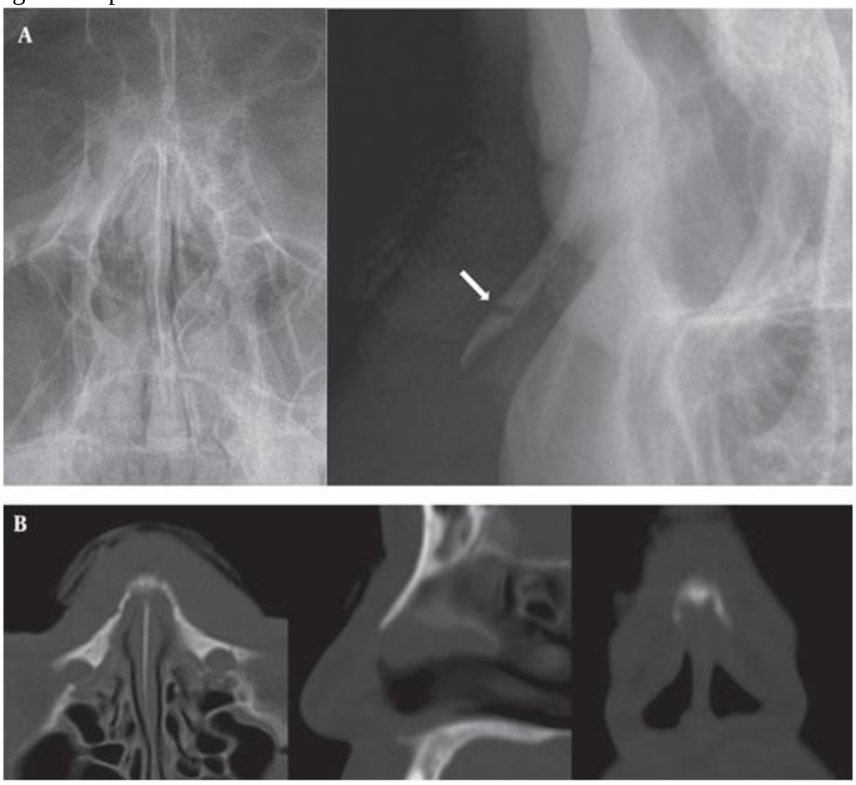

Figure 25: A patient with painful nasal swelling and a simple non-depressed transverse nasal fracture. A, Coronal and lateral conventional radiography images show a discrete simple fracture in the mid-portion of the nasal bone. B, CT images show no discrete fracture on axial, sagittal, and coronal reformatted images (arrow indicates nasal bone fracture)[29]

2. Conclusion

Complex interactions between technology availability, cost considerations and financial reimbursement interplay to provide regional imaging approaches. Correct imaging acquisition, systematic analysis and interpretation according to the anatomic and surgical relevant structures in the maxillofacial regions are essential for an accurate, reproducible, and comprehensive diagnosis in maxillofacial trauma.

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