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Radiodiagnosis

Helical CT Facial Bones in Patients with Facial Trauma

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Abstract: MDCT is an accurate, non-invasive technique for evaluation of patients with facial skeletal injuries. In the setting of acute trauma, MDCT has the advantage of shorter scan time and is increasingly available. MPR and 3D VR images help better evaluation of fractures detected on axial images. This study included 150 patients who had the history of facial skeletal injury and was found to have fractures involving the facial bone. All patients with facial fractures were assessed by analyzing axial images and VR reconstructed images and coronal MPRs to evaluate the diagnostic accuracy of Multiplanar reconstruction and Volume rendering protocol in comparison with axial section.
Keywords: CT - Computed tomography, MDCT - Multidetector -row computed tomography, MPR - Multiplanar reformation / reconstruction, VR - Volume rendering, HU - Hounsfield unit, RTA - Road traffic accident, ED - Emergency department.

INTRODUCTION

The skull consists of 8 cranial bones and 14 facial bones. Few of these bones exist in pairs. The paired bones of the face are the maxilla, palatine bones, zygomatic bones, lacrimal bones, nasal bones, and inferior nasal conchae. The single bones are the vomer and mandible [1].

There are many sutures that hold the facial bones together and keep them aligned; some of the sutures are frontozygomatic suture, frontomaxillary suture, frontolacrimal suture, frontonasal suture, temporozygomatic suture, zygomaticomaxillary suture, lacrimomaxillary suture, nasomaxillary suture and internasal suture.

Injuries of facial bones and soft tissues are a very common pathology. Their incidence ranges from 20% to over 50% of cases admitted to traumatic emergency room.

The most frequent causes of these pathologies include are transportation injuries (up to 80% of cases), direct force, mostly during an assault (up to 60% of cases), falls (up to 25% of cases), and accidents during sports (up to 10% of cases) [2–5].

Radiograph and computed tomography are the two modalities which are used for diagnosis of facial fractures with CT being a vastly superior modality.

Aims and objectives of the study

- To study the distribution of facial bones fractures in patients with trauma to the face.
- To evaluate the diagnostic accuracy of Multiplanar reconstruction and Volume rendering protocol in comparison with axial section.

REVIEW OF LITERATURE

The analysis and classification of facial bone fractures was first partially introduced by Le Fort, at the beginning of the 20th century, and was continuously improved by many authors later on [6, 7].

It bases on the fact that the skeleton of the face is not just a collection of single bones, but constitutes a system of horizontal and vertical reinforcements, supporting one another mutually (and thus having a much higher mechanical resistance than other bone elements), transmitting forces and stresses. Each bone has many attachments to the neighbouring bones which hold them together firmly.

Facial buttresses [8]

A number of facial buttresses have been described. There are four principal vertical buttress groups of facial skeleton: three are bilateral and peripheral and one is centrally located. In addition, three horizontal buttresses are described: superior, middle and inferior.

Vertical Buttresses

The peripherally located vertical buttresses are:

- Nasofrontal buttress
- Zygomatic buttress
- Pterygomaxillary buttress

The central vertical buttress is the nasoethmoid buttress.

Horizontal Buttresses

Superior horizontal buttress is composed of the orbital plates of the frontal bones, roofs of the ethmoid air cells and cribriform plate of the ethmoid. The middle horizontal is composed of the zygomatic process of temporal bone, the body and temporal process of zygoma, the infraorbital process of the zygoma, the orbital surface of the maxilla and the frontal process of the maxilla. The inferior horizontal buttress is composed of the alveolar ridge and hard palate and acts as an important stabilizing bridge between the two maxillary bones.

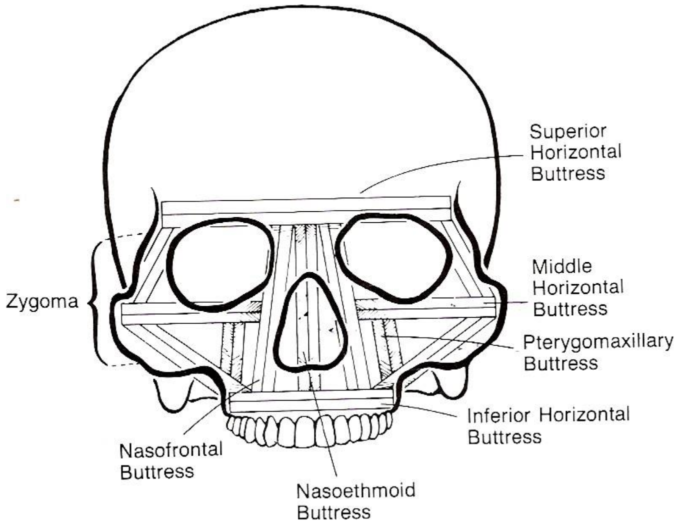

Fig-1: Schematic illustration of the facial buttresses. The various vertical and horizontal buttresses of the human midface are schematically demonstrated.

Imaging modalities

Basic tomography, developed in the early 1900s, overcame some of the limitations in radiographs. In this technique, the X-ray emitter passes over a bodily region of interest during radiation emission, while a mobile film cassette behind the patient records the transmitted image.

MPR have not been used much in conventional CT since spatial resolution along the z-axis used to be poor and stair step artefacts were common. With the advent of Spiral-CT with overlapping image reconstruction, stair step artefacts can be virtually eliminated but image quality still depends on acquisition parameters (effective section thickness). Using thin collimation, excellent results are obtained.

Generally, MPR are helpful whenever pathology cannot be accurately assessed on axial images alone. Most situations involve pathologic interfaces that are oriented parallel to the axial plane or structures that cannot be displayed in their entirety since they run through a number of slices. In these cases, problem oriented imaging planes can be generated using MPR. The quality of these images strongly depends on overlapping image reconstruction and thin-enough slice collimation [9].

Therefore, the complex anatomy and fractures of the facial bones are shown extremely well by CT, and also helps in determining soft tissue complications. In the past few years radiographic facial series has been almost replaced by CT, and is now used only in specific situations, such as very focal facial trauma like nasal bone fracture, or when CT is unavailable.

CT gives better spatial resolution and allows reconstruction of images in multiplanar reconstruction (MPR) and volume rendering (VR) which enhances the ability to identify and report facial fractures.

High resolution helical CT is currently the imaging procedure of choice for most facial fractures.

Fractures involving the facial skeleton may be isolated or complex.

Isolated fractures involve single anatomy structures and are usually a result of a low energy blow [10]. The three most common isolated facial fractures are:

- Nasal fractures.

- Zygomatic fractures.
- Orbital floor fractures.

Complex fractures are due to high energy impact injuries to the mid face and involve several structures, examples of these are:

- Le-fort fractures.
- Nasoethmoid mid-facial fractures.

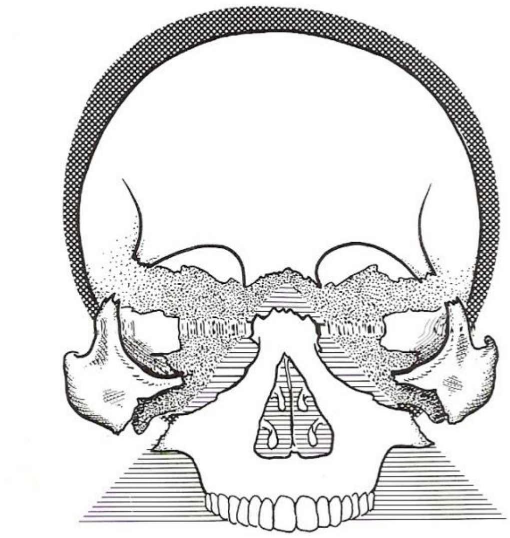

Fig-2: The human skull composed of an ovoid-shaped cranium, a pyramid shaped mid face consisting of the maxilla and the triangle shaped zygomas

METHODOLOGY

Source of data

The study was conducted in patients with facial trauma referred for computed tomography (CT) to the Department of Radio Diagnosis at Sree Balaji Medical College and Hospital, Chennai-600044.

Method of collection of data

The study population included 150 patients who underwent CT evaluation of facial bones when they presented with injury to facial skeleton to the emergency department in Sree Balaji Medical College and Hospital, Chennai attached to the Bharath University.

- The CT was done on the advice of the referring doctor and no patient was made to undergo CT for the sole purpose of this study.
- All the patients gave consent for the scan.
- The scans were acquired with the use of spiral data acquisition technique in the transverse plane.
- The Multiplanar reconstruction (MPR) and Volume rendering (VR) secondary image reconstructions were obtained for each patient.
- Three reviewers evaluated the axial-sections, MPR and VR formats individually.

Study Design: Descriptive study.
Study Period: March 2017 to October 2018.

Inclusion criteria

- All patients with clinical evidence of injury to facial skeleton who underwent Multi-slice CT examination and are shown to be positive for fractures.

Exclusion criteria

- Patients with injury to facial skeleton in whom a CT examination was contraindicated. Eg. Pregnancy.

Data acquisition

- All the CT scans in this study were performed using Hitachi 16-slice CT scanner.

CT protocol used for this study:

- Slice thickness: 1.25 mm.
- Voltage: 120 kV.
- Current: 300 mA.
- Table speed: 27.5 mm/sec.
- Pitch: 1.375:1
- Rotation: 0.6 sec.

Post traumatic fractures were classified on the basis of anatomical location of fractures:

- Frontal bone fractures.
- Orbits, with classification into the orbital walls.
- Nasal bones.
- Maxillary bones with inclusion of maxillary sinus walls.
- Zygomatic arches and bones.
- Body, angle, ramus, and condylar process of mandibular bones.

RESULTS

All patients with facial fractures were assessed by analyzing axial images and VR reconstructed images and coronal MPRs. Few cases are described below with their CT images attached in different formats.

Case 1

A 24-year-old male patient came with the history of assault. We found that there were fractures of both the nasal bone and the anterior nasal septum as seen on axial images.

On comparison with MPR images, it failed to clearly identify the fracture of both nasal bones but nasal septum fracture was clearly seen and VR images shows the fracture of both nasal bone but failed to identify the fracture of nasal septum.

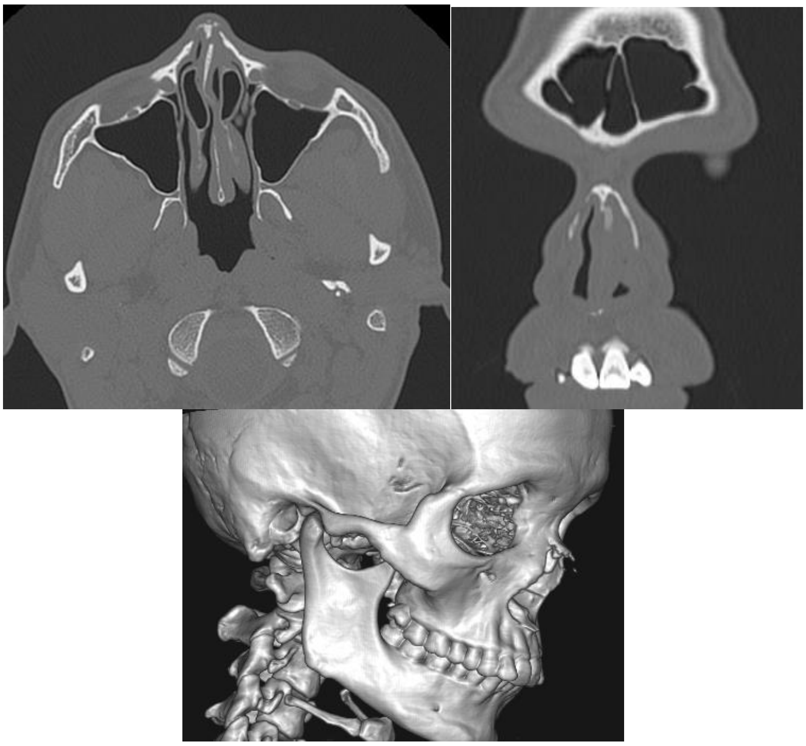

Fig-3: Axial, MPR and VR sections of case 1 depicting facial fractures

Case 2

A 47-year-old patient came to ED with complaints of RTA. We found that there was fracture involving the alveolar margin of the right hemimaxilla on the anterior aspect, with loss of the central incisor on the right side and also the fracture involving the alveolar margin of the mandible (symphyseal region) with loss of central incisors.

All the three reconstruction formats including axial images were identifying the fractures clearly.

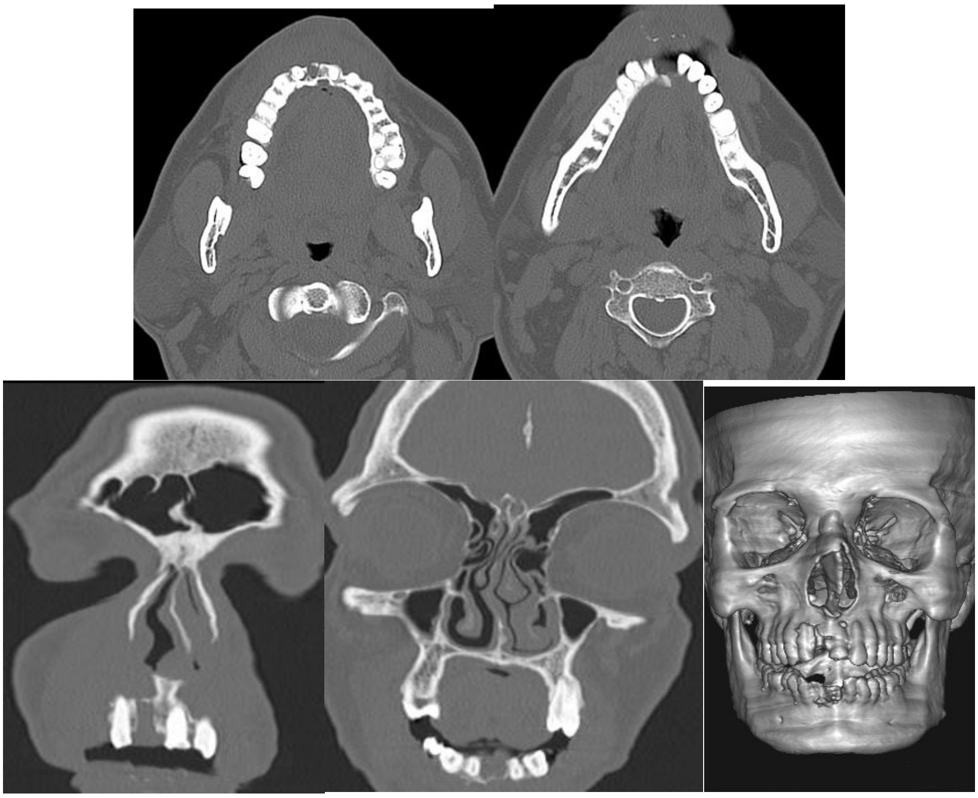

Fig-4: Axial, MPR and VR sections of case 2 depicting facial fractures.

Case 3

A 48-year-old patient came to ED with complaints of RTA. We found that there was fracture noted involving the left zygomatic bone at the orbital articulation site and comminuted fracture involving anterior and the posterolateral wall of left maxillary sinus.

The fractures were clearly seen on axial and MPR images but VR images fail to identify left posterolateral maxillary wall fracture.

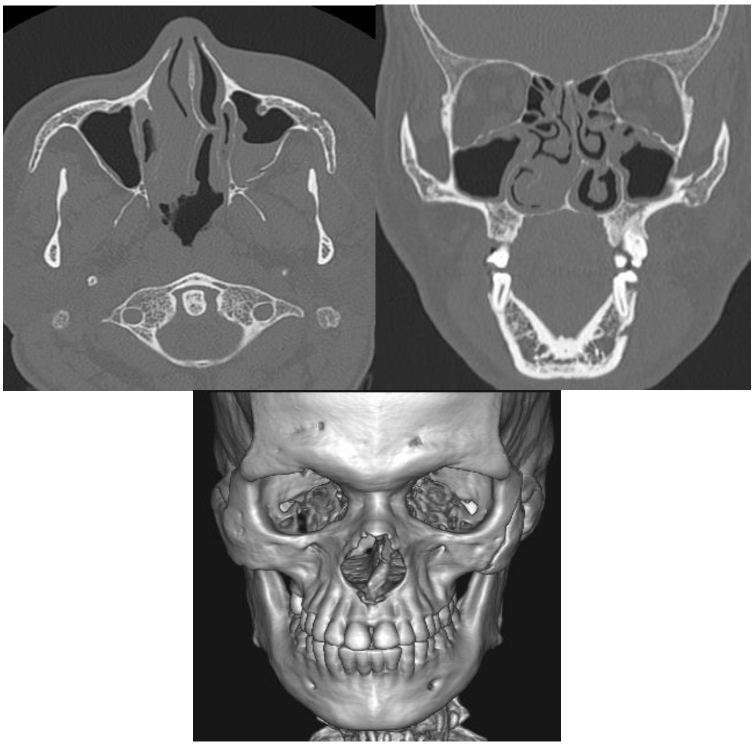

Fig-5: Axial, MPR and VR sections of case 3 depicting facial fractures.

Data analysis

Age distribution of patients in the study

In this study group which comprised of a total number of 150 patients, the most patients belonged to 21-30 and 31-40 years of age groups.

Sex distribution of patients in the study

Among 150 patients included in this study. 63% were males and 37% were females having facial bone fractures.

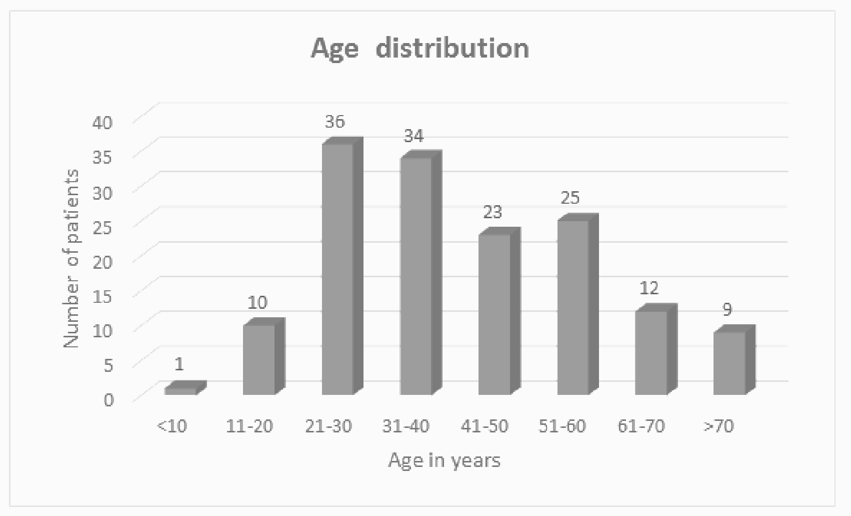

Chart-1: Age distribution of patients presenting with facial fractures.

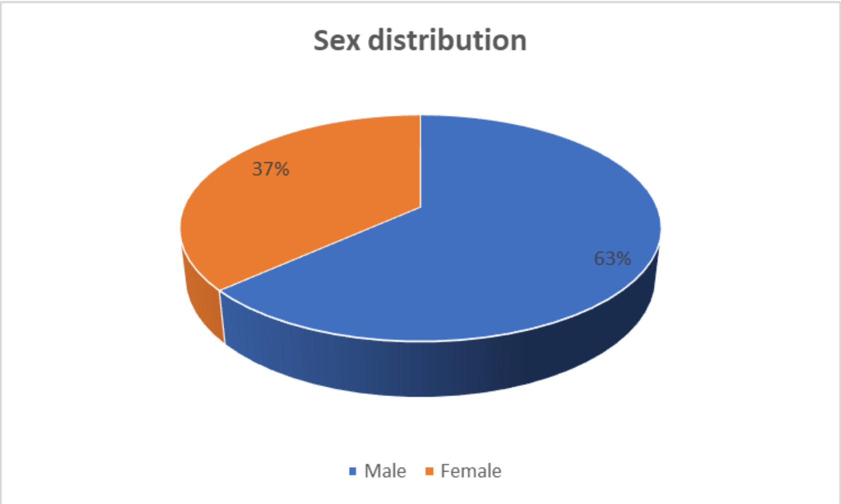

Chart-2: Pie chart depicting the relative percentages of males and females in the study group.

Mode of injury among the study patients

The most common mode of injury in patients presented to the Emergency Department with facial trauma was road traffic accidents, comprising 62% of cases. Others included injuries occurring by fall from height and assault comprising 23 and 15% respectively.

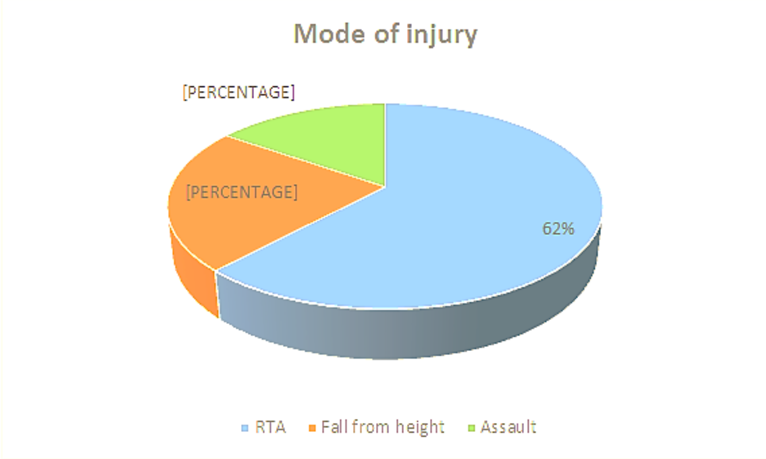

Chart 3: Pie chart showing the different modes of injury in facial fractures.

Sensitivity and specificity

The sensitivity of each reconstruction formats was calculated by using the following formula.

$$\textbf{Sensitivity} = \frac{\textbf{TP}}{\textbf{TP + FN}}$$

$$\textbf{Specificity} = \frac{\textbf{TN}}{\textbf{TN + FP}}$$

(TP: true positive, TN: True negative, FP: False positive, FN: False negative)

In our study none of the reconstruction format shows the false positive results. So, considering the false positive as zero, if we calculate the specificity it comes to 100% for all including axial sections and various reconstruction formats.

Table-1: Shows the sensitivity of detection of fractures by various sections in different bones.

Sensitivity Table (%age)			
	Axial	MPR	VR
Frontal bone	100	89	65
Orbital bone	100	100	56
Nasal bone	100	57	51
Maxillary bone	100	86	49
Zygomatic bone	100	100	90
Mandibular bone	100	82	82

Axial section is considered as the gold standard as it identifies the maximum number of fractures.

MPR sections are found to be equally sensitive as axial sections in fractures of orbital bone and zygomatic bone. MPR is nearly sensitive to axial sections in fractures of frontal bone followed by maxillary bone and mandibular bone.

VR images didn't show significant sensitivity over axial sections in any of the facial bone regions but was nearly sensitive in zygomatic bone followed by mandibular bone.

Comparison charts

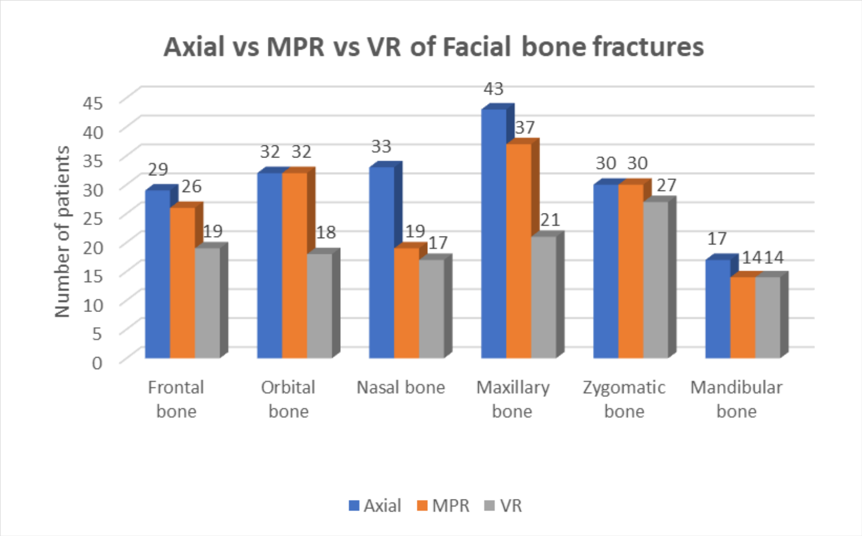

Chart-4: Distribution of fractures in different bones.

Discussion

Facial trauma presents as isolated injuries or part of polytrauma and are clinically important as the disruption of soft tissues and bones of the face cause facial asymmetry and disfigurement which causes emotional and cosmetic concerns [11].

Plain radiographs were the initial modality of choice for imaging in these patients, but they can be inadequate due to superimposition of bony structures [12].

CT is the imaging modality of choice as compared to conventional radiography despite of higher radiation dosage, to display the multiplicity of fragments, the degree of rotation and displacement or any skull base involvement [13].

Tanvikula R, Erol B [14] study shows the comparison and superiority of CT over plain radiography and classification of all facial fractures.

Multi-slice CT is a significant technological advancement in CT imaging, resulting in the opportunity to greatly increase the speed of data acquisition and reconstruction.Hence, speeding the diagnosis.

This study included 150 patients who had the history of facial skeletal injury and was found to have fractures involving the facial bone. The study included the evaluation of these patients with a 16 slice MDCT scanner. The axial images generated were supplemented by the reconstruction of 3D volume rendered images as well as coronal multiplanar reformatted images.

Most patients in this study belonged to 21-30 and 31-40 years of age groups with male preponderance. The most common mode of injury in these patients presented to the emergency department with facial trauma was road traffic accidents, comprising 62% of cases. Assault and fall from height were the other causes, comprising 15 and 23% cases respectively.

In a study done by Fox *et al*. [15] showed that in the zygomatic region, they were able to recognize the presence of injury better on VR (88%) than axial sections (64%), and both of these modalities were superior to MPR(0%).

Whereas in the orbit and maxilla, axial sections (62%,50%) showed better sensitivity in detecting fractures over VR (50%,44%) and MPR (33%,11%).

In fractures involving nasal region, axial (50%) and VR (50%) are more sensitive than MPR (16%). Overall, axial images had higher average sensitivity values than the other two modalities.

In a study done for comparison of facial bone fractures by VR and axial images done by Gillespie et al [16], VR showed 50% poor detection rates than axial images in all the orbital fractures and 50% similar in zygomaticomaxillary fractures.

In a study done by Remmler *et al*. [17], VR was superior to axial images when fractures involving the naso-orbito-ethmoid region are considered (mainly in the inferior orbital rim, piriform aperture and nasomaxillary buttress) but axial was better than VR at lateral nose and medial orbital wall.

Diagnostic accuracy of axial images ranged from minimum of 25.9% at the piriform aperture to a maximum of 88.9% at the medial orbital wall, whereas VR varied from 63.0% at the medial orbital wall to 88.9% at the piriform aperture.

In our study, axial sections were considered as the gold standard as it identified the maximum number of fractures.

MPR sections are found to be equally sensitive as axial sections in fractures of orbital bone and zygomatic bone.

MPR is nearly sensitive to axial sections in fractures of frontal bone followed by maxillary bone and mandibular bone.

VR images didn't show significant sensitivity over axial sections in any of the facial bone regions but was nearly sensitive in zygomatic bone followed by mandibular bone.

According to Tanvikula R, Erol B [14], axial and coronal CT images were adequate for diagnosis of medial orbital wall fractures, and they confirmed the superiority of coronal CT in the diagnosis of fractures of the orbital floor and blow-out fractures, especially in those patients who may develop diplopia or enophthalmos.

Fox *et al*. [15] found that 3D reconstructed CT scans were interpreted more rapidly and more accurately and that 3D CT was more accurate in assessing zygomatic fractures but was inferior to axial images for evaluating orbital fractures.

Many studies have noted that 3D reconstructed images are helpful in the evaluation of fracture comminution, displacement components, and complex fractures involving multiple planes [18].

The extent of communitive fractures is better demonstrated on the 3D-CT, where the size, shape, and displacement of individual fragments are clearly revealed [19-21]. The combination of multislice CT and 3D volume rendering technique allowed several improvements in imaging interpretation.

3D imaging is not indicated, however, for small fractures of the orbital floor or isolated fractures of the maxillary wall, in which the fracture is limited to one plane. Here, examining 3D scans alone can give false-negative results.

Conclusion

MDCT is an accurate, non-invasive technique for evaluation of patients with facial skeletal injuries. In the setting of acute trauma, MDCT has the advantage of shorter scan time and is increasingly available.

MPR and 3D VR images help better evaluation of fractures detected on axial images.

The CT-based MPR and 3D reconstructed images, together with recent advancement in computer graphics, enabled the radiologist to visualize and manipulate volumetric data quickly, permitting advanced imaging to the maxillofacial region.

The advantages of 3D images in the assessment of facial trauma could be described especially in mandible and zygomatic bone.

3D images were better in the identification of Le Fort fracture lines.

The coronal reconstructed images are similar to axial sections in the detection of fractures in the orbital and zygomatic region.

3D images have a limited role in fractures involving the fronto-naso-orbito-maxillary region and also when there is minimal fracture displacement.

Summary

- MDCT is the investigation of choice in the evaluation of patients with maxillofacial trauma.
- 3D images are useful, although variable for different bones, in the assessment of complex fractures involving the face. Coronal images are useful adjunct in detection of facial fractures.
- As there is no additional scanning or radiation involved in the reconstruction of images, 3D VR images and MPR is a valuable tool for the radiologist in interpreting maxillofacial fractures.
- Continuing advances in computer software algorithms and improved precision in the acquisition of radiographic data will make 3D reformatted CT imaging a necessary complement to traditional 2D CT imaging in the management of complex facial trauma.

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