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Multidetector Computed Tomographic Evaluation of Patterns of Facial Bone Fractures

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Abstract
With the increasing numbers of road traffic accidents and violence, Facial injuries causing fracture have become common any emergency department. Multidetector computed tomography (MDCT) is the best choice for imaging facial bones in an emergency setting. The
Objectives: *1. To study the efficacy of axial images in comparison with Coronal and 3 Dimensional CT reformatted images in detection of patterns of fracture in maxillofacial injuries. 2. To asses, the number of fractures, fracture extent and displacement of fracture fragments by comparing axial images with coronal and 3D images 3. To know about the prevalence of maxillofacial injuries. 4. To describe and classify the facial fractures.*
Materials and Methods: *Our study population consisted of 140 patients with facial bone fractures who came to the emergency department of RMMCH. CT scan of facial bones was taken on the advice of the casualty medical officer and images were acquired using Alexion 4-Slice CT (Toshiba) scanner using analyzed at the CT console. 3D images were compared with axial images and scoring was made under the following headings – Fracture Detection, Extent of fracture and Displacement of fracture fragments. Axial and Coronal images were compared in terms of the detection of the fracture.*
Results: *Our study group which comprised of a total of 140 patients, and the age at presentation was from 01 to 80 yrs. The Zygoma was the frequently involved bone followed in frequency by the frontal region fractures. The maxillary fractures were the affected region with fractures detected in 70 % of patients. Naso-orbito-ethmoid and mandibular fractures were detected in 52 and 43 % of patients.*
Conclusion: *The 3D images are useful in the facial trauma, particularly in case of mandibular and zygomatic fracture. Frontal and maxillary bone fractures were detected easily using 3D and their displacement pattern in patients with complex midface region fractures could be easily described. Le Fort type fracture was better identified in the 3D study. The coronal reconstruction helped in the detection of fractures involving the maxilla and medial wall and floor of the orbit. Naso-orbito-ethmoid region fractures were less detected and were not informative on 3 D images. Minimal fracture displacement was also less detected on 3D reformats.*
Keywords: *3Dimages, Computed tomography, Fracture, Naso-orbito-ethmoid, Le Fort;*

Introduction

Patients with facial injuries come to the Casualty as an isolated injury or as a part of polytrauma. With the effective transportation facilities like 108 ambulances and advanced life support measures available, patients who are very badly injured survive till they reach the tertiary care hospitals. With advancements in CT technologies, the facial injuries are easily detected. The important injuries are the facial soft tissue disruption and facial bone pillars fractures which cause disfigurement and asymmetry and are also associated with intracranial complications. The facial injuries are of important cosmetic and social concern.

Before the advent of CT plain skull radiographs in various projections was the investigation of choice in the patients with facial trauma, but they were not giving much information due to complex facial anatomy and superimposition of various facial bones. With advances in CT technology, the diagnosis of fractures of the face has become very easy. Multidetector computed Tomography is the cornerstone in modern emergency radiology which can localize and characterize any facial injuries in addition to the detection of intracranial complication.

In spite of the higher radiation dosage in CT compared to skull radiograph, CT is the preferred imaging modality of choice. In addition to the detection of fractures of facial bones, the involvement of the skull base along with associated complication can be accurately evaluated.

With many improvements in computer software technologies, getting multiplanar reconstruction is easy and accurate. 3D Volume rendering technology (VR) and Surface rendering (SR) technology, Maximum and minimum intensity projections (MIP and MinIP) helps inaccurate evaluation of the extent of fracturing without any added radiation dosage. It also aids the maxillofacial surgeons in classifying fractures as stable and unstable and helps them in getting a visual 3D picture before any reconstructive surgery. Many Radiologists in most of the occasions use only the axial images for the interpretation of facial bone fractures, with the use of 3D reconstructed images in cases of complex facial trauma the pattern of fracture can be better assessed.

Objective

The main objectives our study are:

1. To study the efficacy of axial images in comparison with Coronal and 3 Dimensional CT reformatted images in the detection of patterns of fracture in maxillofacial injuries.
2. To asses, the number of fractures, fracture extent and displacement of fractures by comparing axial images with coronal and 3D images
3. To know about the prevalence of maxillofacial injuries.
4. To describe and classify the facial fractures.

Materials and Methods

The study was carried out in the Radiology department of RMMCH, Annamalai University-Chidambaram, after getting the approval from the Ethical Committee. It was a hospital-based prospective study on 140 patients with trauma to face done from Jan 2017 to June 2018. The scan was performed on the advice of the referring doctor in the casualty.

Inclusion Criteria

Patients with facial injury on clinical examination and confirming the same on CT axial images.

Exclusion Criteria

Pregnant patients and those patients with no detectable facial bone injury.

Consent

Data Acquisition for the study was done only on patients who fulfill the inclusion criteria and after getting their written consent.

CT Protocol

The images were acquired using 4-Slice Alexion Toshiba CT scanner

- Non contrast CT , axial sections, 4 -Slice helical series.
- Beam collimation - 2-3 mm

- Pitch - 1.2
- Voltage- 120KV
- Time of exposure - 18 sec

Along with the axial images, Coronal and multiplanar reformatted (MPR) images were obtained. 3D volume-rendering images were also obtained. The assessment was made in CT console using high definition workstation.

3D and axial images were analyzed and compared under three parameters 1.Fracture Detection, 2.Extent of fracture and 3.Displacement of fracture fragments.

Coronal and Axial images were compared in terms of fracture detection.

The entire assessment was made on the following five facial regions: - 1. Frontal bone region 2. Zygomatic region 3. Naso-orbito-ethmoid (NOE) region 4. Maxillary region 5. Fractures in the mandibular region.

Results

The results obtained from our study were analyzed and tabulated as below:

Age distribution: Of the 140 patient in the study the ages of the patients involved consisted from 1 to 80 yrs and the first maximum involved age group was 20- 30 and the second maximum involved age group was 30- 40 age groups with 41 and 34 patients respectively.

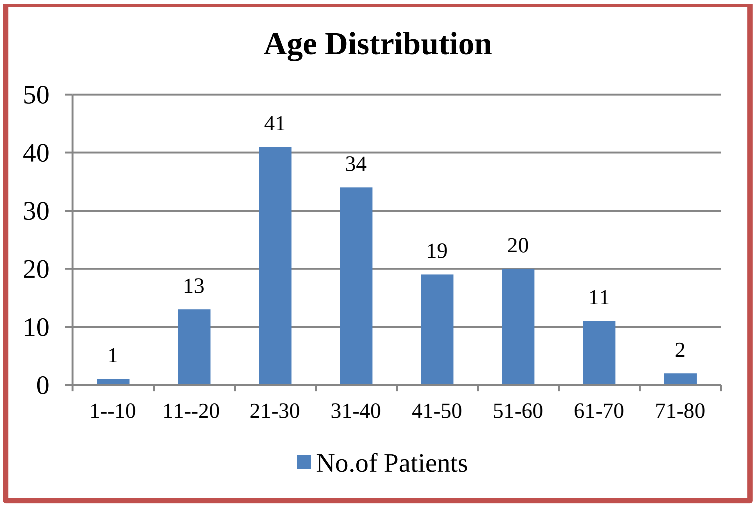

Chart 1: Chart shows the Age wise distribution of fracture.

Sex wise distribution: Male was more involved than the female with the incidence of 84% in males (117/140) and 16 % in female (23/140).

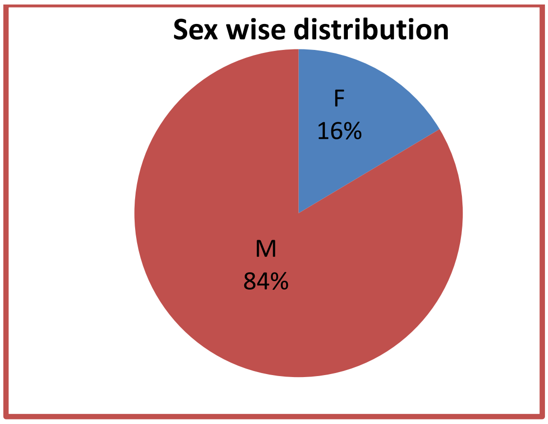

Chart 2: Pie chart shows the sex distribution of fractures.

Mode of injury: The Road traffic accidents were the most common mode of injury with 79 % of cases. Fall from height constitutes 15% and assault constitutes 6 % study population.

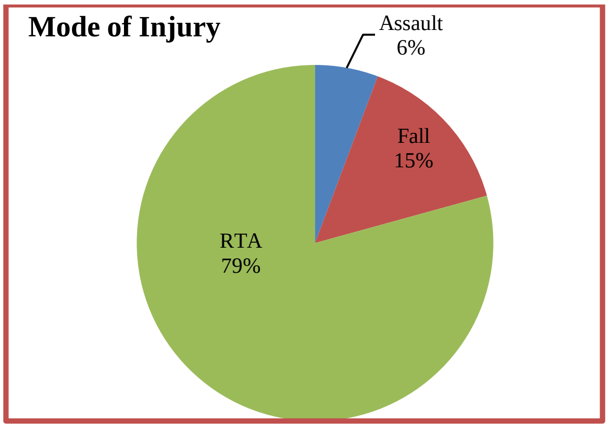

Chart 3: Pie chart showing the cause of fractures

Facial distribution of frequency facial fractures

Table1: Shows the distribution of fractures based on bone involved

S. No	Bones involved	No of cases
1	Frontal bone	51
2	Nasal bone	44
3	Frontonasal process	11
4	Mandible	22
5	Orbit -Superior wall	10
6	Orbit -Medial wall	19
7	Orbit-Lateral wall	26
8	Orbit –Inferior wall	20
9	Maxillary sinus –Anterior wall	46
10	Maxillary sinus Posterolateralwall	45
11	Maxillary sinus –Medial wall	17
12	Zygoma	54
13	Pterygoid plates	11
14	Sphenoid wing	6
15	Temporal bone	8

The Zygomatic bone was found to be most frequently involved followed in frequency by the frontal bone. The anterior wall of maxillary sinus was the third most common fractured bone. Nasal bone was the fourth common bone to get involved.

When the individual facial region is concerned Naso-orbito-ethmoid region was most commonly involved accounting to 28% followed by maxillary region and zygomatic region fractures accounting to 21% each.

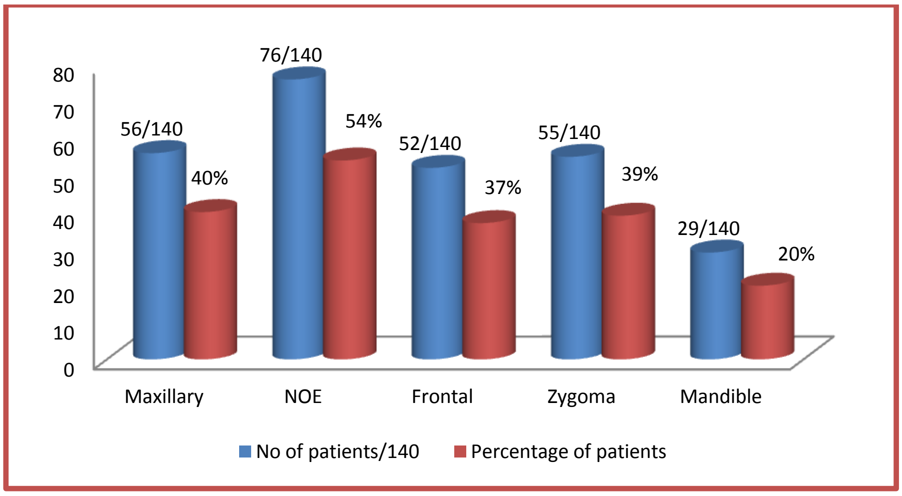

Chart 4: Shows the frequency distribution of the fractures involving the 5 facial regions

Comparison of axialVs3D (detection, extent, displacement) and axial Vs coronal images (detection):

Frontal region: 3D images were better in demonstrating detection and displacement of frontal fractures. But 3D was not useful in finding fracture extension to posterior wall and extension to the roof of orbit. Coronal images and axial images provided the same results.

Zygomatic region: 3D images were better for the detection and extent in about 31 and 35 % of patients respectively. In the case of the assessment of the displacement of fracture fragments, the 3 D images were very much superior to axial images in about 66% of patients.

Coronal and axial images provided similar information.

Naso-orbito-ethmoid region: In our study, the 3D images did not provide much information in the assessment of all the 3 parameters like detection, extent, and displacement of fractures and were considered inferior compared with axial images in most patients. Only in about 5% of patients with NOE fractures, 3D images helped in detection.

Coronal images were much superior to axial images in the detection of fractures in this region particularly the floor of orbit and medial wall of the orbit.

Maxillary region: 3D images more helpful in the detecting the anterior wall fractures whereas axial images were better in the assessment of extent and displacement.

Coronal images were more or less similar or better than axial images in terms of detection

Fractures in Mandible: In the case of mandibular fractures, in most of the patients, 3D and axial images provided the same results in detecting the fracture and the extent of involvement. However, there is much usefulness in assessment of displacement involving the fracture fragments with the use of 3D images. Coronal reformat images and axial images gave the same information in the detection of mandibular fractures.

Associated findings: Hemosinus was the frequent associated finding and was present in 73 patients of the 140 patients involved in the study.

Brain contusions and Extradural hemorrhage were the next common associated findings with facial fractures and they were seen in 20 and 17 patients respectively.

The incidence of Subdural hemorrhage was in 13 patients.

Subarachnoid hemorrhage was seen in 8 patients. Temporomandibular Joint involvement, Pneumocephalus, and base of skull involvement were seen in 11, 7 and 5 patients respectively.

Discussion

Facial trauma are usually associated with polytrauma and are very important as they cause facial soft tissue disruption and fractures the facial bones causing asymmetry of face and disfigurement which causes cosmetic and social concerns and this region is also associated with many important physiological functions[1]. Skull X rays in various views were the initial investigation but they are not very good at detection all fractures due to complex facial anatomy and superimposition of bones.

In spite of the higher radiation dose compared to conventional radiography, CT is the imaging modality of choice to deal with the fractures in this complex anatomical region. Multislice CT is the latest technological advancement in the world of CT, resulting in the acquisition of data in high speed and the possibilities of reconstructions.

Tanrikulu and Erol compared the CT with plain radiography in terms of clinical utility and proved that CT is superior in detection of findings compared to X rays [2].In the Multidetector CT, the data acquisition is continuous and archiving occurs as the entire volume of interest is scanned. Because of this, it is possible to scan a large volume with high image quality with rapidity and allowing thin sections to be made with a low number of artifacts. The scan timing has also has been rapidly reduced thereby reducing movement artifacts [3, 4].

Our study included 140 patient with the history of facial injury and who were found to have facial bones fractures. These patients were evaluated with a 4 Slice MDCT scanner. From the acquired axial images multiplanar and 3Dimensional reconstructed images were obtained using the available software.

The age of involved patients ranges from 1 to 80 yrs. The first maximum involved age group was 20- 30 and, next maximum involved age group was 30- 40 age groups with 41 and 34 patients respectively. The reason attributed to this was the usage of alcohol and the peer pleasure of rash driving in the 20-30 age group.

Male (84%) were more commonly involved then female (16%).The reason being the usage of alcohol and usage of motor vehicles by men. Road traffic accidents were the most common cause for facial fractures accounting to 79 % of cases. Other causes were the Fall from height accounting to 21% and assault was the cause in 8 % patients.

According to most investigators, the road traffic accidents (RTA) were the most common cause of facial fractures. Some authors said that assault was the most common cause. The distribution of the pattern of facial fractures varies based on the social, developmental and cultural factors.

Considering an example: a recent study has shown that motor vehicle accidents are the commonest cause in many industrial countries[6]. These results are consistent and in accordance with the finding in this study. A Zimbabwean study shows that 90% of men were involved with facial fractures and assault was the most common cause accounting to 90%, and predominantly involved age group was 21 – 25 years[7]. Most of the Zimbabwe population do not use motor vehicles and this was the reason given for that.

In assessing the fractures of frontal bone, 3D was superior in assessing the detection and displacement in more number of patients. The extension into the roof of the orbit and the involvement of the posterior wall of frontal sinus were not well seen on 3D images. Coronal images gave the same information as the axial images. In case of zygomatic fractures coronal and axial images gave the same information .3D reconstruction images were little better in detection and extent localization. Displacement of fracture fragments was seen better in 3D images with some more added information.

Medial wall and orbital floor fractures were seen in a better way than on coronal images. 3D was superior in the maxillary antral fracture detection, especially its anterior wall .the extent and displacement were better interpreted in the axial images.

Coronal images gave better or similar information when compared to axial images in the detection of maxillary fractures. Hessel had evaluated that 3D scans have to lead to cancellation or alteration of the surgeries, particularly in case of Naso-orbito-ethmoid fractures[8]. Fox in his study has found that 3D images were interpreted more rapidly and accurately and that 3D CT was more accurate particularly in assessing zygomatic bone fractures but was the same was inferior to axial images in evaluation orbital fractures[9].

Other studies also showed that comminuted fractures of mid third of the face and the zygomatic fractures are better studied with 3D CT[10]. Thus the 3D scans help the clinicians to identify the fracture and helps better to localize the bone fragments and their direction of displacement of fragments. Three-dimensional imaging is not always indicated, for small orbital floor fractures or isolated fractures involving the maxillary wall, in which the fractures are limited to one plane. Here 3D scans examination alone can give many false-negative results[11].

According to Tanrikulu And Erol, axial and Coronal images were sufficient for the diagnosing medial orbital wall fractures and the stated that coronal CT was more informative in the diagnosis of orbital floor fractures and blow-out fractures, particularly in patients with diplopia or enophthalmos[2].In detection, extent localization and displacement identification in fractures of Naso-orbito-ethmoid region 3D images were inferior and less informative compared to axial images.

This region has a bone which is thin which caused "pseudoforamina" due to partial volume effect and also due to overlapping bony structures. 3D and axial images provided the same details in case of detection of fracture and extent of involvement of mandibular fractures in our study. However, displacement details of fracture fragments were better identified using 3D images.

In case of detection of fractures of the mandible, Coronal images and axial images gave the same information. Many studies have shown that 3D images are very useful in the demonstration of fracture comminution, displacement of fracture components, and multiplanar complex fractures[12].

The extent of fracture comminution is demonstrated better on 3D-CT, revealing the size of fragment, shape and displacement details of individual fragments [13]. The combination of CT and 3D VR technique allows improvements in imaging interpretation in a better manner.

This study also shows that comminuted fractures, displacement of each fracture component, and complicated fracture extending to multiple planes were better seen on 3D images.

The finding associated with facial bone fracture commonly was hemosinus which was seen in 73 patients with facial fractures. Lambert et al found that clear sinus sign is a highly reliable exclusion criterion of fractures involving the walls of paranasal sinuses.

Brain contusions and Extradural hemorrhage were the next common associated findings with facial fractures. Brain contusion and Extradural hemorrhage were seen in 20 and 17 patients respectively.

The incidence of Subdural hemorrhage was in 13 patients. Subarachnoid hemorrhage was seen in 8 patients. Pneumocephalus, Skull base involvement, and Temporomandibular Joint involvement were seen in 11, 7 and 6 patients respectively. Fractures involving the frontal bone was most associated with intracranial bleed. Pneumocephalus was also commonly associated with fractures in this region. Similarly, skull base involvement was also a common finding in patients with frontal bone fractures. E.M. Salonen Et Al also reported that skull base involvement was more with frontal bone followed by Le Fort type II and type III fractures[5].

In our study, Naso-orbito-ethmoid and zygomatic region fractures were also associated with hemosinus but the incidences of intracranial bleed were less common. Hemosinus was most seen in fractures of the maxillary region but the incidence of intracranial bleed and skull base involvement was very less. Fractures involving the mandible had the least common association with Hemosinus, intracranial bleed and with skull base involvement. The Temporomandibular Joint was commonly involved with mandibular fractures.

Type 2 frontal bone fractures were found to be most common, seen in about 23 patients (41%). Type 3 is the next common type occurring 10 (18%) patients. Type 1 and Type 4 fractures were seen 11(20%) and 9(16%) patients respectively and Type 5 was found to be least common which was found in 3 patients (5%). Salonen et al also illustrated the similar findings where they found that type 3, 4 and 2 in patients with fall from the height[5].

The orbital lateral wall was most commonly involved and was found in 26 patients (%) followed by the Orbital floor which was involved in involved 39 times (29.5%). The medial wall and roof were involved in 19 and 10 patients respectively. This is not in accordance with studies of orbital fractures where the floor and the medial wall were commonly involved[14].

The mandibular injuries were found in 29 patients which corresponds to 20% of the study population. The most common part involved is the condyle followed by the parasymphysis of the mandible. This is not in accordance with the study by Sivalingam et al where the mandibular fracture was found in 42% of the population [20].A study by hall rl et al, states that most common site for all mandibular fractures (if single and multiple fracture cases are included) is the condylar - subcondylar regions (25-40%)[15]. However, if a single fracture is present, it commonly occurs at the angle[16]. Kruger Go says that the mandibular body fractures occur in about 16-36% of mandibular fractures, with the highest incidence in patients involving in motor vehicle accidents[17].

Le Fort (LF) fractures were noted in total 11 persons. LF II was the most commonly found and was identified in 6 patients (50%). LF I and III fracture were found in 3 and 2 patients each. This is similar to the studies done by Duval Aj et al [18]. Combination of LF I & II and LF II & III fractures were found in 1 patient each.

Combination of LF I and LF III or the combination of LF I, LF II and LF III fracture lines were seen in none of the patients in our study. A study by Bagheri sc et al states that Le Fort type fractures at the same level are less frequently observed than are combinations type Le Fort fractures [19]. This is in accordance with our study as 8 fracture lines occurred in combination out of the total 11 Le Fort lines identified. Most of the findings in our study are similar to the study done by Sivalingam et al[20].

Table 2: Frontal bone fractures (Manolidis Classification I-V)

Fracture type	No of cases	Percentage%
I	11	20%
II	23	41%
III	10	18%
IV	9	16%
V	3	5%

Table 3: Frequency of Orbital wall fractures

Orbital walls	No of cases	Percentage %
Superior	19	25
inferior	26	35
Medial	10	13
Lateral	20	27

Table 4: Mandible fracture classification based on the anatomical region involved

Mandibular injury	Number of fractures (n=49)	Percentage %
Body	5	10
Ramus	3	6
Angular	5	10
Alveolar ridge	2	4
Symphyses	2	4
Parasymphysis	10	21
Condylar	17	35
Subcondylar	5	10

Table 5: Le Fort Fracture types (n=11)

Le Fort Fracture - LF	Number of fractures (n=11)	Percentage%
LF I	3	27
LF II	6	55
LF III	2	18

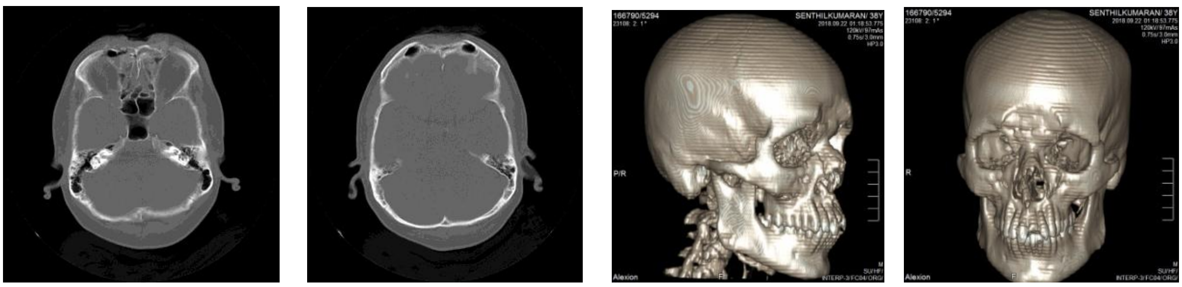

Fig1:a.b.Axial images shows communited fracture involving both tables of frontal sinus and the bilateral nasoethmoid region.

c.d.3D images showing the depressed communited fracture in this region .

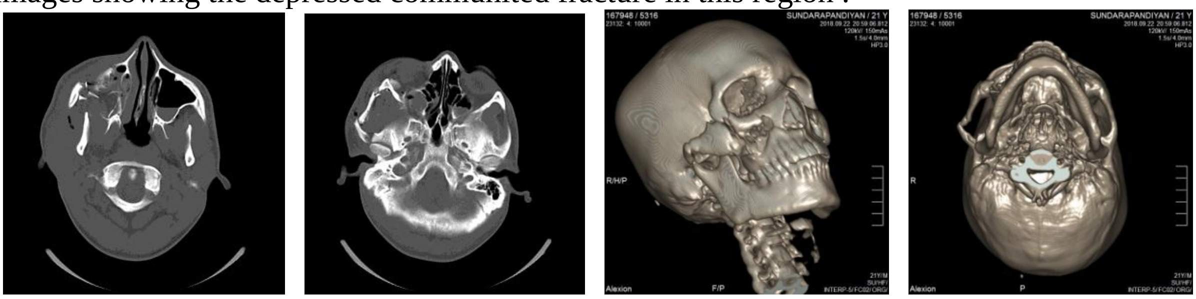

Fig 2:a,b. Axial images shows communited fracture of all walls of right maxillary sinus with fracture of zygomatic arch

c,d. 3D reconstructed image showing the extent and nature of displacement of fracture fragments

Conclusion

MDCT is a non-invasive accurate technique in the evaluation of facial fractures. In emergency conditions, MDCT has the advantage of shorter scan time and is increasingly available. Multiplanar and 3D images aid in the better evaluation of fractures than axial images in terms of detection.

The Multiplanar and 3D reconstruction, together with modern advances in computer graphic software have enabled the radiologist to visualize and analyze the volumetric data rapidly particularly in the maxillofacial trauma. This article demonstrates the important role of 3D and MPR in the evaluation of maxillofacial fractures.

The 3D images are advantageous in the assessing facial fractures particularly in the detection of the mandible, zygomatic bone, and maxillary bones as well as the displacement in patients with midfacial fractures. 3Dimages were superior in the identification of fracture lines.

In case of frontal bone fracture assessment, detection and displacements with 3D were seen better on more percentage of patients. However, fracture extension into the posterior wall of sinus and the roof of orbit were not well seen on the 3D reconstructed images. Bony overlap of the anterior wall of the sinus causes the obstruction in visualization. This is more useful for the evaluation of fractures of maxillofacial region, where the maxillofacial surgeons can receive the 3D data from a CT workstation to the operating room by a network connection, and developing three-dimensional real-time model.

In the identification of Le Fort fractures, 3D images were found to be more useful.

The coronal reconstructed images were found to be more useful in the detection of fractures involving the maxilla and orbit.3D reformatted images have a limited role in fractures involving the Naso-orbito-ethmoid region and also in case of fractures with the minimal displacement of fracture.

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