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Evaluation of Maxillofacial Injuries Using Multislice Computed Tomography

*Jaiganesh Sivalingam[1], Aswin Kumar V[2], Karthiek Yennabathina[3], Rajasekhar K. V.[4]

[1]Associate Professor, Department Of Radiodiagnosis, Meenakshi Medical College Hospital And Research Institute(MMCH & RI). Kanchipuram.
[2]assistant Professor, Department Of Radiodiagnosis, Omandurar Medical College, Chennai
[3]Post Graduate Student, Department Of Radiodiagnosis, Meenakshi Medical College Hospital And Research Institute(MMCH & RI). Kanchipuram.
[4]Professor And Hod, Department Of Radiodiagnosis, Meenakshi Medical College Hospital And Research Institute(MMCH & RI). Kanchipuram.

Abstract: *Maxillofacial trauma usually presents in the Emergency Department (Casualty) as either an isolated injury or as a part of polytrauma. Due to the evolution of more effective emergency transportation facilities and advanced life support, even patients that are severely injured survive to reach specialized trauma centres which are increasing successful in rescuing patients.*

Objective: *The purpose of our study was To describe the advantages of three-dimensional (3D) reconstructed images over axial images in the imaging of patients with facial fractures and to describe and compare the detection of fractures in the axial and coronal planes.*

Materials and Methods: *The study population included 100 patients who underwent CT evaluation of facial bones when they presented with evidence of fracture of maxillofacial bones to the casualty at Meenakshi medical college hospital. The CT was done on the advice of the referring doctor (casualty medical officer, duty assistant surgeon, duty ENT surgeon). The dissertation evaluates various fractures involving the facial bones that were detected in these patients. MDCT evaluation is done only on patients who satisfy the inclusion criteria and only after getting their consent. All the CT scans in this study were performed using 6-Slice CT scanner (Siemens Somatom Emot-6). 3D images were compared with axial images and assessed under the headings – fracture detection, extent of fracture and displacement. Coronal images were compared with axial images for detection of fractures.*

Results: *In this study group which comprised of a total number of 100 patients, the age at presentation ranged from 11 to 65 yrs. The maxilla, especially the walls of its sinus was noted to be the most commonly involve bone with 73% of patients having a fracture in this bone. The naso-orbito-ethmoid region was the next commonly affected region with fractures detected in 69% of patients. Zygomatic bone and mandible fractures were detected in 53 and 42% of patients. Frontal bone fractures were less common in the five regions of the face studied with 37% of patients detected to have fractures in that region.*

Conclusion: *The advantages of 3D images in the assessment of facial trauma could be described especially in mandible and zygomatic bone. The easier detection of fractures in the frontal and maxillary bones as well as their displacement in patients with complex mid facial fractures could be described. 3D images were better in the identification of Le Fort fracture lines. The coronal reconstructed images were superior in the detection of fractures in the orbit and maxilla. 3D images have a limited role in fractures involving the naso-orbito-ethmoid region and also when there is minimal fracture displacement.*

Keywords: *Facial Injury; MDCT; Le Fort's; Trauma;*

I. Introduction

Maxillofacial trauma usually presents in the Emergency Department (Casualty) as either an isolated injury or as a part of polytrauma. Due to the evolution of more effective emergency transportation facilities and advanced life support, even patients that are severely injured survive to reach specialized trauma centres which are increasing successful in rescuing patients. With such advances in trauma care, the severity of diagnosed facial injuries may thus increase. Such injuries are clinically important as the disruption of soft tissues and bones of the face causing facial disfigurement and asymmetry which may cause cosmetic as well as emotional concerns. This region is also associated with several important functions of daily living. Plain radiographs have been the initial modality of imaging in these patients, but they can be inadequate due to the superimposition of bony structures. CT greatly simplifies interpretation MDCT, the cornerstone of modern emergency radiology, can easily detect and characterize injuries not only of the body and spine, but also intracranial and maxillofacial injuries. Despite a higher radiation dosage compared to conventional radiographs, CT is the imaging modality of choice to display the multiplicity of fragments, the degree of rotation and displacement or if there is any skull base involvement. It is also used to assess which areas of facial injuries are stable or unstable for planning corrective or reconstructive surgery. The advances in medical imaging technology such as computer software algorithms in CT have made the generation of coronal and sagittal reconstructed images as well as 3-Dimensional images quick and economical. There is no additional scanning or radiation dosage as the images can be reconstructed from the same axial CT images. 3-Dimensional images may be superior in localization of complex fractures involving multiple planes, in perception of fracture displacement and in the assessment of facial symmetry. However their usefulness in minor trauma with little or no fracture displacement is much less. As experienced radiologists use axial images in the interpretation of facial trauma, the utility of reconstructed images in cases of complex facial trauma may be assessed in detail.

II. Objective

To evaluate the patients with facial injuries and fractures with MDCT.
To describe the advantages of three-dimensional (3D) reconstructed images over axial images in the imaging of patients with facial fractures.
To describe and compare the detection of fractures in the axial and coronal planes.

III. Materials And Methods

Source of Data

The prospective study population included 100 patients who underwent CT evaluation of facial bones when they presented with evidence of fracture of maxillofacial bones to the casualty at Meenakshi medical college hospital from January 2013 – October 2014. The CT was done on the advice of the referring doctor (casualty medical officer, duty assistant surgeon, duty ENT surgeon).

Inclusion Criteria

- Patients with CT evidence of fracture of the maxillofacial bones.

Exclusion Criteria

- Patients without any evidence of fracture of the maxillofacial bones
- Patients with maxillofacial fractures in whom a CT examination is contraindicated - Pregnancy(1^{st} trimester)etc.

Data Acquisition

MDCT evaluation is done only on patients who satisfy the inclusion criteria and only after getting their consent. All the CT scans in this study were performed using 6-Slice CT scanner (Siemens Somatom Emot-6).

CT Protocol consisted of the following:

- Non contrast axial 6-Slice helical series.
- Beam collimation : 2-3 mm
- Detector configuration 6 x 0.63
- Pitch 1.2
- Tube current 220mAs
- Voltage 120KV
- Total exposure time 18 sec

Along with the axial images, Coronal-plane multiplanar reformation (MPR) images were reconstructed with 1.5mm increment. Three-dimensional volume-rendering images were also obtained. The MDCT scans were reviewed using clinical workstation. The fractures detected on CT examination were classified according to the region involved. 3D images were compared with axial images and assessed under the headings – fracture detection, extent of fracture and displacement. Coronal images were compared with axial images for detection of fractures.

These were assessed in 5 regions:

- Frontal bone fractures
- Zygomatic bone fractures
- Naso orbito ethmoid fractures
- Maxillary fractures
- Mandibular fractures

IV. Results

Results of our study were analyzed and tabulated as below:

Age distribution of patients in the study:

In this study group which comprised of a total number of 100 patients, the age at presentation ranged from 11 to 65 yrs. Most patients belonged to the 31- 40 and 21- 30 age groups with 27 and 26 patients respectively.

Sex distribution of patients studied:

There were 89 males (89%) and 11 females (11%) in the patients included in the study group.

Mode of injury:

The most common mode of injury in patients presented with maxillofacial trauma was road traffic accidents, comprising 81% of cases. Fall from height and assault were the other causes, comprising of 13 and 6% respectively.

Frontal Bone Fractures:

Frontal bone fracture detection and displacements were seen better on 3D images in more percentage of patients. However their extensions, especially into the posterior wall of sinus or roof of orbit were not adequately visualized on the 3D images.

Coronal images were found to be similar to axial images in the detection of fractures in frontal bones.

Zygomatic Bone Fractures:

3D images were found to be similar or better for the detection and description of the extent in most patients with zygomatic bone fractures. In the assessment of displacement, it was found to be superior to axial images in most patients.

Coronal images were similar to axial images in the detection of zygomatic bone fractures.

Naso-Orbito-Ethmoid Fractures:

The 3D images were found to be inferior in the assessment of detection, extent and displacement of fractures in the naso-orbito-ethmoid region when compared with axial images in most patients.

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

Fractures in Maxilla:

3D images were superior in the detection of fractures in the maxilla especially with involvement of anterior wall of the sinus. However the extent of involvement and its displacement were better seen on axial images.

Coronal images were similar or better than axial images in the detection of fractures in maxilla of most patients.

Fractures in Mandible:

The detection and extent of involvement assessed by 3D and axial images were similar in most patients with mandibular fractures. However there was a definite advantage in assessment of displacement of fracture fragments with the use of 3D images.

Coronal images were similar to axial images in the detection of mandibular fractures.

Table 1: Distribution of fractures in different bones.

Type of Bone	Occurrence of fractures (n=100)	%
Frontal bone fractures	37	37
Zygomatic bone fractures	53	53
Naso Orbito Ethmoid fractures	69	69
Fractures in Maxilla	73	73
Fractures in Mandible	42	42
Pterygoid plate	9	9
Sphenoid wing	11	11
Temporal bone	13	13
Parietal bone	3	3

The pterygoid plates were noted to be involved in 9 patients (9%). Sphenoid wings were involved in 11 patients. The calvarial bones, temporal and parietal bones were noted to be involved in 13 (13%) and 3 (3%) patients respectively.

The maxilla, especially the walls of its sinus was noted to be the most commonly involve bone with 73% of patients having a fracture in this bone.

The naso-orbito-ethmoid region was the next commonly affected region with fractures detected in 69% of patients.

Zygomatic bone and mandible fractures were detected in 53 and 42% of patients. Frontal bone fractures were less common in the five regions of the face studied with 37% of patients detected to have fractures in that region.

Associated findings:

Hemosinus was the most common finding in patients who presented with facial trauma; it was seen in 73 patients. Brain contusions and EDH were the next commonest findings seen in 20 and 17 patients respectively. SDH was seen in 13 patients. SAH was seen in 8 patients. Skull base involvement, pneumocephalus and TM Joint involvement were seen in 7, 5 and 11 patients respectively.

Table 2: Frontal bone injuries (classified according to Manolidis)

Fracture type	**Number of fractures (n=37)**	**%**
Type 1	6	16.2
Type 2	11	29.7
Type 3	10	27.02
Type 4	6	16.2
Type 5	4	10.8

Table 3: Orbital Injury According To The Walls Involved

Orbital injury	**Number of fractures (n=132)**	**%**
Lateral wall	32	24.2
Medial wall	46	34.8
Roof	15	11.4
Floor	39	29.5

Table 4: Classification of mandible fractures according to the site of involvement

Mandibular injury	**Number of fractures (n=74)**	**%**
1. Condylar	24	32.6
2. Body	24	32.6
3. Subcondylar	5	6.5
4. Coronoid	5	6.5
5. Ramus	5	6.5
6. Angular	2	2.8
7. Alveolar Ridge	4	5.9
8. Parasymphyseal	3	4.4
9. Symphyseal	2	2.2

Table 5: Le Fort Fracture Lines Identified:

Le Fort Fracture Lines Identified	Number of fractures (n=12)	%
Le Fort I	4	33.3
Le Fort II	6	50.0
Le Fort III	2	16.6

Table 6: Combination of Le Fort Lines identified

Le Fort Fracture Lines identified	Number of fractures (n=4)	%
Le Fort I and II	2	50
Le Fort I and III	0	0.0
Le Fort II and III	2	50
Le Fort I, II and III	0	0.0

Fig – 1:
Fig – 2:
Fig – 3:
Fig – 4:
Fig – 5:

V. Discussion

Maxillofacial trauma presents as isolated injuries or part of polytrauma and are clinically important as the disruption of soft tissue and bones of the face cause facial asymmetry and disfigurement which cause emotional and cosmetic concerns and the region is also associated with several important functions of daily living[1].

Plain radiographs have been the initial modality of imaging in these patients. But they can be inadequate due to superimposition of bony structures. Despite a higher radiation dosage compared to conventional radiography, CT is the imaging modality of choice to display the multiplicity of fragments, the degree of rotation and displacement or any skull base involvement. **TANRIKULU** and **EROL** compared the clinical utility of CT with plain radiography and proved the superiority of CT in the diagnosis and classification of all fractures[2].

Multislice CT is a significant advance in the technology of x-ray CT, and the latest technological advance in CT imaging, resulting in the opportunity to greatly increase the speed of data acquisition and reconstruction. It has been demonstrated that multislice CT can obtain a greater range of anatomic coverage during the scan. The continuous data acquisition and archiving occurs as the entire volume of interest is scanned. Consequently, it is possible to scan rapidly a large volume of interest with high image quality, thin sections, and a low artifact rating in short time, thereby dramatically reducing respiratory motion problems[3, 4].

This study included 100 patients who had a history of maxillofacial injury and were found to have fractures involving the facial bones. The study included the evaluation of these patients with a 6 Slice MDCT scanner. The axial images generated were supplemented by the reconstruction of 3D volume rendered images as well as coronal multiplanar reformatted images.

The study population consisted of patients in the age group of 11 to 65 years. Most patients belonged to the 31 – 40 and 21 – 30 age groups with 27 and 26 patients respectively. This study also showed a male preponderance accounting for 89% of the case load.

Kieser Et Al 80% facial fractures (of all injuries) in males[5].

The most common mode of injury in patients presented with maxillofacial trauma was road traffic accidents, comprising 81% of cases. Fall from height and assault were the other causes, comprising 13 and 6% respectively.

Many authors reported that road traffic accidents were the most frequent cause of facial fractures. Although some authors reported that assault (fighting) was the most common cause. RTA was found to be the most common cause of facial fractures in this study as well.

Fall from height and assault being other causes of maxillofacial fractures in this study is also consistent with other similar studies mentioned. Because of social, cultural and environmental factors, the causes of maxillofacial fractures vary. For example, in a study from Zimbabwe, 90% of trauma patients were men and 90% of fractures resulted from fighting, predominantly in the 21 – 25 years age group[6]. The explanation given for this was that most Zimbabweans do not have motor vehicles. More recent studies have shown that motor vehicle accidents remain the most frequent cause in many industrial countries[7]. These results are consistent with the finding in this study as the hospital is situated in a busy industrial sector.

In the assessment of frontal bone fractures, detection and displacements were seen better on 3D images in more percentage of patients. However their extensions, especially into posterior wall of sinus or roof of orbit were not adequately visualized on the 3D images.

This is due to the overlap of the bony anterior wall of the sinus restricting visualization.

Coronal images were found to be similar to axial images in the detection of fractures in frontal bone. 3D images were found to be similar or better for the detection and description of extent in most patients with zygomatic bone fractures. In the assessment of displacement, it was found to be superior to axial images in most patients.

Coronal images were similar to axial images in the detection of zygomatic bone fractures. The 3D images were found to be inferior in the assessment of detection, extent and displacement of fractures in the naso-orbito-ethmoid region when compared with axial images in most patients.

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

3D images were superior in the detection of fractures in the maxilla especially with involvement of anterior wall of the sinus. However the extent of involvement and its displacement were better seen on axial images.

Coronal images were similar or better than axial images in the detection of fractures in maxilla of most patients.

Fox found that 3D reconstructed CT scans were interpreted more rapidly and more accurately and that 3D CT was more accurate at assessing zygomatic fractures but was inferior to axial images for evaluating orbital fractures[8].

Other studies have also described 3D CT as being most useful for imaging comminuted fractures of the middle third of the face and the zygomatic0-maxillary complex[9].

Hessel demonstrated that these 3D CT scans altered or cancelled surgical procedures, particularly in nasi-orbito-ethmoid fractures[10]. These observations indicate that 3D scans enable clinicians to better assess the localization of bone fragments and their direction of displacement.

Three-dimensional imaging is not indicated, however, for small fractures of the orbital floor or isolated fractures of the maxillary wall, in which the fracture id limited to one plane. Here, examining 3D scans alone can give false-negative results[11].

According to Tanrikulu And Erol, axial and coronal CT images are 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[2].

These findings were consistent with the findings in this study with Naso-orbito-ethmoid fractures where 3D images were found to be inferior to axial images in detect of fractures, their extent and in assessing displacement. The thin bones in these regions causing partial volume averaging resulting in “pseudoforamina” and considerable bony overlap could explain this finding.

The detection and extent of involvement assessed by 3D and axial images were similar in most patients with mandibular fractures in this study. However there was a definite advantage in assessment of displacement of fracture fragments with use of 3D images.

Coronal images were similar to axial images in the detection of mandibular 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[12]. The extent of comminutive fractures is better demonstrated on 3D-CT, where the size, shape, and displacement of individual fragments are clearly revealed[13]. The combination of multislice CT and 3D volume rendering technique allows several improvements in imaging interpretation.

In this study as well it was seen that the 3D reconstructions were helpful in the evaluation of comminutive fractures, displacement components, and complex fractures involving multiple planes.

Hemosinus was the most common associated finding in the patients who presented with facial trauma. It was seen in 73 patients (73%).

lambart et al found that the absence of free paranasal sinus fluid (clear sinus sign) in facial CT is a highly reliable criterion for excluding fractures involving the paranasal sinus walls. In this study only one patient had absence of Hemosinus with associated injury to the sinus wall.

Brain contusions and EDH were the next commonest findings seen in 20(20%) and 17(17%) patients respectively. SDH was seen in 13 patients. SAH was seen in 8 patients. Skull base involvement, pneumocephalus and TM Joint involvement were seen in 7, 5 and 11 patients respectively.

Frontal bone fractures were commonly associated with Hemosinus and also with intracranial bleed. Pneumosinus was most commonly associated with frontal bone fractures. Skull base involvement was also more common in patients with frontal bone fractures.

E.M.Salonen Et Al also found increased association of skull base involvement with frontal bone, Le Fort II and III fractures[5]. Zygomatic bone and naso-orbito-ethmoid fractures were also associated with Hemosinus in this study but the incidences of intracranial bleed were less common. Maxillary fractures were commonly associated with Hemosinus. The incidence of intracranial bleed and skull base involvement was much less.

Mandibular fractures were least commonly associated with Hemosinus, intracranial bleed and with skull base involvement. The TM Joint was seen to be more commonly involved in association with mandibular fracture.

The type 2 frontal bone fractures were more commonly seen in this study 11 (29.7%) times. Type 3 is the next common type occurring 10 (27.1%) times. Type 1 and type 4 fractures were seen six times (16.4%). Type 5 was the least common injury seen four times (10.2%). Similar results were also documented by Salonen et al where they found frontal bone fractures to be of type 3, 4 and 2 in patients with fall from height[5].

The medial wall of the orbit was the most commonly involved in 46 (34.8%) of the total orbital injuries detected. Orbital floor was seen to be involved 39 times (29.5%). The lateral wall and roof was seen involved 32 and 15 times respectively. This is consistent with studies of orbital fractures where the floor and the medial wall were commonly involved[14].

The mandibular injuries were most common in the condyle and the body of the mandible. Of the 74 fractures that were detected in the mandible, 24 were noted in the condyle and body each constituting 32.6% each of the total fractures.

Many studies especially the one by hall rl et al, have noted 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 only one fracture is present, it more commonly occurs at the angle[16]. Kruger Go states that the body fractures occur in 16-36% of mandibular fractures, highest incidence occurring in patients involved in motor vehicle accidents[17].

This study where most of the patients presented with a history of RTA, most common site of injury was found to be the condylar region and the body which is consistent with the above mentioned studies.

Fractures in the subcondylar region, the coronoid process and the ramus were detected five times each (6.5%). Alveolar ridge fractures were noted four times (5.9%). Parasymphyseal fractures were noted three times (4.4%). Angular and symphyseal fractures were each noted twice.

Le Fort fracture lines were identified in 8 occasions. The most common Le Fort line identified was the Le Fort II which was seen 4 times (50%). Le Fort I and III fracture lines were identified in 2 occasions each.

This is consistent with the studies done by **DUVAL AJ et al** who showed the Le Fort II fractures to be the most common and the Le Fort III fractures to be the most severe of all three[18].

A combination of Le Fort I & II and Le Fort II & III fracture lines was found in 2 patients each. A combination of Le Fort I and Le Fort III lines or Le Fort I, Le Fort II and Le Fort III fracture lines were not seen in any of the patients.

bagheri sc et al found that Le Fort fractures at the same level are less frequent than are combinations of Le Fort fractures that can occur on either side of face[19].

This is in harmony with this study as 8 fracture lines occurred in combination out of the total 12 Le Fort lines identified.

VI. Conclusion

MDCT is an accurate, non-invasive technique for evaluation of patients with maxillofacial injuries. In the setting of accurate 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 developments in computer graphics, enabled the radiologist to visualize and manipulate volumetric data quickly, permitting ready application of advanced imaging to the maxillofacial region. This has been shown to be useful for the evaluation of maxillofacial fractures, especially when the surgeons can easily receive the 3D data from a workstation to the operating room simultaneously by a network connection, and developing a3D real time model. Familiarity with the normal anatomy and the common pattern of facial fractures will aid the radiologist in providing an accurate and detailed analysis of facial fractures.

This study demonstrates the valuable role of MDCT in the evaluation of maxillofacial fractures. The advantages of 3D images in the assessment of facial trauma could be described especially in mandible and zygomatic bone. The easier detection of fractures in the frontal and maxillary bones as well as their displacement in patients with complex mid facial fractures could be described. 3D images were better in the identification of Le Fort fracture lines. The coronal reconstructed images were superior in the detection of fractures in the orbit and maxilla. 3D images have a limited role in fractures involving the naso-orbito-ethmoid region and also when there is minimal fracture displacement.

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Figures

Fig – 1: 3D VR images showing Complex mid facial fractures with Le Fort II and III lines

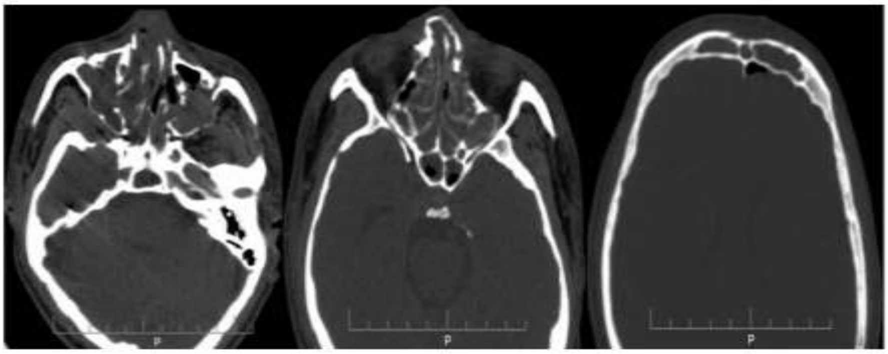

Fig – 2:Axial images demonstrating the fractures in the maxillary and ethmoid sinus with hemosinus and pneumocephalus in left frontal region

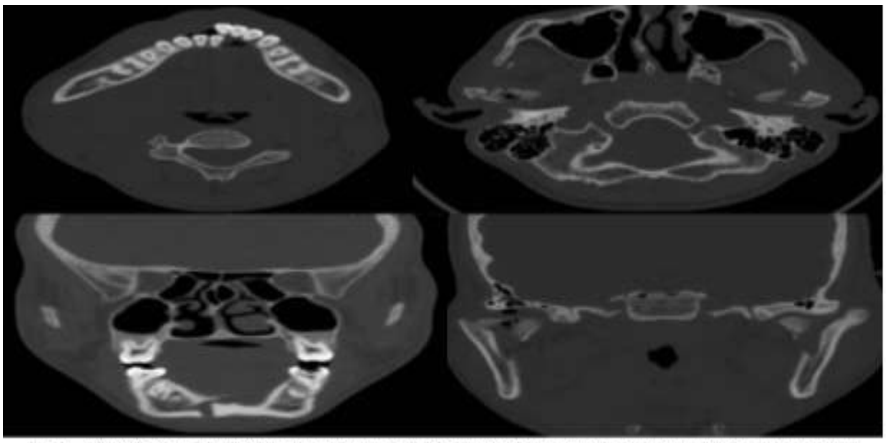

Fig – 3: Axial and Coronal Images showing fracture in the mentum and condylar process of mandible

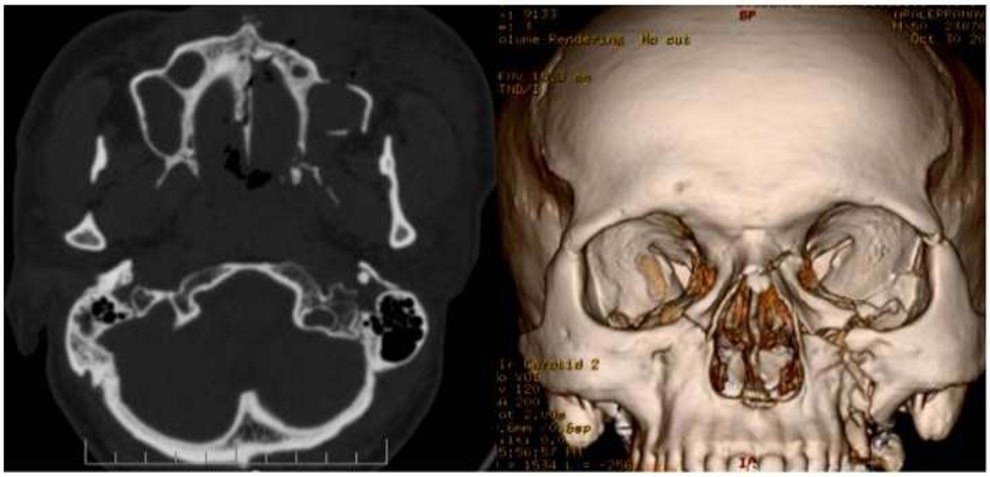

Fig – 4: Axial image showing the fractures in the maxillary sinus walls extending into the hard palate and VR image to Le fort's fracture line on left side.

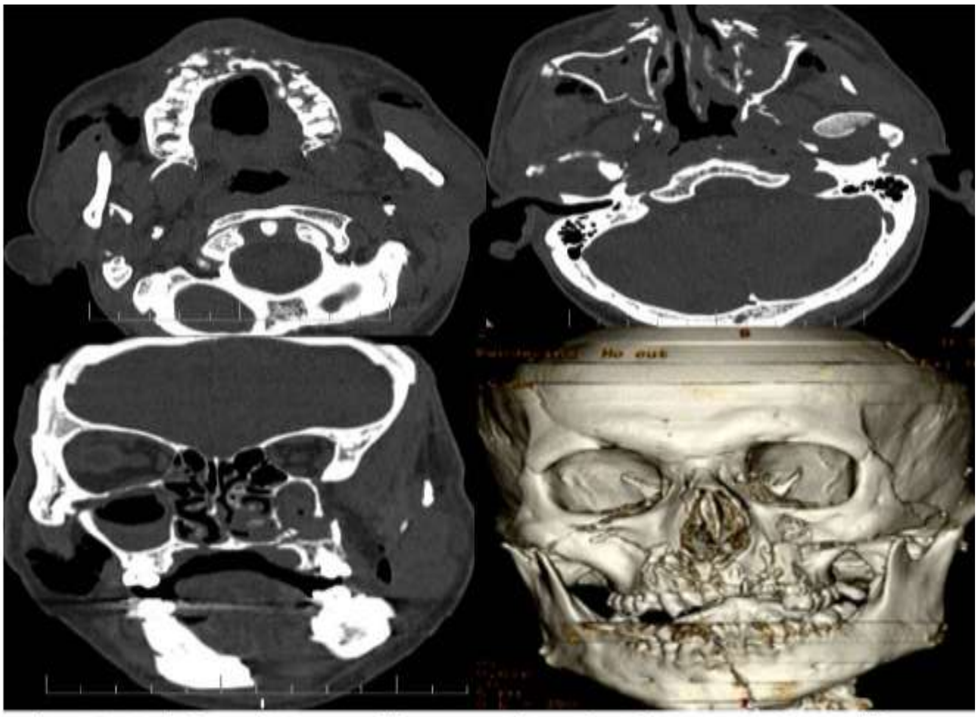

Fig – 5: Axial and Coronal images showing fracture of maxilla and 3D-VR image showing typical Le Fort's Type – I Fracture