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Role of 3d Reconstruction in Complex facial Fracture over 2d Images

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Abstract: *Almost all patients receive a fine cut computed tomography (CT) scan to evaluate the skeletal trauma. Sometimes aO.P.G.x-rayis obtained if a jaw fracture is suspected. With the help of advanced CT software algorithm the multiplanar reformation and three dimensional volume rendering is quick and cost effective. Our study aims to evaluate the efficacy of detection of facial fracture by 3D reconstruction over 2D images in patients with facial bone injuries. This prospective observational study was conducted in patients who underwent CT evaluation of face when they presented with facial trauma to casualty. The advantages of 3D images in the assessment of facial trauma could be described. 3D images were better in the identification of Le Fort fracture lines and have a limited role in fractures involving the naso orbitoethmoid region and also when there is minimal fracture displacement. The aim of the present study is to assess the role, reliability and accuracy of different 3 – dimensional (3D) reconstruction algorithms in detecting undisplaced condylar, zygomatic arch and orbital rim fractures based on cone-beam computed-tomography data set with the 2D images.*
Technological advances in computerized tomography (CT) have reduced data acquisition and reconstruction times so that three-dimensional (3D) CT images of maxillofacial injuries may be economically and quickly generated. 3DCT was judged superior to multiplanar two-dimensional CT in demonstrating the spatial relationships of fracture fragments in complex mandibular and midfacial trauma. Although 3DCT failed to demonstrate soft-tissue injuries well, the surgeon's improved appreciation of the disrupted bony architecture facilitated preoperative planning. 3DCT facilitates the evaluation of complex mandibular and midfacial fractures.

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I. Introduction

There are many causes to facial fractures, which can include motor vehicle accidents, interpersonal trauma, accidents, or work-related or sports-related activities. Patients are often seen in the emergency room for initial evaluation. In the early management period, life-threatening issues are addressed first and facial fracture repairs are only attempted after a patient is stabilized. The transport system and life support has improved a lot in recent years and thus helping many severely injured patients manage to reach the specialized trauma clinics. For many years, physicians relied on two dimensional (2D) radiographs of the facial skeleton to evaluate facial injuries. However, such radiographs were relatively difficult to interpret because of the superimposition of bony landmarks and defects.[**1**] In the 1970s, the multislice 2D CT became more widespread and was better able to represent the defects in the facial skeleton.[**1**] [**2**] Numerous studies have underscored the utility of CT over conventional plain radiographs with respect to diagnostic accuracy and preoperative planning.[**3**] CT's accurate representation of facial fractures and their spatial relationships facilitates surgical exploration, fracture reduction, and the selection and contouring of rigid reconstruction plates. CT, therefore, decreases complications resulting from delays in diagnosis and treatment includingmalunion,[**4**] nonunion, and other functional and aesthetic deficits that may require revision surgery.

Recently, advances in computer software algorithms have permitted three-dimensional (3D) reconstructions of the facial skeleton from 2D CT images. These 3D reconstructions may further facilitate the diagnosis and treatment of facial injuries,[**1**] [**5**] and numerous authors have suggested that such 3D images may prove superior to 2D CT for presurgical planning in complex trauma and in craniofacial reconstruction following cancer resection.[**1**] We review our experience with 2D CT and 3D reconstruction in both the acute and delayed repair of facial defects.

Conflict of interest: None

II. Material And Methods

This prospective comparative study was carried out on patients of Department of Radio-Diagnosis at S SInstituteOf Medical Sciences & Research Centre, Davangere, Karnataka from September 2018 – February 2019. A total of 25 subjects (both male and females) were in this study.
The study population was drawn from casualty at S S Institute of Medical Sciences & Research Centre, Davangere, Karnataka during September 2018 – February 2019with facial trauma and werereferred to the Dept. of Radio-diagnosis for a CT head with Cervical spine screening.

Inclusion criteria:

1. All the patients attending SSIMSRC with facial trauma in need of CT scan.
2. Patients of all age group and both the sexes were included.

Exclusion criteria:

1. Patients contraindicated for CT- example pregnancy.
2. Post-operative patients in need of repeat CT.
3. Patients with facial trauma and no positive CT findings and x-ray findings.
4. Patients not willing to participate in the study.

III. Methodology

All Patients attending SSIMS &RC with facial trauma who fulfill inclusion and exclusion criteria during the study period were included in the study, the sample size was 60 patients

The study was approved by the Institutional Human Ethical Committee. All the patients with maxillofacial and orbital trauma referred from the emergency department to the department of Radio diagnosisfor computed tomography of facial bone. Data is obtained from following technical parameters: The patient was placed in the supine position; the image was obtained in TOSHIBA ACTAVIAN 16 slice CT machine, with slice thickness of 5mm and pitch of 4mm. The reconstruction (volume rendering, 3D reconstruction) of the axial images obtained were reconstructed in 660 ad optima workstation.

The data obtained from the 2D and the 3D reconstruction of the CT images was compared and the role and efficacy of 3D reconstruction was assessed under headings – fracture detection, extent of fracture and displacement and score was given accordingly.

Table 1: Information provided by 3D compared with axial image

Score	3D Assessment
1	Inferior
2	Similar
3	Superior– similar information more rapidly assimilated
4	Superior – additional conceptual information provided

All the data of patient were collected in the prescribed format mentioning age, sex, cause to know the prevalence of maxillofacial and orbital injuries.
These were assessed in 5 regions (33): -

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

IV. Result

Three-dimensional reformatted images were used to illustrate the utility of such reconstruction in the evaluation of facial trauma. Fig. [5] shows lingual views of a nondisplaced left mandibular fracture. These images demonstrate the ability to examine fracture lines from many perspectives to isolate the segment of interest. Fig. [**1**] shows how a displaced right zygomatic arch fracture viewed in an angled 3D reconstruction better demonstrates displacement of fracture fragments than a 2D coronal image. Fig. [**1**] is another example of the use of 3D image manipulation to better illustrate fracture displacement, as demonstrated in this comparison of a 2D axial image and reconstructed images of a displaced right parasymphysial fracture. The Vitrea software allows unobstructed visualization of the fracture from both a buccal and lingual view, which may help facilitate presurgical planning. Fig. [6] further illustrates the utility of 3D reconstruction in the evaluation of complex midface fractures in comparison to multiplanar axial and coronal images.

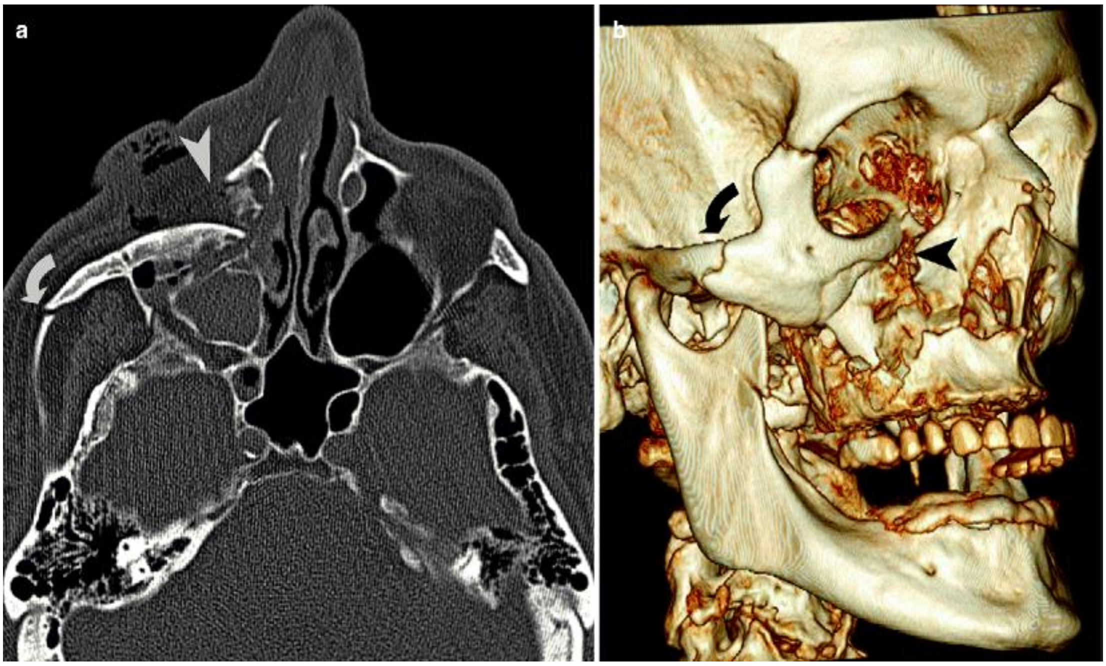


Figure:1 (a) Axial computed tomography images showing fracture of the anterior wall of right maxillary sinus and fracture of right zygomatic arch. (b) Three-dimensional rendered images showing better appreciation of the displaced fracture fragment of the anterior wall of right maxillary sinus

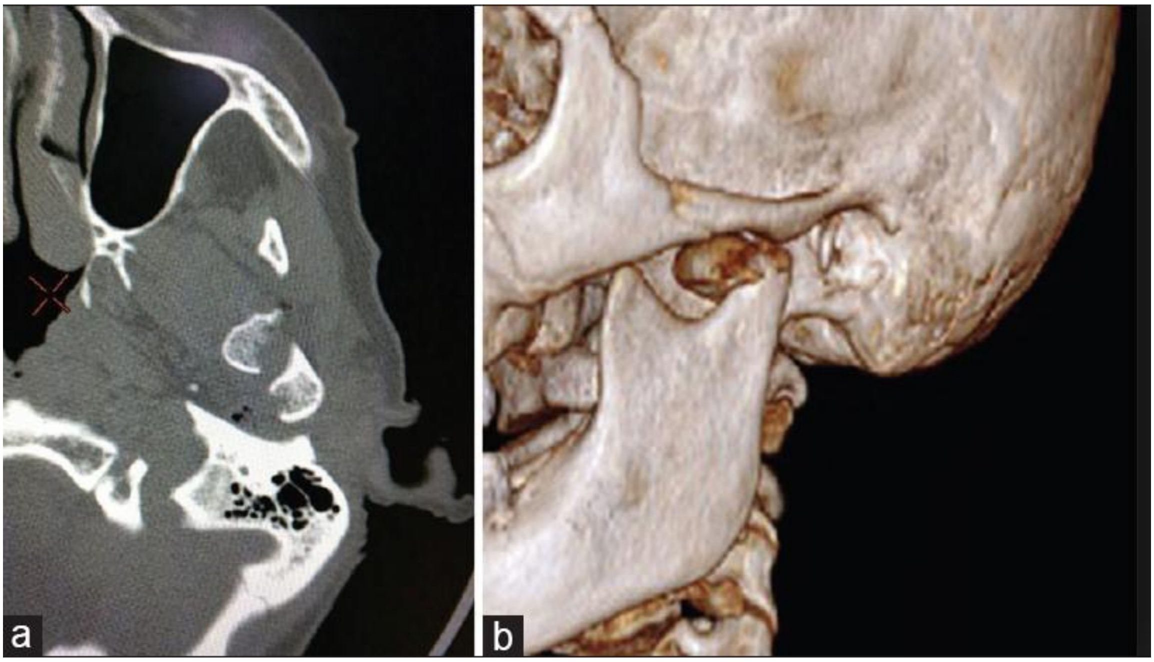


Figure: 2 (a) Axial computed tomography images showing fracture of the left condylar process of the mandible. (b) Three-dimensional rendered images showing better appreciation of the displaced fracture fragment of the left condylar process in the infratemporal fossa

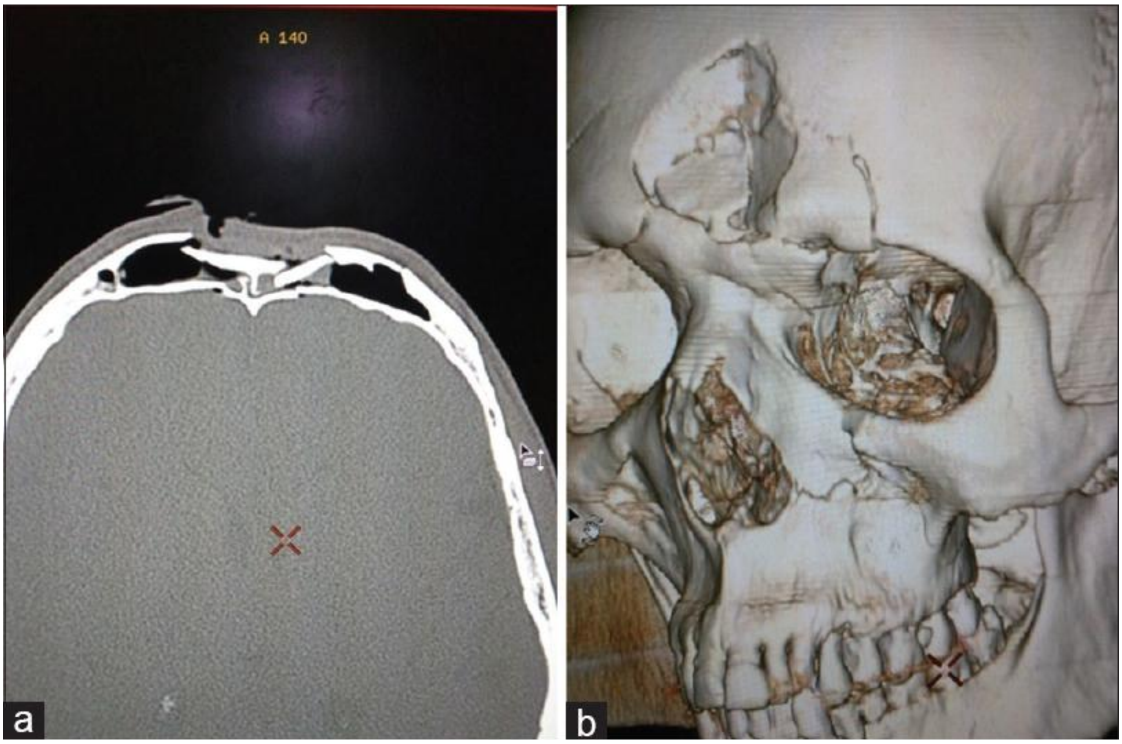


Figure 3: (a) Communited depressed fracture of the frontal bones on axial CT. (b) 3 D rendered images showing better description of displacement of the frontal bone fracture; however, the posterior extent could not be appreciated.

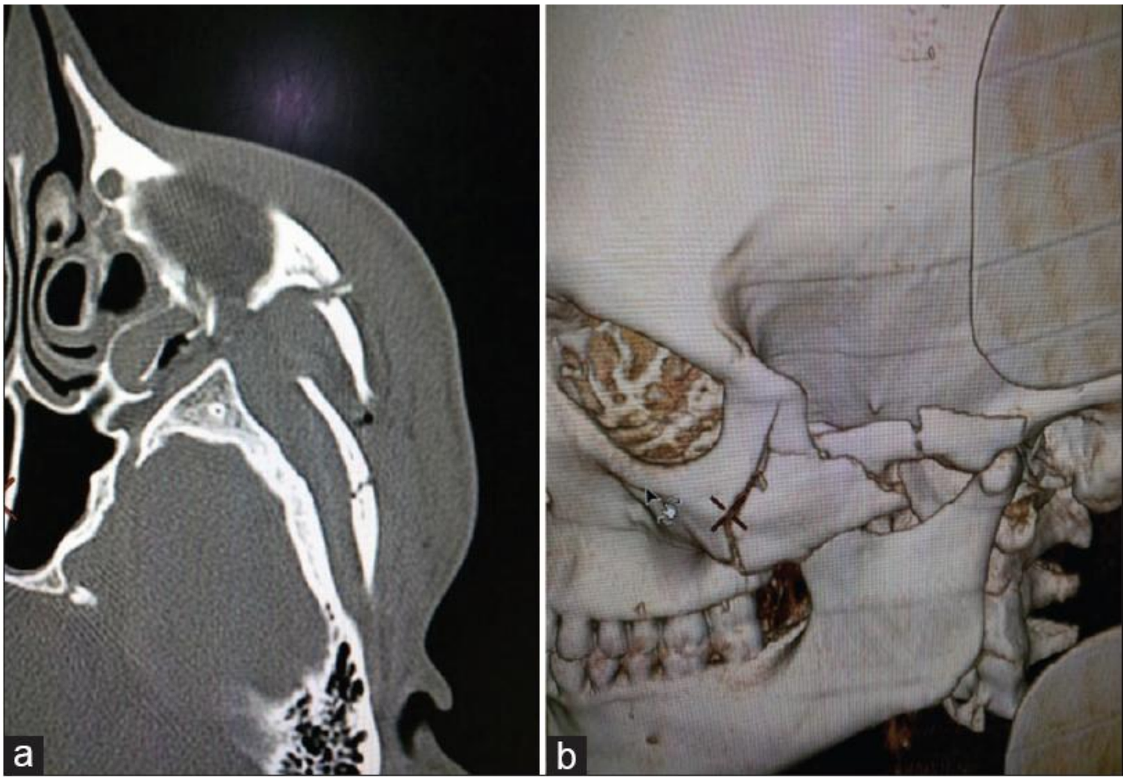


Figure 4: (a) Communited displaced fracture of the left zygomatic bone on axial CT. (b) 3D rendered images showing adequate information with enhanced visual perception of the extent of fracture and the displacement of the fracture fragments.

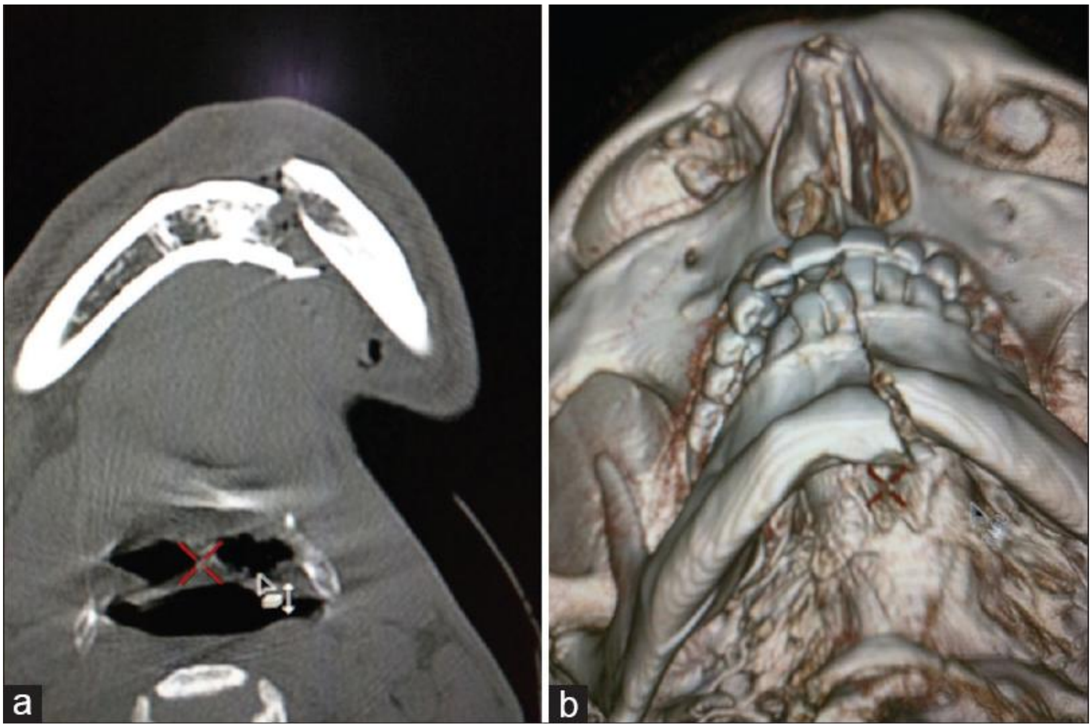


Figure 5: (a) Axial computed tomography images showing displaced linear fracture in the left parasymphyseal region of the mandible. (b) Three-dimensional rendered images showing better understanding fracture pattern and extension

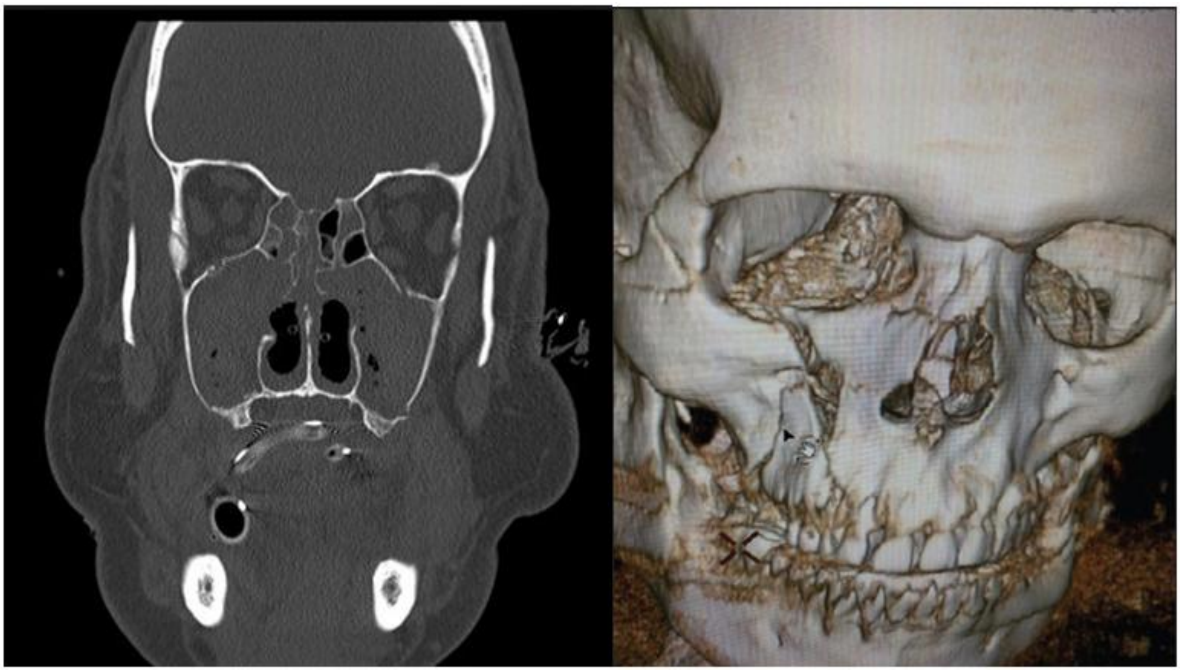
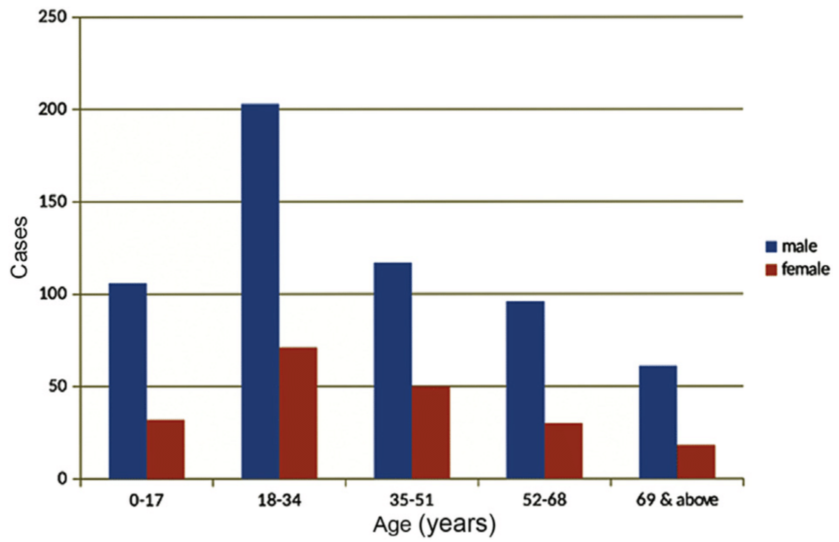


Figure 6: 3 D image showing better understanding of the fracture lines in Le Fort Type II fracture.



MODE OF INJURY

The most common mode of injury in patients presented to the Emergency Department with maxillofacial trauma was road traffic accidents, comprising 72% of cases. Fall from height and assault were the other causes, comprising 17% and 11 % respectively.

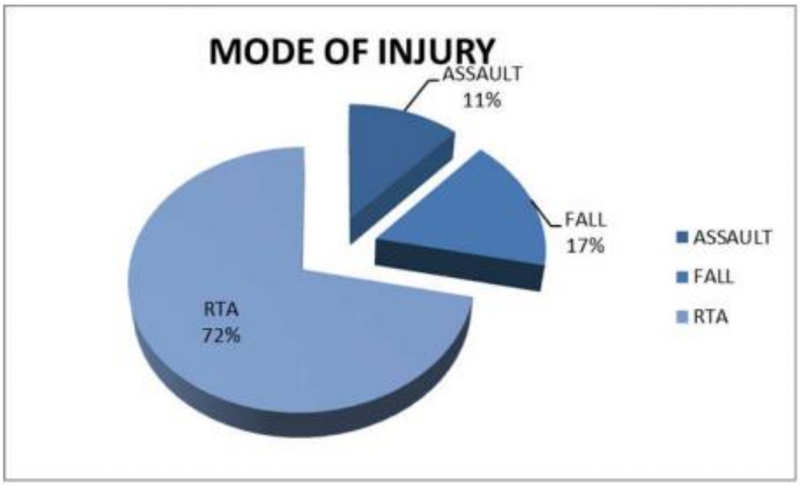


Figure 3: Pie chart representing the mode of injury in the study population.

DISTRIBUTION OF FRACTURES DETECTED IN THE MAXILLOFACIAL REGION:

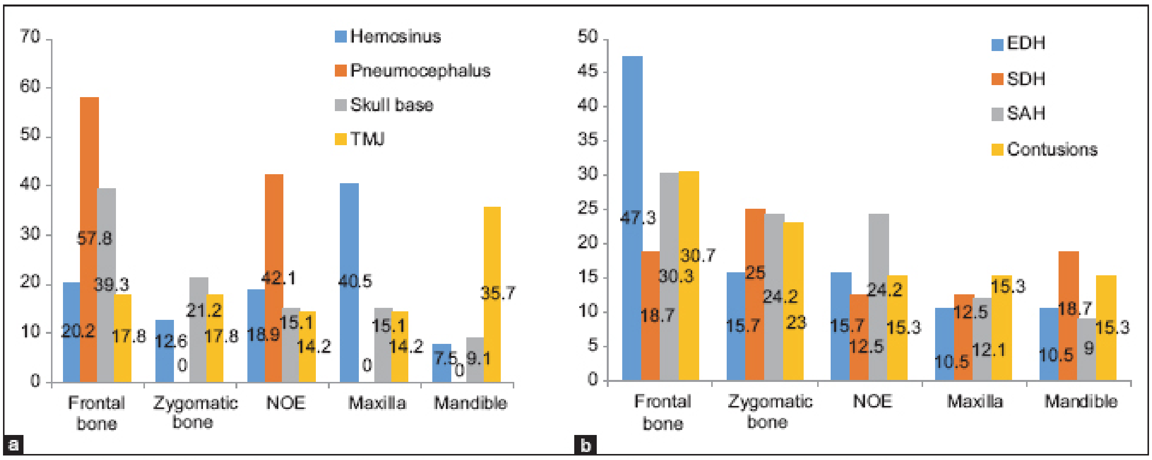


Chart 3: (a) Associated injuries with respect to the region involved. (b) Associated injuries with respect to the region involved

Figure 4: Bar graph depicting the distribution of fractures detected in the maxillofacial region.

Table 4: distribution of type of fracture in the study population

Bone	No.0f patients	Percentage
Frontal	28	47%
Naso-orbito-ethmoidal	33	55%
Maxilla	36	60%
Mandible	9	15%
Zygoma	21	35 %

The fractures were grouped into Frontal, Naso-orbito-ethmoidal complex maxillary and mandibular fractures. The maxilla, especially the walls of maxillary sinus was noted to be the most common fracture with 60% of patients having fracture in this bone The second most common fracture encountered in most patients were nasoorbito ethmoidal fracture .55% of the study population had fracture in the nasoorbito –ethmoidal region. Mandibular fractures were relatively less common as compared to other fractures.10 % of the study population had fracture in the mandible.

FRONTAL BONE FRACTURES

Assessment of 3D images to describe the advantages in detection, extent and displacement of fractures.

Table 5: 2D vs 3D in frontal bone- fracture detection

comparison of 3D images	Detection	Percentage
Inferior to 2D images	3	10.7 %
Similar to 2D images	7	25%
Superior-similar information, assimilated more easily	18	64.2%
Superior - additional conceptual information	0	0.00%
Grand Total	28	100.0%

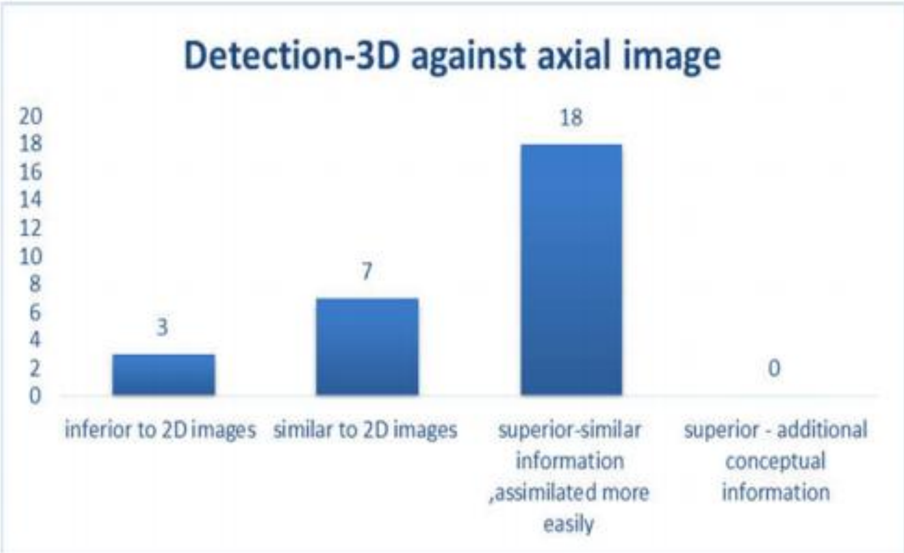


Figure 5: 2D vs 3D in frontal bone- fracture detection.

The volume rendered images were found to be superior to axial images for detection of fractures in 18 patients (64.2% of total frontal fractures). In 7 patients (25%) there was no added advantage by three dimensional images. And in 3(10%) patients the three dimensional images were found inferior to the axial images and these patients had fractures involving the posterior table of the frontal bone which could not be visualized in 3D images

Table 6: 2D vs 3D in frontal bone- fracture extent

comparison of 3D images	Extent	Percentage
Inferior to 2D images	6	21.4 %
Similar to 2D images	14	50.0 %
Superior-similar information, assimilated more easily	8	28.7 %
Superior - additional conceptual information	0	0.00%
Grand Total	28	100.0%

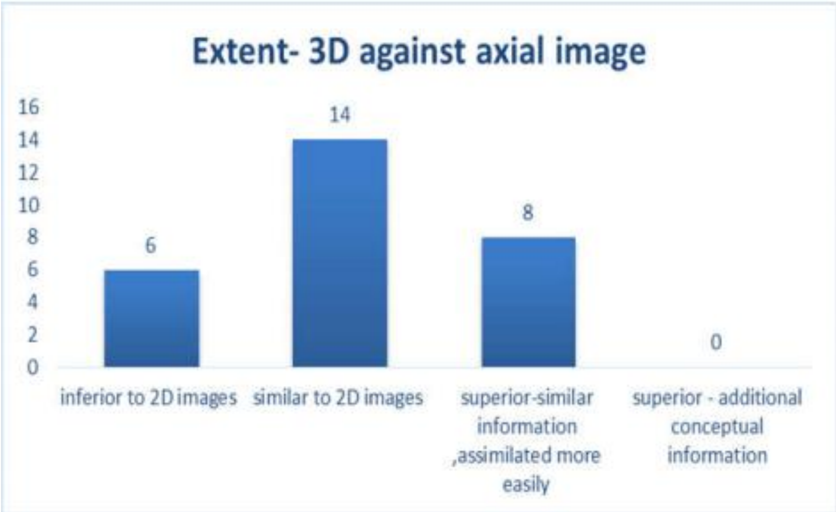


Figure 6: 2D vs 3D in frontal bone- fracture detection

In the assessment of fracture extent, data acquired from 3D and 2D images were found to be similar in about 14 patients (50%). In 8 patients (28.5%) the 3D images were found superior. And in 6 patients the 3D images were inferior to 2D images. In these patients, there was involvement of frontal sinus and their visualization was hindered by bony overlap.

ZYGOMATIC BONE FRACTURES

Assessment of 3D images to describe the advantages in detection, extent and displacement of fractures.

Table 8: 2D vs 3D images in Zygoma- fracture detection

comparison of 3D images	Detection	Percentage
Inferior to 2D images	3	12.5 %
Similar to 2D images	7	29.1 %
Superior-similar information, assimilated more easily	14	58.3 %
Superior - additional conceptual information	0	0.00%
Grand Total	24	100.0%

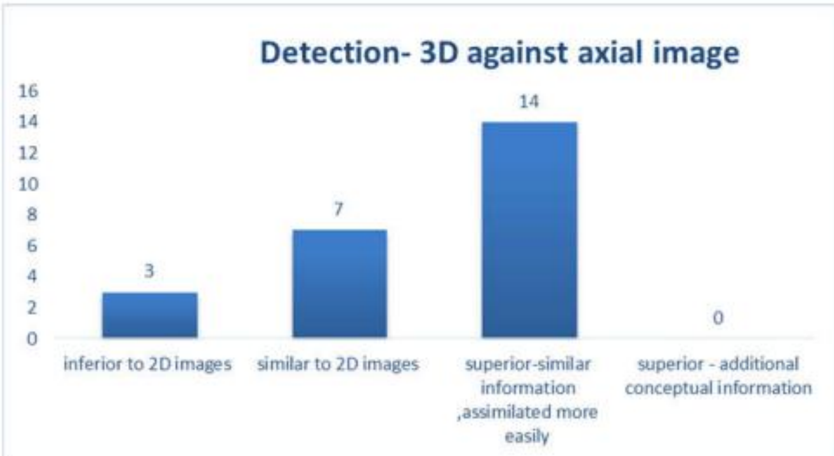


Figure 8: 2D vs 3D images in Zygoma- fracture detection

To detect the fractures, 3D images were found to be superior in 14 patients(58%) .And in 7 patients (29.1%) it was found similar to 2D axial images.

NASO-ORBITO-ETHMOIDAL FRACTURES

Assessment of 3D images to describe the advantages in detection, extent and displacement of fractures.

Table 11: 2D vs. 3D images in Naso-orbito-ethmoidal - fracture detection

comparison of 3D images	Detection	Percentage
Inferior to 2D images	14	43.7 %
Similar to 2D images	10	31.2 %
Superior-similar information, assimilated more easily	7	21.8 %
Superior - additional conceptual information	1	3.1%
Grand Total	32	100.0%

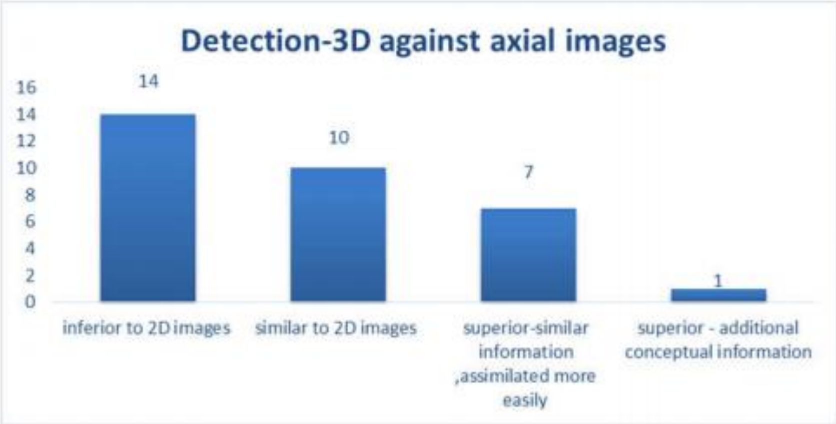


Figure 11: 2D vs. 3D images in Naso-orbito-ethmoidal-fracture detection

In the evaluation of Naso-orbito- ethmoidal fractures, the data interpreted from the 3D images were inferior to the data obtained from 2D images. In 14 patients (43.75%), the data from 2D images were found to be superior as compared to 3D images. The cause could be the thin nature of bones in this region and considerable bone overlap hindering the visualization. In 10 patients, the data from 2D and 3D were found to be similar (31.2%) In 7 patients, the 3D images were found to be superior to 2D images, especially in isolated nasal bone fractures and when the orbital rim is involved.

MAXILLARY FRACTURES

Assessment of 3D images to describe the advantages in detection, extent and displacement of fractures.

Table 14: 2D vs. 3D images in Maxillary-fracture detection

comparison of 3D images	Detection	Percentage
Inferior to 2D images	10	27.78%
Similar to 2D images	15	41.67%
Superior-similar information, assimilated more easily	11	30.56%
Superior - additional conceptual information	0	0.00%
Grand Total	36	100.0%

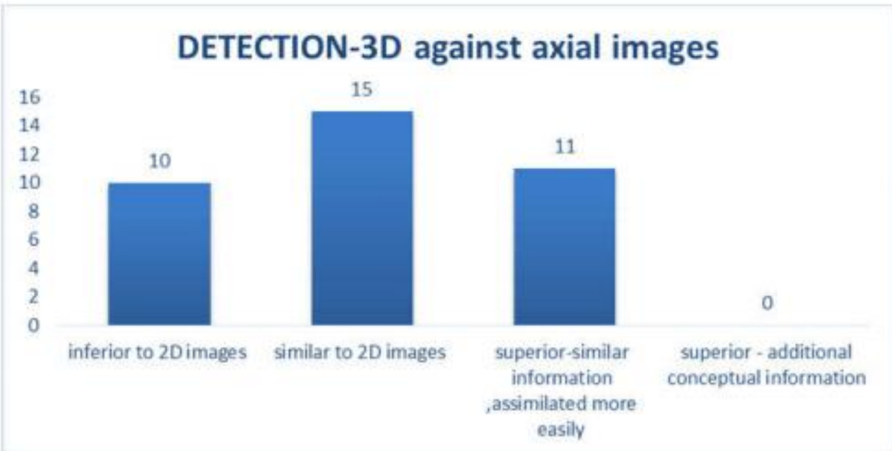


Figure 14: 2D vs 3D images in Maxillary-fracture detection

The 3D and 2D images were similar in 15 patients in terms of fracture detection (15%). In 11 patients 3D images were better in assessing the fractures especially when the anterior wall of the maxilla was involved. In about 10 patients, the 3D images were found inferior to the 2D images when the postero-lateral wall and medial wall of the maxillary sinus was involved.

MANDIBULAR FRACTURES
Assessment of 3D images to describe the advantages in detection, extent and displacement of fractures.

Table 17: 2D vs. 3D images in Mandible-fracture detection.

comparison of 3D images	Detection	Percentage
Inferior to 2D images	0	0.00%
Similar to 2D images	1	10.0 %
Superior-similar information, assimilated more easily	8	80.00%
Superior - additional conceptual information	1	10.00%
Grand Total	10	100.0%

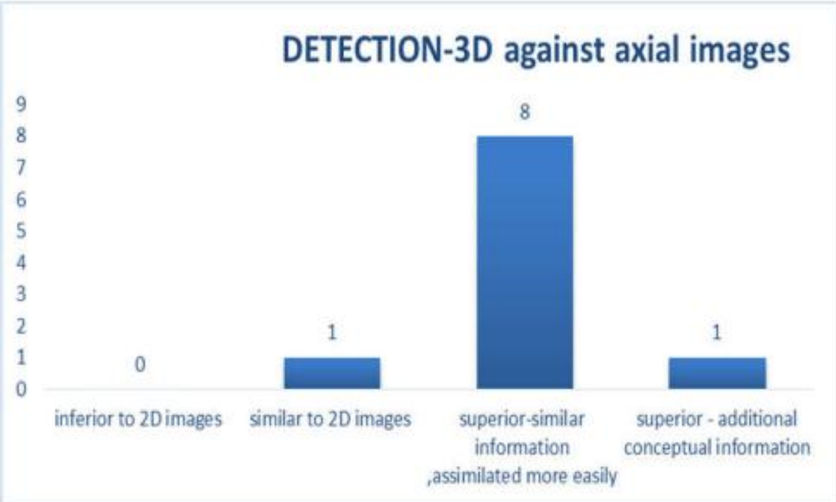


Figure 17: 2D vs. 3D images in Mandible-fracture detection

The detection assessed by 3D and axial images were similar in most patients, however interpretation was easier as compared to the 2D images in 80% of patients.

V. Discussion

Although 2D axial and coronal CT is more accurate and more sensitive than 3D reformatting, numerous studies have explored the utility of 3D imaging. Three-dimensional images are created from the original 2D slices; therefore, there is no new information in the images, and artifacts may be produced in the reformation process. Nonetheless, reconstructed 3D images may assist in the visualization of large comminuted, displaced, and complex fractures involving multiple planes, particularly in regard to the midface.[6] To accurately assess symmetry and fracture lines, reconstructed images must be angulated carefully to exclude any false positives.[7] 3D images provide only information regarding bony architecture; fat and muscle entrapment, encephaloceles, hematomas, and associated injuries must be assessed radiographically through 2D CT manipulation of soft-tissue windows.

We found that 3D reconstructed CT scans were interpreted more rapidly and more accurately by clinicians 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 zygomatico-maxillary complex.[5] [9] It was demonstrated that these 3D CT scans altered or concealed surgical procedures, particularly in nasoorbital-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 is limited to one plane. Here, examining 3D scans alone can give false-negative results.[5] [7] With this in mind, it is useful to think of 3D imaging as a complementary study that can add important information to multiplanar imaging.

It was reported that individuals at different levels of experience showed differential appreciation for the traumatic injuries illustrated by radiograph, 2D CT, and 3D reconstruction.[**3**] Non-radiologist viewers correctly diagnosed the fractures in 75.7% of 3D cases, 71.5% of radiographs, and 64.7% of conventional CT.[**3**] Viewers showed a preference for 3D CT over conventional CT over radiograph in a survey conducted as a part of this study, and a similar survey performed by Alder also demonstrated that surgeons preferred 3D reconstructions to 2D versions for treatment planning. However, experienced radiologists continue to prefer and interpret 2D CT better than 3D. These findings underscore the importance of 3D CT as a valuable tool at training institutions but also substantiate the need for evaluation of 2D CT by an experienced radiologist and for the subsequent availability of 3D reconstructions for review by the surgeons.

Patients incur no additional risks secondary to 3D CT; the scans are formatted using the 2D images and require no additional scanning or radiation exposure. Although there is increased interpretation time for the radiologist, recent trends in 3D prototyping have drastically improved the processing time and cost, and thereby the accessibility, of these images. It is now possible to routinely access images with 0.5-mm slices for reconstruction that produce high-resolution images with little artifact. Radiologists can now use computer graphic systems to manipulate volumetric data and present their quantitative information in a manner more useful to surgeons for preoperative planning.[**5**]

VI. Conclusions

Our experience demonstrates the utility of 3D rendered reconstruction images of 2D CT scans in cases of complex facial trauma. Essentially, 3D reformatting of a 2D CT recreates the surgeon's complex mental process of visualizing fractures in operative planning. Disadvantages of the technique include the potential introduction of artifacts resulting in reformatting errors and the inability to represent soft tissue structures. Nonetheless, 3D CT permits isolation of affected sections of the facial skeleton and enables perspectives that may not readily be generated or appreciated by the clinician in his or her "mind's eye." 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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