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Research Article

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Evaluation of Maxillofacial Injuries Using Multi-Planar and Three-Dimensional Computed Tomography

Sukanya S[1], Cherukara Nihil[2], Kasiviswanathan M[3], Lihil CK[4], Karthika Aravindakshan[5]

Abstract

Background: Maxillofacial injuries, comprising 20%–50% of emergency cases, often result from trauma. This study assesses the role of 2D multiplanar and 3D CT reconstruction in their evaluation. Le Fort's classification, later refined, emphasizes the facial skeleton's reinforced structure, enhancing resistance to mechanical forces.

Objectives: To assess and compare three-dimensional volume rendering (3D) and two dimensional (2D) multiplanar CT images in maxillofacial injuries.

Methods: A prospective study was conducted on 100 patients with maxillofacial fractures who underwent CT evaluation over nine months.

Results: MDCT is a noninvasive, accurate tool for evaluating maxillofacial injuries, offering shorter scan times in acute trauma. This study assessed 100 patients using 128-slice MDCT to compare 2D and 3D CT in detecting fractures and Le Fort classifications. While 2D CT was superior in detecting fractures in the medial maxillary wall, orbit, and frontal sinus, 3D CT provided better spatial visualization for surgical planning. The difference in detection rates was statistically significant ($p < 0.05$), confirming 2D CT as the preferred diagnostic tool for most facial fractures.

Conclusion: 2D CT serves as the foundation for diagnosing facial fractures, accurately detecting tiny and deep fractures. 3D CT acts as a complementary tool, providing a clearer visualization of Le Fort fractures. It is particularly useful for preoperative planning and treatment design.

Keywords: Maxillofacial Injuries; Le fort Fracture; Computer Tomography

Introduction

Maxillofacial injuries account for 20%–50% of emergency department admissions and commonly result from road traffic accidents, assaults, falls, and sports injuries [1-4]. Accurate assessment and management of these fractures are crucial, with computed tomography (CT) playing a key role. This study evaluates the effectiveness of two-dimensional (2D) multiplanar and three-dimensional (3D) reconstruction CT in diagnosing and managing maxillofacial fractures.

Le Fort introduced the classification of facial bone fractures in the early 20th century, later refined by multiple authors [5,6]. The facial skeleton functions as an integrated system of horizontal and vertical reinforcements, enhancing mechanical resistance to trauma. Horizontal reinforcements

Affiliation:

[1]Radiology Consultant, Department of Radiology, Medical Trust Hospital, Kochi – 682016 India

[2]Medical Officer, INHS Sanjivani Hospital, Kochi, 682004 India

[3]Radiology Consultant, Department of Radiology, INHS Sanjivani Hospital, Kochi, 682004 India

[4]Resident, Department of Radiology, INHS Asvini Hospital, Mumbai – 400005 India (Corresponding Author)

[5]Medical Officer, Kochi - 682036 India

Corresponding author:
Cherukara Nihil, Medical Officer, INHS Sanjivani Hospital, Kochi, 682004 India.

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include the frontal bone, zygomatic arches, and hard palate, while vertical supports extend from the maxillary bone to the frontal and sphenoid bones [7]. These structural properties influence fracture patterns, with forces commonly producing multiple fractures. The mandible, acting as a closed ring via temporomandibular joints, is particularly prone to complex fractures.

Le Fort fractures are categorized into three types:

a. Le Fort I: Involves the lower maxilla and alveolar processes, with fractures extending through the maxillary sinus walls, leading to hard palate separation.

b. Le Fort II: A pyramidal fracture extending from the pterygoid process to the maxillary sinus, orbit, and nasal base.

c. Le Fort III: A craniofacial dysfunction affecting the zygomatic arches, orbital walls, and nasal base [8].

Additionally, zygomaticomaxillary complex fractures are classified into three types:

a. Type 1. Zygomatic arch fractures.

b. Type 2. Fractures involving the frontal process of the zygomatic bone.

c. Type 3. Tripod fractures, involving all three processes of the zygomatic bone [8].

Accurate imaging is essential for diagnosis and treatment planning. Delayed treatment can result from a patient's critical condition or misdiagnosis, leading to long-term complications [9–14]. While conventional X-rays help detect fractures and foreign bodies, they have limitations in visualizing complex bone structures and soft tissues [15,16].

Multidetector computed tomography (MDCT) offers superior imaging with multiplanar and 3D reconstructions, improving surgical planning and postoperative monitoring. Modern CT technology, with multi-row detectors, reduces scan time while providing high-resolution images. Though CT involves higher radiation exposure, it remains the gold standard for assessing fracture complexity, displacement, and skull base involvement. Advanced software algorithms enable rapid generation of coronal, sagittal, and 3D images from axial scans without additional radiation exposure. This study aims to compare 2D and 3D CT in fracture detection and evaluate their role in planning maxillofacial trauma management.

Objectives

To assess and compare three-dimensional volume rendering (3D) and two dimensional (2D) multiplanar CT images in maxillofacial injuries.

Primary Objective

To compare the detection rates of maxillofacial injuries in 2D and 3D reconstruction CT.

Secondary Objective

a) To assess the distribution of fractures in different bones in maxillofacial injuries

b) To assess the mode of maxillofacial injuries

c) To identify the percentage of Le Fort fracture lines and to find whether detection rates better in 3D CT.

Lacunae In Literature

Review of literature shows that, not many studies have been conducted regarding the predictive accuracy of 3D reconstruction and 2D multiplanar computed tomography in maxillofacial injuries. So, comparison with earlier studies cannot be done.

Methodology

This prospective study was conducted over nine months on 100 patients who presented with clinical evidence of maxillofacial fractures at the emergency department of a tertiary hospital in Kerala. CT evaluation was performed based on the advice of the referring casualty medical officer. A 128-slice multidetector CT (MDCT) scanner was used for imaging, generating axial images supplemented by coronal and sagittal multiplanar reconstructions and volume-rendered 3D reformatted images. Data collected were tabulated using MS Excel and analysed using SPSS version 16.0. Results on continuous measurements were presented as mean and standard deviation (SD). The distribution of fractures in different bones was represented using frequencies and percentages.

Patients with CT-confirmed maxillofacial fractures were included, while those with contraindications for CT, such as pregnant women in the first trimester, those without consent, and hemodynamically unstable patients, were excluded. The association between categorical variables was assessed using the chi-square test, with p-values estimated for each site. A p-value <0.05 was considered statistically significant. The study aimed to compare the detection rates of 2D and 3D CT reconstructions, assess the mode of maxillofacial injuries, and evaluate the frequency of Le Fort fracture lines. Diagram 1 to 3 present examples of 2D and 3D CT images from one of the cases included in this study.

Results

In this study which comprised of a total number of 100 patients with facial fractures, the age at presentation ranged from 3 to 83 years. Most of the patients with facial trauma are males (85%) and the most common age group ranges from 21 -30 yrs. The most common cause of facial injury is RTA (84%). Other causes include fall (11 %), assault (5%).

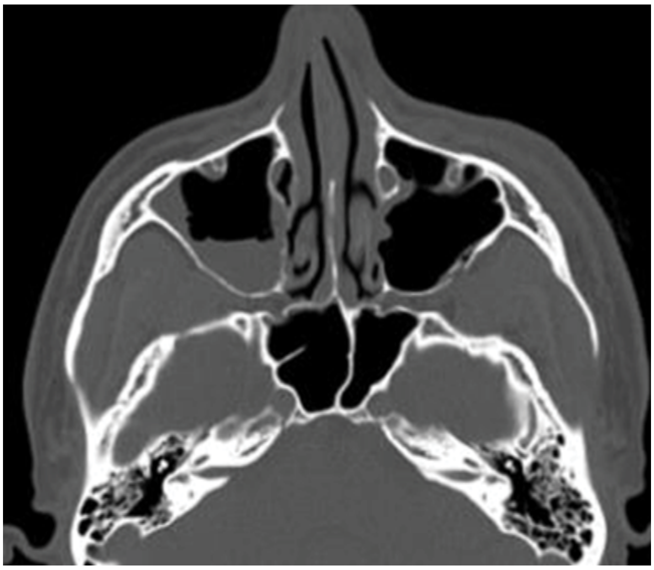

Diagram 1: 2D image shows minimally displaced fracture lateral wall of left maxillary

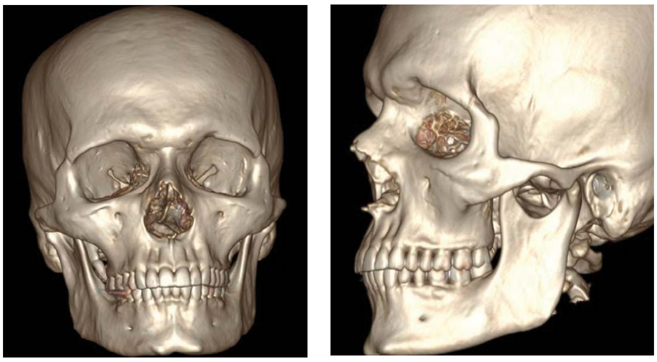

Diagram 2 & 3: 3D image shows no evidence of fracture in lateral wall of left maxillary sinus

Distribution based on age:

Table 1: Age Distribution

Age in years	Frequency	Percent
≤ 10	1	1
Nov-20	14	14
21 – 30	29	29
31 – 40	18	18
41 – 50	14	14
51 – 60	10	10
61 – 70	7	7
>70	7	7
Total	100	100

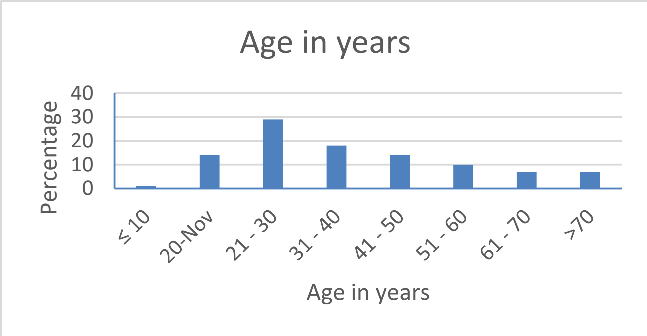

Diagram 4: Age Distribution

b. **Distribution based on sex**

Table 2: Based on sex distribution

Sex	Frequency	Percent
Female	15	15
Male	85	85
Total	100	100

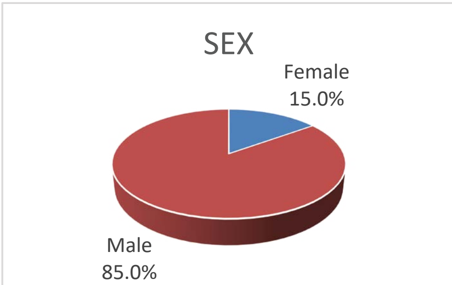

Diagram 5: Based on sex distribution

There were 85 males and 15 females in the patients included in the study group.

c. **Distribution based on mode of injury**

(i) **Mandible fracture - Detection rates in 2D and 3D**

Table 3: Mode of injury and their frequency of occurrence

MOI	Frequency	Percentage
RTA	84	84
FALL	11	11
ASSAULT	5	5

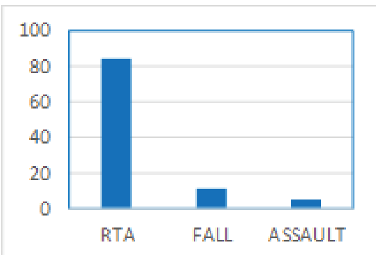

Diagram 6: Bar diagram showing distribution of patients according to mode of injury

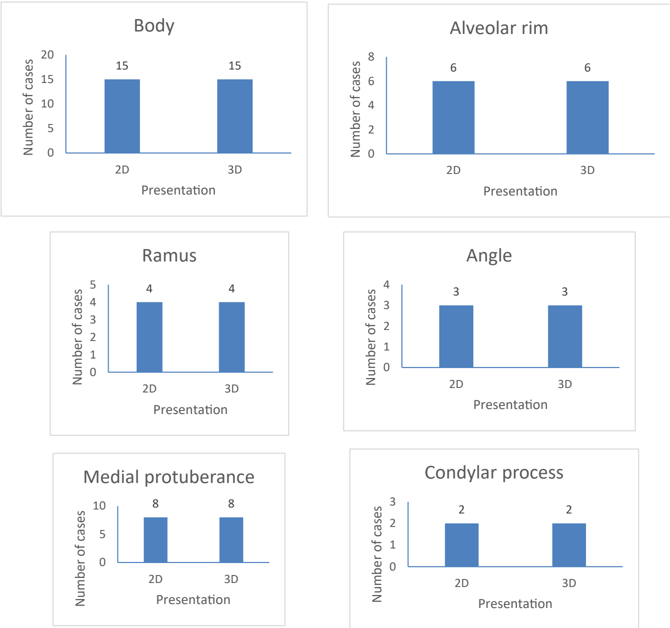

Diagram 7-12: Bar diagram showing fracture detection in 2D and 3D in different parts of mandible.

Number of fractures detected using 2D and 3D CT are equal in mandibular fractures. Most common site involved is body of mandible and second commonest site involved is medial protuberance.

(ii) Maxillae fracture - Detection rates in 2D and 3D

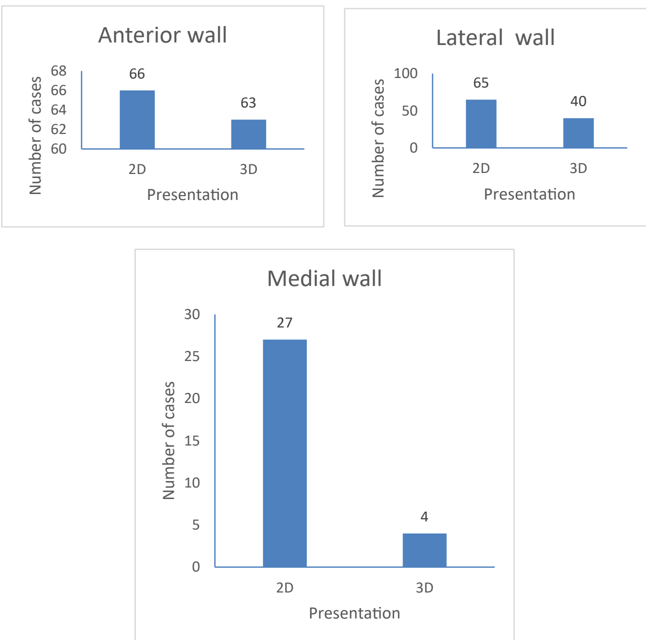

Diagram 13-15: Bar diagram showing fracture detection in 2D and 3D In different parts of maxillae.

3D CT is inferior to 2D CT in detection of maxillae fractures especially in medial walls. Detection rates in the anterior wall fractures are almost equal in 2D and 3D.

(iii) Zygoma fracture – detection rates in 2D and 3D

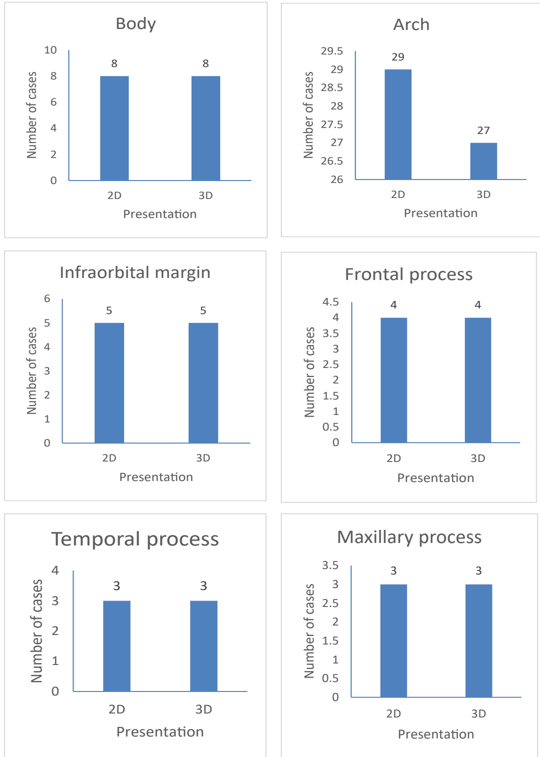

Diagram 16- 21: Bar diagram showing fracture detection in 2D and 3D in different parts of zygoma

In zygomatic fracture most common site involved is arch. Fracture detection rates of 3D and 2D are almost equal except in zygomatic arch fractures where 3D is inferior to 2D.

(iv) Orbital fracture – detection rates in 2D and 3D

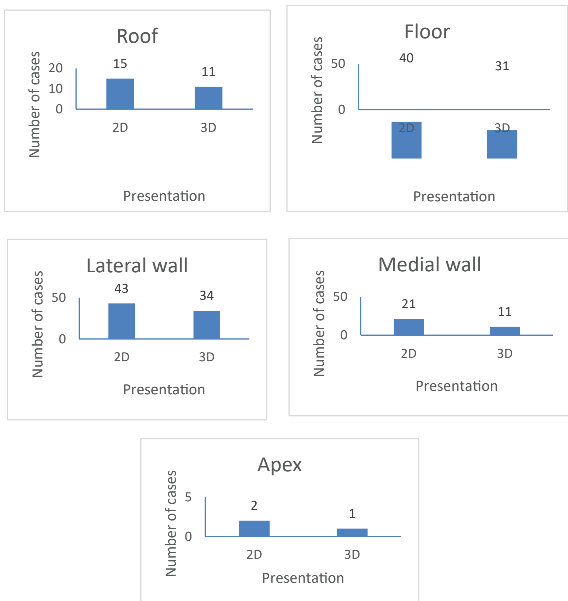

Diagram 22- 26: Bar diagram showing fracture detection in 2D and 3D in different parts of orbit 3D CT is inferior to 2D CT in orbital fracture.

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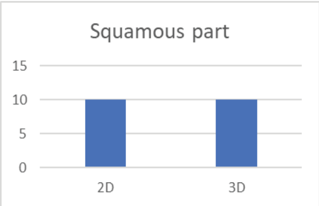
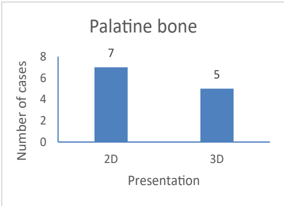
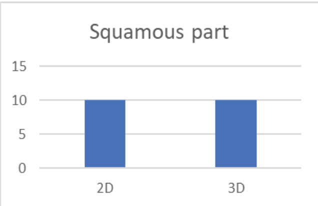
(v) Vomer bone fractures

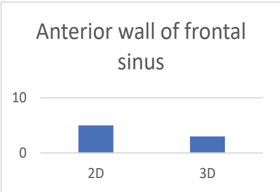
(ii) Vomer bone fractures

-Palatine bone fracture









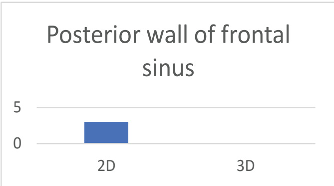


Diagram 29- 31: Bar diagram showing fracture detection in 2D and 3D in different parts of frontal bone Fracture In posterior wall of frontal sinus couldn't be assessed with 3D CT.

Fracture In posterior wall of frontal sinus couldn't be assessed with 3D CT.

(vii) Lefort fractures

Among 100 patients with facial injury 10 were identified as Le Fort fractures. Number of patients with Le Fort I, Le Fort II and Le Fort III accounted for 4%, 5% and 1 % respectively.

Among 10 patients with Le Fort fractures, three were compound fractures of Lefort I/II. Compound fractures are most common type.

Table 4: Types of Le Fort fractures and number of fractures detected in 3D and 2D

	2D	3D
Le Fort I	4	4
Le Fort II	5	5
Le Fort III	1	1

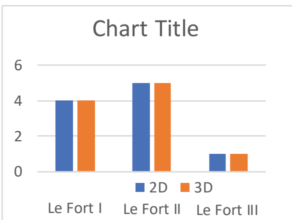


Diagram 32: Bar diagram showing fracture detection in 2D and 3D in Le Fort fractures

Although Le Fort fractures can be equally identified on both 2D and 3D CT, 2D CT could be used to define the tiny fractures and the deep structure fractures more accurately compared with 3D –CT. But 3D CT could clearly demonstrate the whole shape of Le Fort type fractures and identify the classification of Le Fort fracture.

(e) Overall finding

Table 5: Overall percentage of facial fractures detected in 2D and 3D and P value obtained

Location		Presentation				P
		2D		3D		
		n	%	n	%	
Nasal bone		37	37	26	26	.001
Maxillae	Anterior wall	66	66	63	63	.250
	Lateral wall	65	65	40	40	.000
	Medial wall	27	27	4	4	.000
Mandible	Alveolar rim	6	6	6	6	1.000
	Body	15	15	15	15	1.000
	Ramus	4	4	4	4	1.000
	Angle	3	3	3	3	1.000
	Coronoid process	0				
	Condylar process	2	2	2	2	1.000
	Medial Protuberance	8	8	8	8	1.000
Zygoma	Body	8	8	8	8	1.000
	Arch	29	29	27	27	.500
	Infraorbital margin	5	5	5	5	1.000
	Frontal process	4	4	4	4	1.000
	Temporal process	3	3	3	3	1.000
	Maxillary process	3	3	3	3	1.000
Orbit	Roof	15	15	11	11	.125
	Floor	40	40	31	31	.004
	Lateral wall	43	43	34	34	.004
	Medial wall	21	21	11	11	.002
	Apex	2	2	1	1	1.000
Vomer bone		11	11	5	5	.031
Palatine bone		7	7	5	5	.500
Frontal		18	18	18	18	1.000

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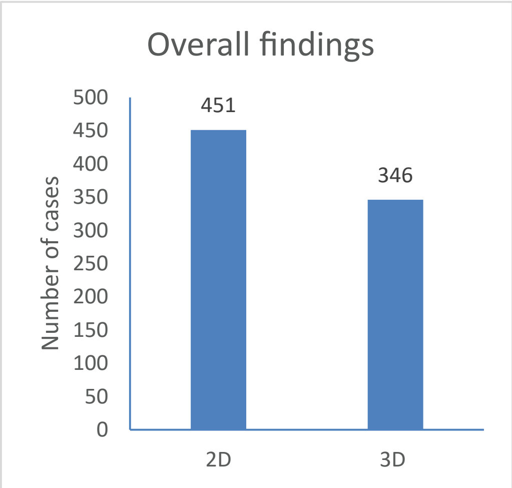

Diagram 33: Bar diagram showing overall facial bone fracture detection in 2D and 3D

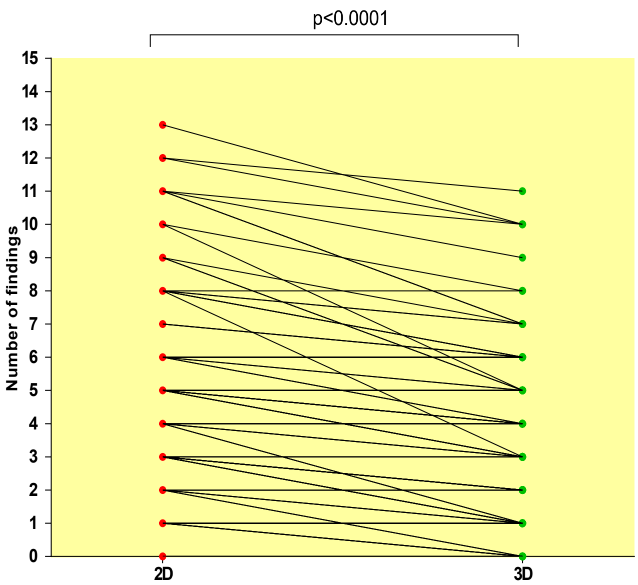

Diagram 34

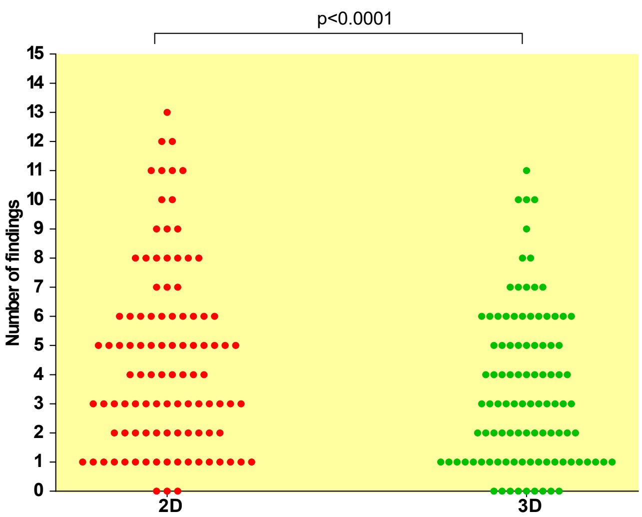

Diagram 35

Since P value is < 0.05, there is significant difference in detection rates of fractures by 2D and 3D CT. Hence 2D is best in detecting facial bone fractures compared to 3D CT, especially in such sites that are medial wall of maxilla, medial and lateral wall of orbit, posterior wall of frontal sinus.

Discussion

Maxillofacial injuries can present as isolated injuries or part of polytrauma that are clinically important as the disruption of soft tissues and bones of the face can cause facial asymmetry and disfigurement which causes emotional and cosmetic concerns and the region is also associated with several important functions. MDCT is an accurate, non-invasive technique for the assessment of patients with maxillofacial injuries. In the setting of acute trauma, MDCT has the advantage of reduced scan time and is increasingly available. MPR and 3D VR images help better evaluation of fractures detected on axial images and this study aims at assessment and comparison of 2D and 3D CT in the evaluation of maxillofacial injuries.

This study included 100 patients with history of maxillofacial injury. These patients were evaluated using 128 slice MDCT scanner. The axial images generated were supplemented by the reconstruction of coronal and sagittal multiplanar and volume rendered reformatted images. The study population consisted of patients in the age group of 3 to 83 years. Most patients belonged to the age group of 21- 30 and 31 to 40 with 29 and 18 patients respectively. This study also showed a male preponderance accounting for 84 % of the case load. The most common mode of injury in patients presented to the Emergency Department with maxillofacial trauma was road traffic accidents, comprising 84%. Assault and fall from height were the other causes, comprising 11 and 5 % respectively. Maxillae and orbital walls are the two sites where most of the fractures detected.

In the evaluation of mandible number of fractures detected using 2D and 3D CT are equal. Most common site involved is body of mandible (15%) and second commonest site involved is medial protuberance (8%). Other common sites include alveolar rim, ramus and angle of mandible. 3D CT is inferior to 2D CT in detection of maxilla fractures especially in medial walls. 2D CT detected fracture in medial wall of maxillae in 27 %. However, in 3D CT only 4% had medial wall fracture. Similarly, 2D CT could detect fractures in lateral and anterior walls of maxillae in 65 and 66 % of patients respectively. However, with 3D CT only 40 % and 63 % had these fractures. Detection rates in the anterior wall fractures are almost equal in 2D and 3D. In zygomatic fracture most common site involved is arch. Fracture detection rates of 3D and 2D are almost equal except in zygomatic arch fracture where 3D is inferior to 2D. 2D CT detected 29 patients with zygomatic arch fracture, whereas 3DCT could detect only 27 of these and rest two were minimally displaced fractures which couldn't be well identified by 3D CT.

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In orbital fractures most commonly, injured site is the lateral wall. 3D is inferior to 2D in orbital fracture in all the areas especially in medial walls. 2D CT detected fracture in medial wall of orbit in 21% patients. 3D CT could detect fracture in medial orbital wall only in 11 % patients. Least commonly involved site is apex of the orbit. 3D CT is inferior to 2D CT in vomer, nasal bone and palatine bone fractures. Fracture in posterior wall of frontal sinus couldn't be assessed with 3D CT. However almost equal detection rates can be seen with squamous part of frontal bone and anterior wall of frontal sinus. Among 100 patients with facial injury 10 were identified as Le Fort fractures. Number of patients with Le Fort I, Le Fort II and Le Fort III accounted for 4%, 5% and 1 % respectively with equal detection rates in 2D and 3D CT. Among 10 patients with Le Fort fractures, three were combined fractures of Le Fort I/II and one with combined Le Fort II /III. Compound fractures are most common in Le Fort type fractures. Although detection rates are equal in this study 3D images are simple and easier in understanding Le Fort fracture lines.

2D CT could be used to define the tiny fractures and the deep structure fractures more accurately compared with 3D CT. But 3D CT could clearly demonstrate the whole shape of Le Fort type fractures and identify the classification of Le Fort fractures. The difference in detection rates of fractures by 2D and 3D CT appear statistically significant since p value is less than 0.05. Hence 2D is best in detecting facial bone fractures compared to 3D CT, especially in such sites that are medial wall of maxilla, medial and lateral wall of orbit, posterior wall of frontal sinus.

In the evaluation of the maxillofacial injuries, 2D reconstructions in the axial plane were the most successful, for most of the locations. Results obtained in this way provided us with more diagnostic data than 3D reconstructions. This was especially true for fractures of the lamina within the inferior orbital wall and the superior wall of the maxillary sinus. This follows from the fact that these structures are located and run in the transverse plane, parallel to the examined plane. As a result, the shadows of bone structures of the examined area and adjacent regions overlap. This produces a false image and thus makes it difficult to diagnose.

In a study done by PWang [52], 50 patients who suffered from facial trauma were scanned with both conventional axial CT and 3D reconstruction CT. The scanning range included upper teeth to superior edge of orbit. This study concluded that axial 2D CT can be better used to identify facial fractures than 3D reconstruction in such sites that are medial wall of the maxilla (5/0 sides), lateroposterior wall of the maxilla (49/44 sides), upper alveoli (14/12 sides), lateral wall of orbit (34/33 sides) and pterygoid process of the sphenoid bone (19/9). Three-dimensional reconstruction was superior to 2D CT in demonstrating fracture of anterior wall of the maxilla (60/57 sides) and shapes of the facial fracture. 2D CT is equal to 3D CT in detecting fractures of zygomatic bone, nasal bone and mandible.

FOX established through his study 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 assessing orbital and maxillary fractures [53]. Other studies have also found out that 3D CT being most useful for imaging comminuted fractures of middle third of face and the zygomatico-maxillary complex [54]. In the article by Olszycki [55], special attention was paid to the meaning of 3D reconstructions in imaging of the lower orbital wall. The authors concluded that according to their studies, a useful and successful method of imaging of injury-related sequelae of this region was the 3D reconstruction.

In this work, the highest sensitivity in detecting fractures of the inferior orbital wall was revealed by 2D reconstructions. It was found that in imaging of thin and delicate bone structures (such as cribriform plate of the ethmoid bone), orbital floor, and in some cases also the anterior wall of the maxillary sinus, 3D reconstructions are less useful than 2D reconstructions. The use of 3D reconstructions in these areas often produces false images suggestive of inexistent holes, that are difficult or impossible to differentiate from fracture fissures.

This risk was mentioned by Różyło-Kalinowska [56] in his study, who stated that 3D reconstructions cannot be used as the only imaging modality in visualization of fracture fissures, and especially of the lower orbital wall. When comparing the results of imaging with the use of direct acquisition of raw data, with 3D reconstructions, it is also worth noticing their susceptibility to artefacts, i.e. occurrence of false images that do not exist in real. They may follow from the study protocol only. For example, if the slice is too thick during 2D reconstruction, a 'stair-step' artefact appears. Similarly, negative phenomena appear as a result of patient's movements or attenuation of the X-ray beam after its passing through strongly absorbing structures, such as metal dental fillings and metal prostheses. Artefacts can be prevented or minimized with the use of appropriate and reliable study protocols [57].

In a study done by chen WJ and Yang Y J [58] to evaluate the importance of 2D and 3D CT in the identification and classification of Le Fort type fractures, they found that the patients with Le Fort I, Le Fort II fracture and Le Fort III fracture accounted for 16.1%, 14.5% and 12.9% respectively. The compound fractures were the most common type and accounted for 56.5 %, mostly Le Fort I and II. Fifty-five cases coexisted with other fractures in maxillofacial region. 2D CT could be used to identify the tiny fractures and the deep structure fracture more accurately compared with 3D CT. But the real impression of the Le Fort fractures could not be correctly evaluated on 2D CT. 3D could clearly demonstrate the whole shape of Le Fort fractures and identify the classification of Le Fort fractures.

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Conclusion

It can be concluded that 2D- CT should be regarded as the foundations of diagnosing facial fractures and 3D-reconstructions as a useful complementary tool. 2D CT could be used to define the tiny fractures and the deep structure fractures more accurately compared with 3D CT. Although Le Fort fractures can be diagnosed by 2D CT, 3D CT could clearly demonstrate the whole shape of Le Fort type fractures, especially for the design of treatment plan before surgery

Declarations:

Ethics approval and consent for participate:

The consent for this research work was obtained from the institutional Ethics Committee and an informed consent was taken from the patient.

Consent for publication:

An informed consent for publication purpose was obtained from the patient.

Availability of data and material:

The datasets used are/or analysed during the current study are available with the author.

Funding: Not Applicable

Limitation: One of the main limitations of this study is interobserver variations. There can be interobserver variability in detection of fractures, especially in 3D CT. This study is based on interpretation by single radiologist.

Authors' Contributions

Author 01: Played a primary role in the management of the patients, retrieved informed consent, and contributed to the preparation of the case report.

Author 02: Assisted in data collection, manuscript preparation, and served as the corresponding author, ensuring communication and verification of data.

Author 03: Managed and verified imaging modalities and contributed to the verification of the final manuscript.

Author 04: Assisted in the preparation of the final manuscript and compilation of references

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