# "Role of Multidetector Computed Tomography as a Diagnostic Tool in Maxillofacial Trauma"- An Original Study

**Stevenson Hasanalli[1], Mehaboob Shaik[2], S. Ravi Raja Kumar[3], Anusha Nallapu[4], Golla Gowtham[5]**

[1]Department of Oral and Maxillofacial Surgery, Panineeya Institute Dental Sciences and Research Centre, Hyderabad, Telangana, India.
[2]Department of Oral and Maxillofacial Surgery, Care Dental College, Guntur, Andhra Pradesh, India.
[3]Department of Oral and Maxillofacial Surgery, St. Dental College, Eluru, Andhra Pradesh, India.
[4]Department of Periodontics, Panineeya Institute Dental Sciences and Research Centre, Hyderabad, Telangana, India.
[5]Department of Oral and Maxillofacial Surgery, St. Joseph Dental College, Eluru, Andhra Pradesh, India.

## Abstract

**Background:** To evaluate maxillofacial trauma patients using multidetector computed tomography (MDCT) with multiplanar reformation and 3D imaging. **Materials and Methods:** Twenty-five patients who sustained multiple maxillofacial fractures were randomly selected for this study, irrespective of age and sex. In all these cases, MDCT and 3D computed tomography were taken and evaluated for diagnosis and better treatment plans. **Results:** The results of this study suggest that the posterior extension of LeFort fractures, orbital trauma, especially undisplaced fractures of lateral, medial and inferior orbital walls, and orbital muscle and fat entrapment were clearly visualized on the MDCT scan. The displacement and communication of the zygomatic complex are clearly appreciated in dimensional imaging of the MDCT scan. **Conclusion:** During the course of the study, the MDCT was found to be standard in radiological investigations including assessment of, accuracy, and extension of fracture in maxillofacial trauma, whereas conventional radiographs have limitations in accuracy and extension of fracture. They seem to become superior radiological investigations for diagnosis and better treatment outcomes.

**Keywords:** 3D images, Midfacial fractures, Multidetector computed tomography, Multiplanar reformation.

## Introduction

The fracture morphology of maxillofacial trauma is often complex and the clinician should be familiar with the imaging findings.[1] Severe injuries often occur as a result of motor vehicle collisions, interpersonal, domestic violence, and sports.[2] Injury to the facial region may lead to life-threatening situations, airway compromise, and profuse blood loss. Due to soft tissue swelling, lacerations, and pain, it is difficult to physically examine the patient with facial trauma. Maxillofacial fractures require accurate radiologic diagnosis and surgical management to prevent severe functional debilities and cosmetic deformity.[3]

The role of magnetic resonance imaging in trauma is to assess soft-tissue injuries, it has good soft tissue contrast, and it also aids in assessing patients with neurological deficits but is not useful as compared to computed tomography (CT) in the evaluation of complex fractures.[4]

A CT scan has the advantage of providing images of thin slices of the facial skeleton, overcoming the problem of the superimposition of structures that inevitably occurs on plain radiographs.[5]

**Access this article online**

**Website:**
www.jrad.co.in

**DOI:**
https://doi.org/10.53064/jrad.2022.15.4.522

Recently, advances in computer software algorithms have permitted three-dimensional (3D) reconstructions of the facial skeleton from 2D CT images. The 3D reconstruction may further facilitate the diagnosis and treatment of facial injuries and numerous authors may prove superior to 2D CT for pre-surgical planning in complex trauma.[6]

The widespread introduction of multidetector CT (MDCT) has revolutionized the field of CT. This revolution can be attributed to three primary properties of MDCT: its ability to produce a vast quantity of volumetric data in a reduced amount of time, the high resolution, and the ability to create isotropic voxel data and, consequently, reliable multiplanar and three-dimensional 3D reconstructions.[7]

**Address for correspondence:** Dr. Golla Gowtham,
Department of Oral and Maxillofacial Surgery, St. Joseph Dental College,
Duggirala, Eluru, Andhra Pradesh, India.
Email: gowthamomfs@gmail.com

**Received:** Dec. 10, 2023; **Accepted:** Mar. 03, 2024; **Published:** Mar. 18, 2024



**How to cite this article:** Hasanalli S, Shaik M, Raja Kumar SR, Nallapu A, Gowtham G. "Role of Multidetector Computed Tomography as a Diagnostic Tool in Maxillofacial Trauma"- An Original Study. J Res Adv Dent 2024;15(4):1-7.

MDCT is markedly superior to radiographs in musculoskeletal injuries, especially in areas of complex bony anatomy due to its spatial resolution and multiplanar reconstruction techniques.[8]

Interpretation of 3D CT and multiplanar reformation (MPR) images by CT as supplying more information than axial 2D images, by providing more reliable diagnosis, effective therapeutics, evaluation of the treatment and consequently reducing the manifestation of sequelae.

MPR can be associated with the workstation using 3DCT as adjunct information and producing relevant improvements in the diagnosis of fracture of the maxillofacial region.

As the scanning time of MDCT is less, it allows rapid scanning of critically ill, elderly, and uncooperative patients. Early and proper diagnosis allows the clinicians for prompt management of maxillofacial trauma, and hence, preventing early and late complications.

3D reconstruction and MPR in coronal and sagittal planes are very useful in assessing the bony architecture in large comminuted, displaced, and complex fractures involving 16 multiple planes.[10]

The goals of this study were to investigate the characteristic MDCT findings of maxillofacial trauma for a better understanding of fracture patterns and related soft tissue injuries.

## Materials and Methods

The study was conducted in the Department of Oral and Maxillofacial Surgery, St. Joseph Dental College, Duggirala, Eluru. Twenty patients who sustained multiple maxillofacial fractures were randomly selected for this study with in the age group of 20–60 years of both genders. In all the cases, MDCT with 3D CT was taken and evaluated for diagnosis and a better treatment plan.

The material used in the study is MDCT with MPR and 3D imaging.

The MDCT (Figure 1) unit used in this study was the Siemens whole-body scanner. The slice thickness used in this study ranges from 1.5 mm to 2 mm (Figure 2). Slices were programed from the top of the frontal sinus to the chin; reconstructions were performed in all cases using high-resolution bone and soft-tissue windows as well as 3D reconstruction (Figure 3). A continuous volume scan was taken in axial, coronal, and sagittal planes, which makes an image of three-dimensions or a 3D reconstruction. The MDCT scan cycle time was approximately 34 s.

Sixteen, 32, and 64 slice scanners allow the acquisition of datasets with nearly isotropic voxels for multiplanar imaging of both coronal and sagittal planes, which have similar spatial resolution compared with axial planes.

Maxillofacial trauma patients were evaluated with MDCT for better diagnostic purposes. All patients had a standard


**Figure 1:** Multidetector computed tomography scanning machine

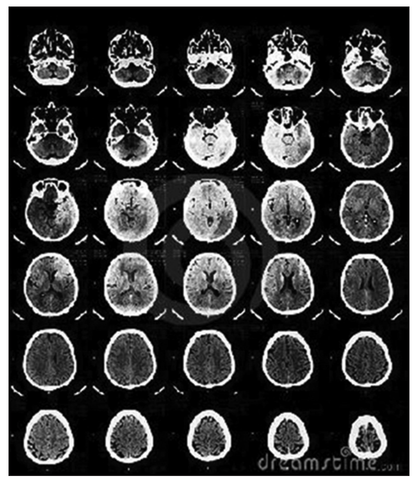


**Figure 2:** Multidetector computed tomography

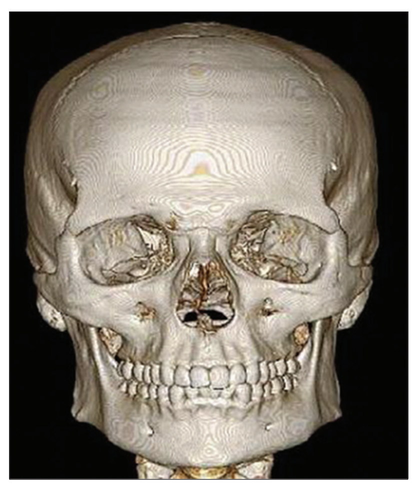

**Figure 3:** 3D multidetector computed tomography

viewing format, which was created by transferring all images to high-resolution VHS (volume helical shuttle) videotape. The selected MDCT sections were individually recorded to display bony structures. The following parameters were used, kv 120, thickness 1.5 mm, matrix size 512 × 512, field of view 180 mm, and reconstruction interval 0.5 mm.

The plain radiographs taken in maxillofacial trauma patients were compared with MDCT images to arrive at a better diagnosis and accurate treatment planning.

## Results

All patients were evaluated clinically and with conventional radiographs, e.g., OPG, PNS, submento-vertex, etc., according to the need, followed by MDCT scan investigations for better outcomes of a treatment plan.

The additional information obtained after the MDCT scan was used to confirm the diagnosis of the fracture site. MDCT proved to be effective in the diagnosis of undisplaced fractures of the maxillofacial region. The results of the study were described using the following Table 1.

### The following observations using MDCT and other radiographs

The displacement and comminution of the zygomatic complex and mandibular fractures are clearly appreciated in three-dimensional imaging of CT. Fractures of the nasal bone and also the comminution of the anterior, middle, and posterior lateral walls of the maxillary sinus with the presence of an air-fluid level (hemosinus) were evident on MDCT.

In cases, number 1, 2, 5, 11, 13, and 25, there is clear evidence of zygomatic arch fracture in the MDCT scan, which cannot be appreciated in conventional radiographs of the same patient.

In case, number 4, there is clear evidence of bilateral LeFort 1 fracture with nasal bone, zygomatic complex fractures with soft tissue swellings, hemosinus, and air pockets in MDCT scan, compared to conventional radiographs.

In case number 7, there is clear evidence of undisplaced right frontal bone fracture that is well-interpreted in an MDCT scan and cannot be appreciated in conventional radiographs of the same patient.

In case number 8, 15, 20, and 21, undisplaced fractures of the lateral rim of the orbit can be clearly appreciated in the MDCT scan, when compared with other radiographs.

In case number 6, and 14, there is clear evidence of undisplaced subcondylar fractures in MDCT scans compared to conventional radiographs.

In case number 18, orbital floor fracture with herniation of the inferior rectus and orbital content into the maxillary sinus (trap door sign) is clearly evident in the MDCT scan. These findings are not appreciated in conventional radiographs.

In our study, we found that undisplaced fractures of the maxillofacial region are clearly evident in MDCT scans, whereas undisplaced fractures failed to explode in conventional radiographs. The advantages of MDCT are an enormous increase in imaging acquisition speed, more coverage of the patient, and high spatial resolution.

## Discussion

The role of magnetic resonance imaging in trauma is to assess soft tissue injuries: It has good soft-tissue contrast, and it also aids in assessing patients with neurological deficits but is not useful as compared to CT in the evaluation of complex fractures.[1]

Conventional radiography has played a major role in the diagnosis and treatment planning of maxillofacial injuries. Superimposition of bony structures and hindered visualization of underlying fractures by soft-tissue swelling and hemorrhage.[11]

Cone beam CT is also used for the diagnosis of maxillofacial trauma. Despite a higher radiation dosage compared to radiography, in craniomaxillofacial injuries, CT is the imaging technique of choice to display the multiplicity of fragments, the rotation and dislocation degree, or any skull base involvement.[1]

The usefulness of spiral CT scanning was measured by the mean of 100% accuracy. In the evaluation of facial trauma, coronal sections are superior to axial. CT provides an adequate radiological evaluation of the maxillofacial area. For combined head and maxillofacial injury, CT can be done for both at the same time and considered as imaging of choice in unconscious patients.[12] CT scan provides images of thin slices of the facial skeleton, overcoming the problem of the superimposition of structures that inevitably occurs on plain radiographs.[5]

3D CT was found statistically more significant in terms of fracture site detection compared to conventional radiographs. 3D CT was superior in displaying the extent of fractures and comminution as well as displacement and it provided additional conceptual information as compared to conventional radiographs. The interpretation of 3D CT took less time than conventional radiographs.[13]

MDCT has revolutionized the field of CT. This revolution can be attributed to three primary properties of MDCT: its ability to produce a vast quantity of volumetric data in a reduced amount of time, the high resolution, and the ability to create isotropic voxel data and consequently, reliable multiplanar and three-dimensional 3D reconstructions.[7]

MDCT allows high-quality MPR and isotropic viewing, all of which improve the diagnostic power of this imaging modality, thus benefiting facial trauma patients. The application of MDCT technology to multi-trauma imaging affords important advantages in injury detection and characterization. Decreasing slice thickness and the ability to routinely acquire whole-body imaging using isotropic data sets have resulted in true multiplanar CT imaging.[14]

MDCT is the modality most often used for imaging evaluation in such cases because the high image resolution available with thin-section acquisitions allows the detection of even subtle non-displaced fractures of the facial skeleton. MDCT provides

**Table 1: The following table shows the data of each patient**

| S. No. | Conventional radiograph | Additional findings in MDCT | Diagnosis |
|---|---|---|---|
| CASE 1 | Haziness in the maxillary sinus and fracture of the lateral rim of the orbit. | Displaced fracture in left zygomatic arch. | Left zygomatic complex fracture. |
| CASE 2 | Haziness in the right maxillary sinus and fracture of the lateral rim of the orbit. | Fracture of the right zygomatic arch.<br>Fracture of the ramus of the right mandible. | Right zygomatic complex fracture with right ramus of the mandible. |
| CASE 3 | Left zygomatic arch fracture. | The same findings of conventional radiographs. | Right zygomatic arch fracture. |
| CASE 4 | Haziness in the bilateral maxillary sinus. | Fracture in the antral wall of the maxillary sinus, zygomatic buttress extending to lateral pterygoid plates on both sides. | Bilateral LeFort 1 fracture. |
| CASE 5 | Haziness in the right maxillary sinus and fracture of the lateral orbital rim. | Fracture of the right zygomatic arch. | Right zygomatic complex fracture. |
| CASE 6 | Haziness in right maxillary sinus and fracture of right mandibular Para symphysis. | Fracture of left mandibular subcondyle. | Fracture of the antral wall of the right maxillary sinus with left subcondyle and right Para symphysis. |
| CASE 7 (Figure 4a-d) | Haziness in the bilateral maxillary sinus and bilateral infraorbital fracture extending to the zygomatic buttress. | Naso ethmoidal and right frontal bone fracture. | Bilateral zygomatic buttress fracture with naso ethmoidal and right frontal bone fracture. |
| CASE 8 | Haziness in the right maxillary sinus and fracture of the right zygomatic arch. | Undisplaced fracture of the lateral rim of the right orbit. | Right zygomatic complex fracture. |
| CASE 9 | Haziness in the right maxillary sinus and fracture of the lateral rim of the orbit. | Undisplaced fracture of lateral and inferior margins of orbit. | Right zygomatic complex fracture. |
| CASE 10 | Haziness in the right maxillary sinus. Fracture of the lateral rim of the orbit right para symphysis and left body of the mandible. | The same findings of conventional radiographs. | Right zygomatic buttress fracture with right para symphysis and left the body of the mandible. |
| CASE 11 | Haziness in the right maxillary sinus and fracture of the lateral rim of the orbit. | Undisplaced fracture of the right zygomatic arch. | Right zygomatic complex fracture. |
| CASE 12 | Fracture of left subcondyle. | The same findings of conventional radiographs. | Left subcondylar fracture |
| CASE 13 | Haziness in the left maxillary sinus and fracture of the lateral rim of the orbit. | Undisplaced fracture of the left zygoma and zygomatic arch with hemosinus. | Left zygomatic complex fracture. |
| CASE 14 | A fracture of left para symphysis and body fracture. | Undisplaced fracture of right mandibular subcondyle. | Left para symphysis and body fracture with right sub-condylar fracture |
| CASE 15 (Figure 5a-d) | Haziness in the left maxillary sinus and bilateral fracture of the mandible. | Undisplaced fracture of the lateral rim of the left orbit. | Left zygomatic complex with bilateral body fracture. |
| CASE 16 | Fracture of left subcondyle. | The same findings of conventional radiograph | Left subcondylar fracture. |
| CASE 17 | Nasal bone fracture. | Undisplaced fracture of the right maxillary sinus. | Fracture of the antral wall of the right maxillary sinus with nasal bone. |
| CASE 18 | Haziness in left maxillary sinus and fracture of left infraorbital and lateral rim of the orbit. | Fracture of left zygomatic arch.<br>Herniation of inferior rectus and inferior orbital content into the maxillary sinus. | Left zygomatic complex fracture. |
| CASE 19 | Fracture of left parasymphysis and angle of the mandible. | The same findings of conventional radiographs. | Fracture of the right angle and left parasymphysis of the mandible. |
| CASE 20 | Haziness in the left maxillary sinus. | Undisplaced fracture of the lateral rim of the left orbit. | Left zygomatic complex fracture. |
| CASE 21 | Haziness in theleft maxillary sinus, fracture in the right zygomatic arch, and left mandibular parasymphysis. | Undisplaced fracture of the lateral rim of the left orbit. | Right zygomatic complex fracture with left mandibular parasymphysis. |
| CASE 22 | Fracture of bilateral subcondyle. | A fracture involving the lingual cortex of the mandible. | Bilateral condylar fracture with symphysis fracture. |
| CASE 23 | Fracture of right maxillary alveolus. | The same findings of conventional radiographs. | Maxillary dento- alveolar fracture |
| CASE 24 | Fracture of the right condyle and left parasymphysis fracture. | The same findings of conventional radiographs. | The right condyle and left parasymphysis fracture of the mandible. |
| CASE 25 (Figure 6a-d) | Haziness in the right maxillary sinus | Fracture of the right lateral rim of the orbit. | Right zygomatic complex fracture. |

better delineation of osseous and soft-tissue features, offers both multiplanar and three-dimensional image reconstruction, and can be performed more quickly than radiography, with easier patient positioning.[15]

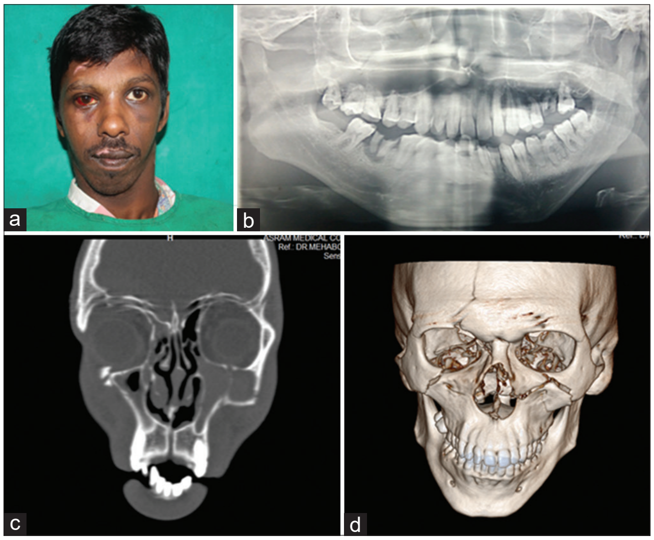


**Figure 4:** (a) Pre-operative profile, (b) Conventional radiograph, (c) multidetector computed tomography (MDCT), (d) 3D MDCT

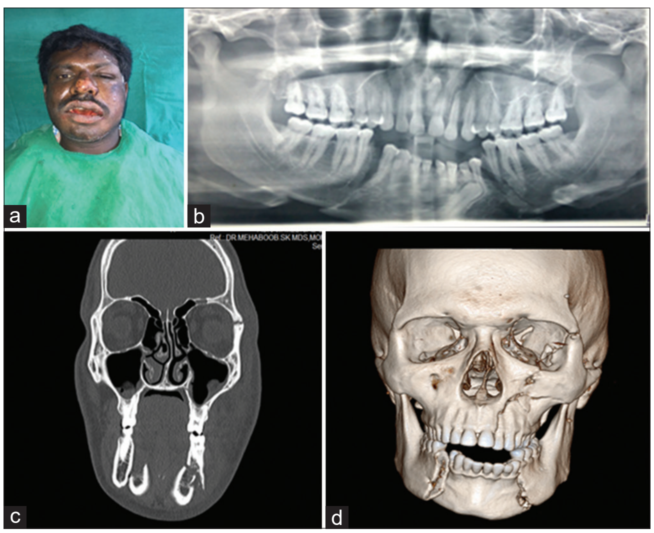


**Figure 5:** Pre-operative profile, (b) pre-operative radiograph, (c) multidetector computed tomography (MDCT), (d) 3D-MDCT

MDCT is markedly superior to radiographs in musculoskeletal injuries, especially in areas of complex bony anatomy owing to its spatial resolution and multiplanar reconstruction techniques.[8]

According to Ahmad *et al*.,[10] mandibular fractures comprise the fracture of symphysis, alveolar process, body or horizontal ramus, angle, ascending ramus, coronoid process, and mandibular condyle. Pain, trismus, difficulty in chewing, malocclusion, swelling, and fractures are the common presentations of mandibular trauma. Any asymmetry in the occlusion is highly suggestive of mandibular fracture.

MDCT is an important imaging modality in diagnosing mandibular fractures. Mandibular condylar fractures are better evaluated on a sagittal plane while 3D reconstructions are very helpful in planning surgical management. MDCT

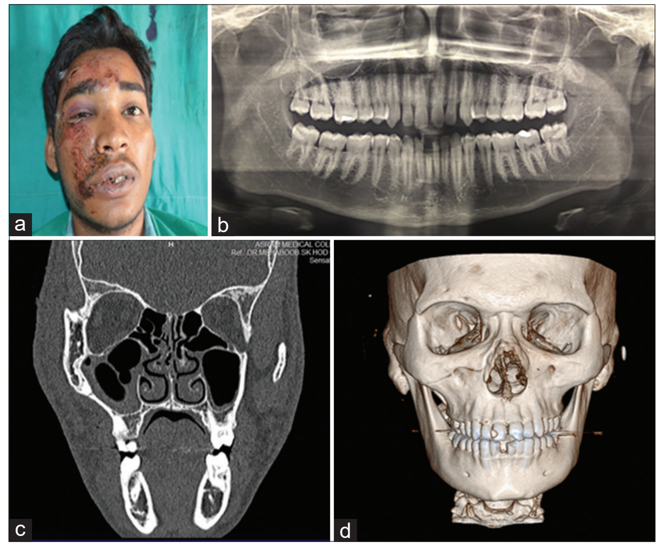


**Figure 6:** (a) Pre-op profile, (b) Pre-operative radiograph, (c) multidetector computed tomography (MDCT), (d) 3D- MDCT

detects mandibular fracture with 100% sensitivity whereas orthopanoramic radiographs and conventional X-rays had 86% sensitivity.

The spatial resolution of MDCT is excellent, which enables MPRs and 3D reconstructions, allowing better diagnostic accuracy and surgical planning. 3D reconstruction and MPR in coronal and sagittal planes are very useful in assessing the bony architecture in large comminuted, displaced, and complex fractures involving multiple planes which helps the surgeons with appropriate planning.

In MPR and 3D reconstructions, there is no additional burden of radiation exposure to patients, as these images are obtained from the original 2D images, which enable MDCT as the imaging modality of choice in patients of maxillofacial trauma.

Ogura *et al*.[1] demonstrated the maxillofacial fractures using MDCT and conducted that the zygomaticomaxillary complex fracture was most frequently involved in falls and violence. The most common form of interpersonal violence is a hit with a fist, but high-energy means, such as the use of brass knuckles or kicking. The high energy resulting from falls or violence was applied in the facial region, causing direct fractures of the zygomaticomaxillary complex type.

In our study, MDCT was extremely useful for the detection of the zygomaticomaxillary complex when compared to panoramic radiography because of its high sensitivity.

Vijay Kumar *et al*.[16] described low-energy fractures due to their occurrence with low-energy trauma. However, in some instances, they can be "Sentinel injuries" suggesting high-energy fractures such as LeFort fractures. Furthermore, low-energy fractures and isolated zygomatic arch fractures were never detected alone. Therefore, patients who have sustained low-energy fractures should undergo MDCT to reveal any high-energy injuries. In LeFort fractures, asymmetric and combined entities were common. Further LeFort fractures were also accompanied by other fractures.

The role of MDCT in trauma is about diagnosis, treatment planning, and assessing outcomes. The recognition of sentinel fractures leads to active searching and detection of subtle other important fractures. MDCT also is useful in the detection of complications and planning for surgical fixation.

Other imaging modalities like plain radiographs only show obvious large fractures as there is significant overlap and lack of imaging of the inner bones of the face and base of the skull.

In our study, we also believed that the MDCT scan was 100% sensitive in the detection of fractures when compared to ortho panoramic radiographs and conventional X-rays which had less sensitivity and low imaging quality.

According to Tomich *et al*.,[17] orbital floor fractures were the most common in their series and associated in most cases with fractures of the maxillary sinus walls. One of the mechanisms of this fracture is the blowout, first described by Pfeiffer in 1943. This occurs when the force of a direct impact on the eyeball is absorbed by the orbital rim (which remains intact) and is transmitted to the orbital floor, which shatters (usually in the middle third, near the infraorbital canal). The eyeball usually remains undamaged. The presence of an air-fluid level or the complete occupation of the maxillary sinus is common. Fat protrudes through the fracture line (the sign of the pending drop or tear). Herniation of the inferior rectus muscle and inferior oblique muscle may also occur and it can be associated with diplopia. Muscle entrapment and acute enophthalmos are indications for immediate surgery.

Less often, fracture segments can herniate upward into the orbit, which is called blow-in fracture. When there is orbital rim involvement in fractures of the orbital floor, these fractures should be considered separately from blow-out fractures, in which, by definition, orbital rims remain intact. Orbital rim involvement has implications for the surgical therapy technique, and therefore it is important to differentiate both types of fractures. Fractures of the orbital floor are clearly seen, mainly on coronal reconstructions from MDCT.

In our study, we conclude that MDCT was useful to access the bony architecture of zygomatico-orbital complex fractures when compared to conventional radiographs because of complex anatomy. In case number 18, there is herniation of inferior orbital content into the maxillary sinus was clearly seen in coronal sections of MDCT.

According to Patil *et al*.[18] mid-facial fractures can be very difficult to assess by conventional radiography because of the complex facial anatomy. MDCT provides high-quality imaging in the three planes and excellent 3D reconstructions. CT is the most widely accepted method in the evaluation of patients with maxillofacial trauma, as it makes it possible to identify and quantify fractures, recognize their true extent and if there are bone displacements or not, as well as assess soft-tissue injuries.

In patients with zygomatic bone fractures, coronal images were similar to axial images in the detection. In patients with zygomatic arch fractures axial CT were superior to coronal in detecting fractures. Zygomatic bone fractures 3D images were found to be similar or better for the detection and description of extent in most patients. In the assessment of displacement, 3D was found to be superior to axial images in most patients. The latter is particularly useful to assess bony architecture in large comminuted, displaced, and complex fractures involving multiple planes. They allow an adequate visualization and easy interpretation of the fracture segments.

According to Wahab *et al*.,[2] mid-facial fractures can be very difficult to assess by conventional radiography because of the complex facial anatomy. CT scan images have superior resolution compared to plain films. They are also better for helping delineate multiple fractures; axial sections were the best for analyzing the posterior wall of the maxillary antrum, the pterygoid plates, the hard palate, dentoalveolar segments, the zygomatic arch and body, and the lateral wall of the orbit. Coronal sections provided the best images for analyzing the anterior wall of the maxilla, the inferior orbital rim, the palate, and the orbital floor. Furthermore, the medial and posterolateral walls of the maxillary sinus were adequately assessed by the coronal images. Coronal images also provided details for injuries to the cribriform plate, nasofrontal recess, orbital roof, and floor. Three-dimensional (3D) reconstructed CT scan images are of questionable value in detecting fractures when compared with planar images. These observations were found to be true in our study.

According to Farook *et al*.,[4] plain radiography is the initial imaging modality in trauma patients but since it cannot provide adequate information regarding the internal and skull base anatomy its significance in assessing cranial and facial fracture trauma has declined. MPR and 3D sequences are widely used for successful, identification of fracture sites. This is especially true for fractures of the cranial and facial region.

The highest sensitivity in diagnosing fractures of the maxilla, frontal, and nasal bone was revealed by MPR. It was noted that in imaging of thin and delicate bone structures such as the cribriform plate of the ethmoid bone and orbital floor, and anterior wall of the maxillary sinus, 3D reconstructions were less useful than MPR. The use of 3D reconstructions in these areas often produces false-positive images suggestive of inexistent holes that are difficult or impossible to differentiate from fractures. Hence, 3D reconstructions cannot be used as the only imaging method for visualization of fractures. Furthermore, in the visualization of free, dislocated fracture fragments, MPR reconstructions turned out to be more successful in the assessment of post-traumatic lesions involving the orbits and maxillary sinuses.

Our study has reinforced the role of MDCT with MPR and 3D images and has become a standard part of the assessment of maxillofacial injury because of the exquisite sensitivity of this imaging technique for fracture. It has been observed that MDCT is a good imaging technique for the detection of undisplaced, comminuted, and complex mandibular fractures when compared to plain radiographs.

## Conclusion

This study highlighted the valuable role of MDCT in assessing maxillofacial fractures. MDCT offers faster acquisition speed (0.37 s rotation speed) and volume data compared to conventional CT (1 s rotation speed and individual slice data). It enables easier detection of frontal, maxillary bones, and midface fracture displacement. Coronal reconstructed images excel in detecting orbit and maxilla fractures. 3D images are less useful for fronto-zygomatic and zygomatic arch fractures. MDCT's soft tissue window reveals soft tissue injuries and air pockets. Despite being costly, MDCT is the preferred radiological investigation for accurate maxillofacial fracture assessment over conventional radiography due to its superior imaging quality.

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