Original Article

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Imaging Maxillofacial Trauma: The Role of Multidetector Computed Tomography

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Abstract

Background: Facial fractures account for substantial emergency department visits in the world and are allied with great levels of morbidity and mortality. The maxillofacial region is one amongst the most complex anatomical regions of the human body and is further linked with several crucial daily activities. The main objective of this study was to assess the role of Multislice Computed Tomography in the evaluation of maxillofacial trauma. **Subjects and Methods:** This Hospital-based prospective study was carried out over 9 months from JAN 2021 to SEP 2021 at the Department of Radiodiagnosis, Narayana medical college, Nellore. The study population included 48 patients- imaged with non-contrast axial 16 slice or 128 slice helical series. In conjunction with the axial images, coronal-plane MPR images were scrutinized to ascertain the presence of facial fractures. 3-Dimensional volume-rendering images were also procured. The GE workstation was used to review MDCT scans. **Results:** Out of the 48 cases, eight individuals were excluded from our study owing to motion artefacts. The peer age-group of this study was within 30 to 40 years with male preponderance of 70%. RTA was most prevalent mode of injury comprising 67.5% of cases. The maxillary fractures were most frequently eyed in 75% of patients and naso-orbito-ethmoid region accounted for 70% of patients forming the next routinely affected region. Most familiar coexistent finding in the patients with facial injury was hemosinus and spotted in 80% (n=32) patients. Some of the fractures were missed on three-dimensional imaging (3 D) compared to the axial scans but the extent of the complex fracture lines as well as degree of displacement were assessed with increased accuracy. **Conclusion:** The technological advances in medical imaging, particularly computer software algorithms in CT have fabricated the generation of coronal and sagittal reconstructed images along with 3- Dimensional images expeditious and economical without auxiliary burden of radiation exposure. We conclude that MDCT is highly diagnostic and is, therefore, the best imaging modality for evaluating maxillofacial injuries and its associated findings in backdrop of trauma and thus playing a crucial role in the planning of surgery.

Keywords: Computed Tomography, Multiplanar Reformations, Maxillofacial trauma.

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Introduction

Facial fractures account for substantial emergency department visits in the world and are allied with great levels of morbidity and mortality attributable to damaged facial structures, associated complications, and trauma sustained by other parts of the body.[1]

Any physical insult to face is termed as facial trauma or maxillofacial trauma. Blunt or penetrating trauma sustained during motor vehicle accidents, pedestrian accidents, assaults, work-related accidents, falls and sports injury are the common causes of facial fractures in our country.

The emergence of more effective emergency transportation facilities as well as advanced life support has made it easier even for severely injured individuals to reach the specialized trauma centers which are successfully increasing the rescue rate. The severity of diagnosis of facial injuries is gradually increasing with the advancing trauma care.

The maxillofacial region is one amongst the most complex anatomical regions of the human body and is further linked with several crucial daily activities. Further, injuries of maxillofacial region cause facial asymmetry and disfigurement which leads to emotional as well as cosmetic concern.

The radiological imaging of this area becomes more strenuous in traumatic patients. MDCT, mainstay of modern emergency radiology, is the modality of choice and most accurate investigation in evaluating the victims of

maxillofacial trauma in addition to detection of intracranial complications.[2]

Despite a higher dosage of radiation exposure on comparison with conventional radiography; MDCT helps in detecting the exact location, number and extent of fractures, displacement of fracture fragments, degree of rotation, soft tissue injuries and skull base involvement in least amount of time.[2]

The exemplary spatial resolution of MDCT enables Multiplanar Reformations (MPR) and 3-D reconstructions allowing superior diagnostic accuracy and provides excellent information about comminution and displacement of the fracture fragments.[3]

Aim

1. To describe advantages of 3-Dimensional reconstructed images over axial in the analysis of individuals with facial trauma.
2. The purpose of present study is to describe and categorize fractures detected on CT evaluation in patients with maxillofacial injury (according to the bones involved).
3. To describe and compare the identification of fractures in the axial and coronal orientations.

Subjects and Methods

Source of Data

The main source of data for study will be patients attending department ofRadiodiagnosis, Narayana Medical College, Nellore.

Method of Collection of Data (including sampling procedure if any)

The study participants will include 48 patients who will undergo CT evaluation on presenting with facial trauma in a period of 9 months from JAN 2021 to SEP 2021 at Narayana Medical College and Hospital, Nellore.

CT imaging will be done on the advice of referring physician and no patient will be made to undergo CT for the sole purpose of this research.

Inclusion Criteria

The study includes

- Both males & females of age group 10- 60 years.
- Multislice CT examination performed on all victims with clinical evidence of maxillofacial injuries and will demonstrate the existence of fractures.

Exclusion Criteria

The study will exclude

- Patients with maxillofacial injuries in whom CT examination is contraindicated.

Eg- Pregnancy.

- Patients with maxillofacial trauma no fractures after CT examination.

Equipment and Technique Used

- Once a patient met the study's inclusion criteria, he or she would be subjected to CT evaluation after giving their consent.
- All the CT scans in present study will be done with -
  - SIEMENS SOMATOMSCOPE 16 SERIAL SLICE CT SCANNER
  - GE OPTIMA 128 SERIAL SLICE CT SCANNER

CT Protocol consisted of the following:

- Non-contrast axial 16 slice and 128 slice helical series.

To begin with, the patients were positioned supine, and a lateral tomogram was acquired to determine the region of face to be examined. Subsequently, region from the chin to a point 3–4 cm above supraorbital margins was subjected to a continued volume scan with 5mm thickness of the axial section.

The imaging data was then transferred to computer console. In conjunction with the axial images, coronal-plane MPR images were generated with 0.5 mm increments. 3-Dimensional volume-rendering images were also procured.

The GE workstation was used to review MDCT scans.

Magnification mode was frequently employed. The scans were reviewed on a console display at various window settings (i.e., soft tissue and bone windows) to examine the osseous involvement and associated findings.

The fractures revealed on CT were categorized according to the region of involvement. Fracture detection, extent, and displacement were all evaluated using 3-D imaging compared to axial scans.

Coronal pictures were compared with axial for the purpose of detecting fractures.

Maxillofacial trauma was evaluated in five key facial regions

1. Frontal
2. Naso-orbitoethmoid (NOE)
3. Zygomatic
4. Maxillary
5. Mandibular region.

Frontal bone injuries were categorized (Manolidis):[4]

- Type-1- Fracture of anterior wall alongwith minor comminution andwithout accompanying orbital or Naso-Orbito-Ethmoidal fractures.
- Type-2 – Anterior wall comminuted fracture with possible extension into Naso-Orbito-Ethmoidal region or orbital margin.
- Type-3 – Fractures of anterior as well as posterior walls without considerable dislocation or damage to dura.
- Type-4 – Fractures of anterior & posterior walls, as well as dural damage and CSF leakage.
- Type-5 – In addition to type 4 fracture, there is significant disruption of Anterior Cranial Fossa or further bone loss.

Orbital injuries in accord with wall involvement:

- lateral wall
- medial wall
- roof
- floor

Fractures in Maxillary region in consonance with the region involved:

- Anterior, lateral and medial wall of the sinus
- Alveolar rim

Mandibular fractures based on the location:

- Condylar
- Subcondylar
- Coronoid
- Ramus
- Angular
- Body
- Alveolar ridge
- Parasymphyseal
- Symphyseal

The Le Fort approach was used to classify complex midfacial fractures:[5]

- Le Fort I
- Le Fort II
- Le Fort III

Results

Findings of our study were reviewed & compiled as follows:

Age Distribution

Present analysis comprised 48 individuals of age-group ranging from 10 to 60 years.

Eight individuals were excluded from our study owing to motion artefacts.

The peer age-group of this study was within 30 to 40 years(62.5%), with only 3 cases above 50-year age and the mean being 36 years.

Table 1: Age distribution of individuals with facial injury

Age group	No of patients
10-20	3(7.5%)
20-30	4(10%)
30-40	25(62.5%)
40-50	5(12.5%)
50-60	3(7.5%)

Gender Distribution-

The study group comprised of forty patients, with the male preponderance of maxillofacial injuries (n= 28, 70%) over females (n=12, 30%).

Mechanism of Injury

Amongst 40 cases presenting to Emergency with maxillofacial trauma, RTA was most prevalent mode of injury comprising 67.5% (n= 27) of cases. Assault & fall from height accounted for 22.5 & 10% of total, sequentially.

Dispersion of fractures in maxillofacial region-

The maxillary fractures were most frequently eyed in 75% of patients, especially involving walls of maxillary sinuses.

The naso-orbito-ethmoid region accounted for 70% of patients forming the next routinely affected region.

Zygomatic bone and mandibular fractures were discovered in 52.5 and 35% of patients respectively.

Fractures involving frontal bone were unfamiliar amidst the regions of face principally evaluated in existing research with 20% of patients possessing fractures in these regions.

Pterygoid plate fractures were eminent in 13(32.5%) patients.

The sphenoid wings were affected in 22.5% (n=9) of the patients, whereas the temporal & parietal bones were involved in 7(17.5%) and 5(12.5%) of patients, respectively.

Associated findings

Most familiar coexistent finding in the patients with facial injury was hemosinus and spotted in 80% (n=32) patients. The subsequent customary finding was pneumocephalus in 42.5% (n=17) patients followed by brain contusions in 37.5% (n=15) patients. Other prevailing intracranial complications such as SAH, SDH & EDH were espied in 17.5% (n=7), 27.5% (n=11) and 22.5% (n=9) patients respectively.

Maxillary fractures were habitually associated with hemosinus whereas the association with intra and extra-axial hemorrhages was limited.

Mandibular fractures had a minimal association with hemosinus and intracranial findings but the major coexistent finding was TM joint involvement.

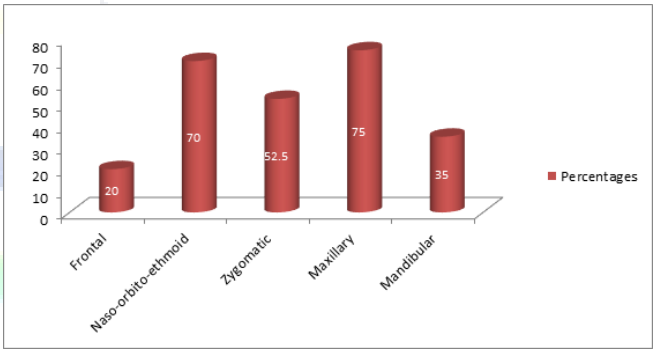

Chart 1: Dispersion of fractures in maxillofacial region

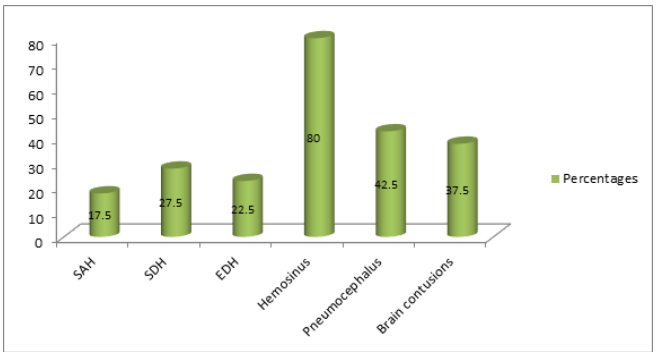

Chart 2: Associated findings

Comparison of axial Vs 3-D images (detection, extent, displacement) and axial Vs coronal images (detection):

Frontal bone fractures:

The detection and displacements of fractures involving frontal bone were finely perceived on 3-Dimensional images in majority of patients. Nevertheless, 3-D images were incompetent in depicting fracture extension into posterior wall of sinus as well as roof of orbit.

In detecting fractures of frontal bone, coronal & axial images were identical.

Naso- Orbito- Ethmoid Fractures

In most subjects, 3D scans were less accurate than axial imaging in terms of detection, extension, and displacement of naso-orbito-ethmoid fractures.

Coronal imaging was preferable than axial imaging in detecting fractures in the orbit's medial wall and floor.

Zygomatic Bone Fractures

3-dimensional imagery was equivalent to axial in terms of detecting & assessing zygomatic bone fractures. Despite that, 3D images were ascertained to be superior to axial views for fracture displacement in majority of instances.

Zygomatic fracture detection on coronal images was identical to that on axial images.

Fractures in Maxilla

3-D pictures were comparable to axial in detecting fractures in maxilla, yet superior particularly in cases where anterior sinus wall was involved. Extent of involvement & its displacement were easily discernible on axial imaging. In many patients, coronal views were equivalent to or way better than axial imaging in detecting fractures of maxilla.

Fractures in Mandible

Detection & extent of involvement of fractures of mandible as evaluated with 3-Dimensional and axial imaging were analogous in majority of patients. Yet, utilization of 3-D images had a definitive advantage in assessing displacement of fracture fragments.

Coronal imaging was observed to be equivalent to axial in diagnosis of mandibular fractures.

Table 2: Tabulation of mandibular trauma based on area of inclusion.

Location	No of fractures (n=14)	%
1. Symphyseal	2	8
2. Parasymphyseal	8	32
3. Condylar	10	40
4. Subcondylar	1	4
5. Coronoid	2	8
6. Body	4	16
7. Ramus	3	12
8. Angle of mandible	1	4
9. Alveolar Ridge	2	8

Image Gallery

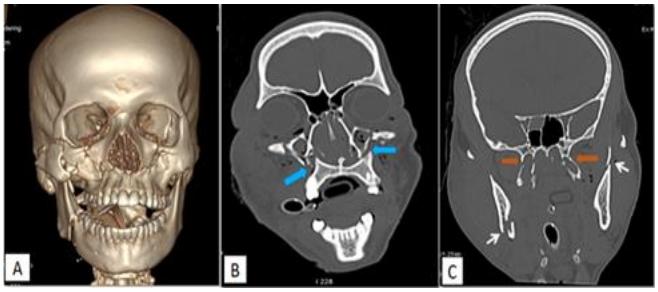

Figure 1: A- 3D image, B and C- Coronal images illustrating a horizontal fracture line involving the anterolateral walls of nasal cavity above the alveolar ridge(blue arrows) and displaced fractures of bilateral medial and lateral pterygoid plates(orange arrows).
- Le Fort I maxillofacial injury
- Linear displaced fracture noted involving the body of the mandible(white arrows).

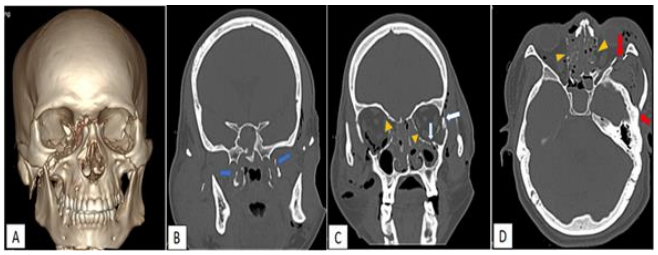

Figure 2. A- 3D image, B and C- Coronal images, D- Axial image demonstrating –Fractures involving maxillary process of right zygomatic arch, bilateral lamina papyracea (arrow heads), root of nose along with lateral and medial walls of bilateral maxillary sinus. Fractures of bilateral medial and lateral pterygoid plates (blue arrows).- Le Fort II maxillofacial injury.
- Linear minimally displaced fracture noted in frontal and temporal process of left zygomatic bone (red arrows) and frontal process of right zygomatic bone.
- Communited fracture involving lateral and inferior wall of left orbit (white arrows).
- Oblique displaced fracture extending from condylar notch to the ramus of mandible with dislocation of right temporo-mandibular joint.

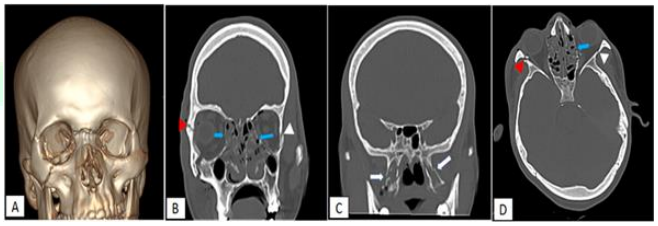

Figure 3. A- 3D image, B and C- Coronal images, D- Axial image showing –
- Transverse fracture in lateral wall of right orbit(red arrow head), lamina papyracea on both sides(blue arrows), root of nose crossing midline and lateral wall of left orbit(white arrow head). Comminuted displaced fracture noted involving bilateral medial and lateral pterygoid plates (white arrows), bilateral greater wings of sphenoid.
- Le fort III maxillofacial injury
-Linear undisplaced segmental fracture involving right zygomatic arch.
-Minimally displaced fracture involving lateral and posterior walls of right maxillary sinus extending into inferior orbital plate.

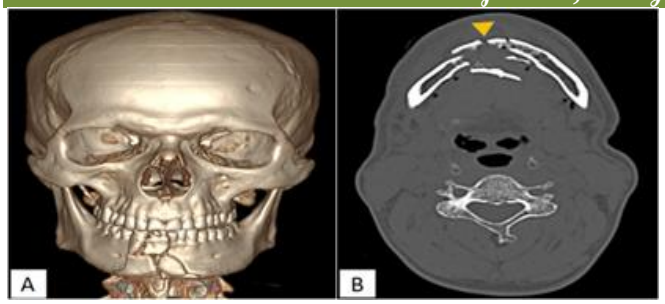

Figure 4: A- 3D image, B- Axial image demonstrating Comminuted displaced fracture involving symphysis menti (arrow head) and body of mandible extending upto inferior alveolar processes of right incisors and canine.

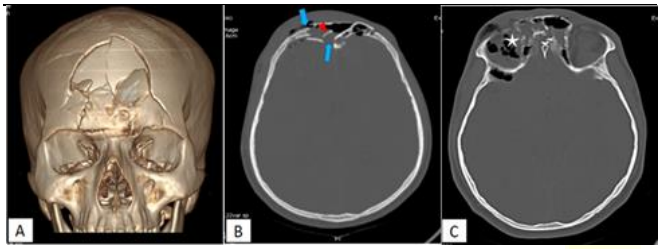

Figure 5. A- 3D image, B and C- Axial Computed tomography images illustrating-
Comminuted depressed fracture in the frontal bone involving outer and inner table of frontal sinus (blue arrows) with resultant hemosinus. Note the displaced bony fragments in frontal sinuses (arrow head). The fracture is extending to the roof of the bilateral orbits with resultant bilateral pneumo-orbit (asterisk).
-Comminuted undisplaced fracture noted in the medial wall of right orbit.

Discussion

Maxillofacial trauma portrays as solitary injury or a component of polytrauma.[6] Maxillofacial injuries materialize by either of the following- blunt or penetrating forces or a combination of both. Multiple elements may effectuate the disparity in frequency of facial fractures; primarily patient's age, socioeconomic status, geographical location, and level of industrialization.[6]

Despite higher radiation dosage, CT has been preferred imaging technique to unveil the number of fragments, their degree of rotation & displacement, or associated finding likely involvement of base of skull.

In 2001, TANRIKULU and EROL analyzed clinical value of CT versus plain radiographs on 40 patients & concluded the excellence of CT in identification as well as categorization of all fractures.[7]

MDCT is principal imaging modality and precise investigation in examination of patients with craniofacial trauma.[8]

The present study comprised 48 patients who encountered a maxillofacial injury & were spotted with fractures pertaining facial bones. Eight patients were excluded from our study owing to motion artefacts.

The community of present analysis comprised of patients in 10 to 60-year age-group. There were also age-group differences, with a high incidence (62.5%) between 30-40 years. Lowest incidence was noted at the age below 20 and above 50 years comprising 7.5% (n=3) patients.

Van Hoof et al,[9] over duration of 14-years evaluated 1,420 European victims with facial injuries & concluded most prevalent age-group as 20–30 years.

Males had a higher rate of maxillofacial injuries than females, with 70 percent (n=28) and 30 percent (n=12) instances, respectively. Our study is in harmony with 784 patient survey undertaken by Sohns et al that reported male preponderance.[10]

RTA's were most frequent cause of trauma in patients who arrived to emergency room, encompassing for 67.5 percent of victims. Alternative sources of injury were recorded as assault & fall from height, constituting 22.5% and 10% respectively.

The majority of authors proclaimed road traffic accidents as the most persistent cause of facial fractures.

Out of the forty cases, maxillary fractures were predominant in this analysis (n=30, 75%), followed by naso-orbito-ethmoid (n=28, 70%) and zygomatic fractures (n=21, 52.5%).Subsequently, the incidence of mandibular and frontal bone fractures was noted as 35% (n=14) and 20% (n=8).

Nasal bone fractures were eyed in 12 (30%) patients of maxillofacial trauma. Pterygoid plates were involved in 32.5% (n=13) of patients.

Our study is similar to the 50 patient study conducted by Prasad VN, et al.[3] during April 2014 to September 2016 wherein maxillary sinus wall fracture was the commonest reported fracture.

Frontal Bone Fractures

Frontal bone is notably conspicuous and generally injured in individuals presenting with maxillo-facial trauma. Frontal bone fractures may be restricted to either anterior or posterior table individually or involve both anterior & posterior sinus walls.

Type 3 fractures were frequently eyed in this study in 37.5% out of eight frontal bone fractures. Type 2 was the next frequent fracture in 25% patients. The least fractures espied once were type 1, 4 and 5.

3-Dimensional imaging was excellent in assessing the identification and displacement of frontal bone fractures in this study.

Naso Orbito Ethmoid Fractures

Integrated injuries of the nasal bone, medial wall of orbit, as well as frontal process of maxilla split the naso-orbito-ethmoidal complex.

The detection, extent, and displacement of naso-orbito-ethmoid fractures in 3D images were less adequate in comparison with axial imaging. Coronal pictures were finer than axial imaging in detecting fractures in this location, primarily in the orbit's medial wall and floor.

Medial wall of orbit was regularly affected and was spotted in 4(50%) patients with subsequent involvement of orbital floor 3(37.5%) times. The fractures of lateral wall & roof were discerned in three and one patients correspondingly. This seems to be in congruence with research on orbital

fractures which found that floor & medial wall were frequently involved.[11]

The prospective study of Tanrikulu & Erol on 40 consecutive subjects who underwent CT for complicated mid-facial fractures between 1995-1997 concluded that axial along with coronal imaging were adequate for detection of medial orbital wall fractures.

Zygomatic Fractures

Zygomatic fractures emanate from a direct blow to lateral mid-face.

In this series of fourty cases, 3D images were corresponding to the axial images for assessing detection & extent of zygomatic fractures. In analyzing displacement, 3D images were revealed to be beneficial over axial in several patients with some more added information.

In majority of patients, coronal scans provided same information as axial imaging in detecting zygomatic fractures.

Dos Santos et.al and Mayer et.al reported that 3-D CT wastageous for assessing comminuted fractures of middle third of face & zygomatico-maxillary complex.[12]

Maxilla

Assessment of detection of fracture involving maxillary sinus on 3D images was similar to axial whereas evaluation of extent and displacement was inferior to that of axial imaging. However, 3D images were preferable in fracture detection of anterior wall of maxillary sinus.

Coronal representations were analogous to axial in 58.6% of patients & considerably better than axial in detecting maxillary fractures in 26% patients.

Mandible

Mandibular fractures are segregated in accordance with anatomic region involved.

In present series, mandibular fractures accounted for 35% (n=14) of the total.

Assessment of detection & extent of mandibular fractures by 3-D imaging were considered to be effective to some degree compared to axial in this study. However, three-dimensional reconstructions had obvious superiority in assessment of displacement, in particular, cases of fractures with multiple fragments and/or displaced bone fragments.

Coronal images were revealed to be equivalent to axial in mandibular fracture detection.

As reported by Pickrell BB et al, the most frequent loci in mandibular fractures (both solitary & complex fractures) are condylar - subcondylar region (25-40%). Yet, fractures frequently arise at angle on the condition of existence of a sole fracture.[13]

Associated Findings

The most consistently observed associated finding was hemosinus in individuals with maxillofacial injury and was spotted in 32 (80%) subjects.

LAMBART et al, from their study concluded non-existence of free fluid in paranasal sinuses (clear sinus sign) in CT as an authentic yardstick for eliminating fractures of paranasal sinus walls.[14] In this series merely two patients had an injury to sinus wall without associated hemosinus.

The most frequent association of hemosinus was with maxillary fractures and was noticed in 93.3% (28/30) of fractures involving this region followed by Naso-Orbito-Ethmoid fractures in 85.7% (24/28) subjects.

Fourty cases of maxillofacial injuries- LeFort fracture lines were detected in 17 patients. LeFort II had a higher frequency amongst LeFort lines identified and espied 9 times (52.9%). LeFort I & III fracture lines were acknowledged in 5(29.4%) and 3(17.6%) occasions each.

Our study is similar to study conducted by Phillips BJ, wherein LeFort II fractures constituted to be frequent and LeFort III fractures to be critical of all three.[15]

The conjunction of LeFort fracture lines was identified in 7 patients. Association of LeFort I & II and LeFort II & III fracture was detected in 4 & 3 patients each. Coexistence of LeFort I & LeFort III lines as well as LeFort I, LeFort II, & LeFort III was not noted.

MDCT being a precise and non-invasive approach is the current modality of choice for evaluating victims with craniofacial injuries. MDCT provides benefit of increased availability and speedy acquisition in event of acute trauma.

The technological advances in medical imaging, particularly computer software algorithms in CT have fabricated the generation of coronal and sagittal reconstructed images along with 3- Dimensional images expeditious and economical without auxiliary burden of radiation exposure.

Furthermore, it aids the maxillofacial surgeons in classifying fractures as stable and unstable and helps them to obtain a visual 3D picture before any reconstructive surgery.

Conclusion

- The composite skeletal anatomy of face mandates multiplanar scanning techniques for a precise evaluation.
- The principal objective of diagnostic imaging is MDCT offers exceptional spatial resolution, which in succession enables exquisite multiplanar reformations & 3-D reconstructions, permitting improved diagnostic efficacy & early surgical management improving outcome in these common traumatic injuries.
- Finally, we conclude that MDCT is highly diagnostic and is, therefore, the best imaging modality for evaluating maxillofacial injuries and its associated findings in backdrop of trauma and thus playing a crucial role in the planning of surgery.

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