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Sudan University of Medical Sciences and Technology

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A Study of Craniofacial Fractures Using Computed Tomography

دراسة كسور عظام الراس والوجه باستخدام الاشعة المقطعية المحوسبة

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بسم الله الرحمن الرحيم

يرفع الله الذين آمنوا منكم والذين أوتوا العلم درجات

صدق الله العظيم

Dedication

I would like to dedicate this work to

My mother& my brother

Who has been my constant source of inspiration

My husband

Who gave me derives and disciplines to tackle any task with enthusiasm and determination

Without their love and support this project would not have been made possible

Rawan

My little angel

Acknowledgement

I would like to acknowledge the inspirational, instruction and guidance my supervisor Dr.Husein Ahmed Hasan.

Special thanks to Mr. Rafat Abd Allah who help me in this research.

Abstract

Complex craniofacial injuries are encountered among both road traffic accident and other trumatic cases. Computed tomography is a necessary and effective tool for the evaluation and treatment of these injuries.

The aim of this research was to study craniofacial fractures using computed tomography. Specifically to identify visible fracture in CT, to evaluate craniofacial fractures between axial cut and 3DCT, to evaluate craniofacial fractures between sagittal cut and 3DCT and to evaluate craniofacial fractures between coronal cut and 3DCT.

This study compared between different CT planes and 3DCT in different types of fractures and in different craniofacial bone fractures and then found out better reconstruction for visualization of craniofacial fractures.

This descriptive study was conducted in Khartoum-Sudan, data were collected from 200 adult patients clinically diagnosed as having fracture to craniofacial bone and who had undergone craniofacil, CT scan was perform with TOSHIBA 16 slices. All scans were unenhanced. Standard protocols were basic (1:1 pitch, 120 –140 kV, and 175–250 mA). All images were obtained in axial with thin slice 3-5mm and reformat images wre obtain in coronal, sagittal and 3D. The radiologist analyzed all cranifacial CT images to determine which image plane and types demonstrates craniofacil fractures

The study showed that fracture type better seen in 3D images in traumatic patients was depressed fracture appeared in 3DCT (118) (100%), linear fracture appeared in 3DCT (52) (63.4%) with *p* value (0.00) that mean there is significance relation . also In evaluation the difference between fracture type and axial plane in traumatic patients was found that depressed fracture appeared in axial plane (106) (89.8%), linear fracture appeared in axial plane (75) (91.4%) with *p* value (0.448) that mean there is insignificance relation.

In comparison between axial plane and 3DCT we found that there was (155) (85.6%) craniofacial fractures appeared in both with *p* value (0.312) that mean there is insignificance relation, but in sagittal and coronal cut there was (147) (93%) with *p* value (0.00) and (142)(94.6%) with *p* value (0.00) respectively that mean there was significance relation.

Based on results of this study and previous study conclude that 3D reconstruction may offer a problem solving option, 3D imaging can provide useful information to both radiologist and surgeon in cases of severe facial trauma.

The study concluded the study of craniofacial fracture, multiplannar reconstrction and 3D increase the effectiveness of visibility and extend of cranifacial fractures.

A study recommended that 3DCT should be added as a routine imaging for head injury patients, in future studies researcher should use larger sample size for better evaluation; specification of bone under study will ease up findings and data acquisition.

مستخلص البحث

تتسبب حوادث الحركة والحوادث الاخرى فى كسور عظام الوجة والجمجمة, التصوير المقطعى المحوسب هو اداة ضرورية وفعالة لتقييم وعلاج هذه الاصابات .

الهدف الرئيسي من هذا البحث هو دراسة الكسور القحفية في التصوير المقطعي. على وجه التحديد لتحديد الكسر المرئي في التصوير المقطعي ، لتقييم الكسور القحفية الوجهية بين القطع المحوري و 3التصوير المقطعي ثلاثي الابعاد، لتقييم الكسور القحفية الوجهية بين القطع السهمي و التصوير المقطعي ثلاثي الابعادولتقييم الكسور القحفية بين القطع الإكليلي و التصوير المقطعي ثلاثي الابعاد

قارنت هذه الدراسة بين تقنيات التصوير المقطعي المحوسب المختلفة و التصوير المقطعي ثلاثي الابعاد في أنواع مختلفة من الكسور وفي كسور عظام قحفية مختلفة ، ثم اكتشفت إعادة بناء أفضل لتصور الكسور القحفية الوجهية.

تم إجراء دراسة وصفية على (200) مريض تم تشخيصهم إكلينيكيًا على أنهم كسر في عظم قحفي وجهي وخضعوا للأشعة المقطعية باستخدام 16 شريحة من توشيبا وتم الحصول على صور محورية وإكليلية وسهمية وثلاثية الأبعاد.

في تقييم العلاقة بين نوع الكسر والصور ثلاثية الأبعاد في مرضى الصدمات وجدنا أن الكسر المكتئب ظهر في التصوير المقطعي المحوسب ثلاثي الابعاد (118)(100٪) ، الكسر الخطي ظهر فيالتصوير المقطعي المحوسب ثلاثي الابعاد (63.4) (52)٪ مع قيمة (0.00) p وهذا يعني أن هناك هي علاقة متجانسه. أيضا في التقييم وجد الفرق بين نوع الكسر والمستوى المحوري في مرضى الرضوض أن الكسر المكتئب ظهر في المستوى المحوري (106) (89.8٪) ، الكسر الخطي ظهر في المستوى المحوري (75) (91.4٪) بقيمة (0.448 pهذا يعني أن هناك علاقة غير متجانسة.

بالمقارنة بين المستوي المحوري و التصوير المقطعي ثلاثي الابعاد وجدنا أن هناك (155) (85.6٪) كسور قحفية وجهية ظهرت في كلاهما بقيمة (0.312) p وهذا يعني وجود علاقة غير متجانسة ، ولكن في القطع السهمي والإكليلي كان هناك (147) (93) ٪ بقيمة (0.00) p و

(142) (94.6٪) بقيمة (0.00) pعلى التوالي مما يعني وجود علاقة متجانسة.

بناءً على نتائج هذه الدراسة وخلصت الدراسة السابقة إلى أن إعادة البناء ثلاثية الأبعاد قد توفر خيارًا لحل المشكلات ، يمكن للتصوير ثلاثي الأبعاد أن يوفر معلومات مفيدة لكل من أخصائي الأشعة والجراح في حالات صدمة الوجه الشديدة.

خلصت الدراسة الى ان تركيب الصور متعدد المحوار والتصوير ثلاثى الابعاد يحسن من تشخيص وعلاج كسور الوجة والجمجة.

أوصت إحدى الدراسات بضرورة إضافة التصوير المقطعي ثلاثي الابعاد كتصوير روتيني لمرضى إصابات الرأس ، في الدراسات المستقبلية يجب على الباحث استخدام حجم عينة أكبر من أجل تقييم أفضل ، وسيكون تحديد نوع الكسر أفضل لسهولة التقييم وأيضًا تسهيل تحديد العظام قيد الدراسة حتى النتائج والحصول على البيانات.

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CHAPTER I

CHAPTER I

Introductory to chapter

In this chapter will give a brief background about research and research objectives will be clearly stated, and the way in which study was pursued.

1. Introduction

A CT scan makes use of computer-processed combinations of many X-ray images taken from different angles to produce cross-sectional (tomographic) images (virtual "slices") of specific areas of a scanned object, allowing the user to see inside the object without cutting. (Herman 2009).

CT scanning generates 3D reconstructions (models) in voxels for qualitative 3D structural analysis, and the voxels can be converted to coordinates for quantitative morphometric analysis (Rajion ZA, 2006) (Swain MV,2009) (Kapila S,2011) Furthermore, 3D models allow reconstruction of 2D images in various planes for improved viewing of anatomical or pathological features compared with original imaging planes (e.g. sagittal images from original axial slices). In essence, 3D CT has enhanced image analysis capability compared with conventional 2D radiographs. The 3D datasets can also be used for 3D printing of custom made skull implants and periodontal scaffolds in regenerative therapy (Requicha JF, 2013) .However, the observation that significant errors can be associated with replication of anatomical structures (such as foramina, sutures, notches, tuberosities and teeth) emphasizes the importance of referring to original CT or MRI images during surgical treatment (Fasel JH, 2013). Image quality and data accuracy can also be affected by beam hardening, ring artefacts and other artefacts (e.g. from metallic restorations) that can be partially corrected but with the added risk of image distortion (Schladitz K.,2011) (Vendermeulen D, 2006) (Sohns JM,2013)

3D images reconstructions provide as with additional diagnostic information or can them be used independently. Previous study work on to explain that CT is image of choice for suspected craniofacial fracture, and after they finished decided that analysis with MIPs is a useful addition to obligatory MPRs. (Altobelli DE,et al ,1993). Other study found that 3D and CT had a similar performance in fracture detection and both were markedly better than MPR. It was concluded that ct and 3D are comparable in detecting midfacial fractures and both are superior to MPR. 3D reconstructions are superior for localization of complex fractures involving multiple planes. Also there is study of Three-dimensional reformations of computed tomography in the assessment of facial trauma by (J.E.Gillespie,2005) were obtained in 15 patients presenting with facial injuries of differing severity. The 3D images were compared with standard radiographs and high resolution CT, including multiplanar reformations, and assessed under the headings of fracture detection, extent and displacement using a simple scoring system. 3D was valuable in severe trauma with multiple fractures, providing a clear demonstration of fraction extent and fragment displacement. 3D was much less useful in minor trauma in which little or no fragment displacement had occurred, and demonstrated fewer fractures overall than either radiography or CT in all categories of facial injury. When used as part of a high resolution CT examination 3D imaging can provide useful information to both radiologist and surgeon in cases of severe facial trauma.

This study compared between different CT planes and 3DCT in different types of fractures and in different craniofacial bone fractures and then found out better reconstruction for visualization of craniofacial fractures.

1.2 Objectives:-

1.2.1 General

To study craniofacial fractures using computed tomography.

The work aimed to provide answer to the question:

3D images reconstructions provide as with additional diagnostic information or can they be used independently?

1.2.2 Specific

- To identify visible fracture in CT.
- To evaluate craniofacial fractures between axial cut and 3DCT.
- To evaluate craniofacial fractures between sagittal cut and 3DCT and to evaluate craniofacial fractures between cor
- onal cut and 3DCT.

CHAPTER II

CHAPTER II

2. Theoretical Background & Literature Review

Introductory to chapter

In this chapter will represent basic knowledge and theory that used in this research.

2.1Computed Tomography (CT)

A CT scan makes use of computer-processed combinations of many X-ray images taken from different angles to produce cross-sectional (Tomographic) images (virtual "slices") of specific areas of a scanned object, allowing the user to see inside the object without cutting.(Herman 2009).

Digital geometry processing is used to generate a three-dimensional image of the inside of the object from a large series of two-dimensional radiographic images taken around a single axis of rotation. Medical imaging is the most common application of X-ray CT. Its cross-sectional images are used for diagnostic and therapeutic purposes in various medical disciplines. The rest of this article discusses medical-imaging X-ray CT; industrial applications of X-ray CT are discussed at industrial computed tomography scanning.(Kuszyk BS, et al 1995)

A CT scanner emits a series of narrow beams through the human body as it moves through an arc, unlike an X-ray machine which sends just one radiation beam. The final picture is far more detailed than an X-ray image.(Kuszyk BS, et al 1995)

Inside the CT scanner there is an X-ray detector which can see hundreds of different levels of density. It can see tissues inside a solid organ. This data is transmitted to a computer, which builds up a 3D cross-sectional picture of the part of the body and displays it on the screen.(Kuszyk BS, et al 1995)

2.2 Introduction of 3D Imaging

Having arrived at a point of recognition that 3D imaging techniques are valuable, the challenge facing an institution is to develop a practical basis for performing 3D imaging. At our institution, we have set up a 3D imaging laboratory for the purpose of developing special expertise that is easily accessible.(Kuszyk BS, et al 1995)

The process of 3D imaging began with image acquisition protocols, which were optimized for subsequent post-processing. We have taken the step of identifying certain CT protocols that would always require 3D analysis and modified these protocols so that 3D imaging is an integral part of these studies. Referring physicians ordering these examinations now understand that they are simultaneously requesting additional 3D analysis. However, there are certain studies in which 3D imaging does not appear important prior to imaging the patient, but on reviewing axial images the radiologist may feel that 3D reconstruction may offer a problem solving option. In these situations, it is preferable to reconstruct the volumetric helical data in thinner sections and use this data for appropriate 3D reconstructions.(Kuszyk BS, et al 1995)

Based on the standardized protocols, the technologists in the 3D laboratory apply the appropriate 3D rendering software to create a data set of 3D images that is returned to the Picture Archiving Communications System (PACS) associated with the source images. Development of close communication between physicians and 3D technologists and close proximity of the 3D laboratory to the CT interpretation area allows radiologists to participate in 3D reconstruction with the technologists. In addition to 3D renderings there are a number of applications, which require quantitative measurements. These include planning prior to aortic stent graft placement or volumetric analysis prior to liver resection and living related organ donation.(Kuszyk BS, et al 1995)

2.3Principles of three-dimensional CT technology

Scanners in the early 1970s imaged objects with thin, ‘pencil beam’ X-rays in a linear translatory motion (on a straight line), with repetitions occurring after small rotational movements (1o steps) over a 180o range. The ‘pencil beam’ was soon replaced by a wider ‘fan beam’ (resembling a hand held fan) and a larger detector arc, eliminating the translatory movements during imaging. The ‘slice race’ soon ensued, with the number of simultaneous scans/slices per beam increasing from four in the late 1990s to 64 in the mid 2000s.(kalender ,2006) Current state of the art CT imaging in maxillofacial practice with MDCT acquires 16 to 64 slices simultaneously and produces images that can be viewed at high resolution from any plane(Boeddinghaus R, 2013). However, high radiation dose is an issue because of associated cancer risk (Miglioretti DL,2013).

In an attempt to acquire images more quickly at a lower radiation dose, a new 3D ‘cone beam’ CT (using a wider cone shaped beam compared to the ‘fan beam’) was pioneered at Nihon University School of Dentistry, Japan, in the 1990s and became commercially available the following decade. The principles of operation, image acquisition and interpretation specific to 3D CBCT have been described by Scarfe et (Scarfe et al,2012). Ongoing innovations in imaging technology over the past decade have enabled high resolution imaging with micro computed tomography (micro CT) (5–50 μm) and nano computed tomography (nano CT) (50 nanometres),23 exceeding those of MDCT (from 200 μm to over a millimetre)3, 24 and CBCT (76–600 μm).22 However, significant technological advancements will be required before nano CT becomes more efficient and more widely available, and this will not be discussed further here except to state that it is likely to become a key modality to study the 3D relationship between the organic and inorganic interfaces in bioceramic materials, such as enamel, dentine and bone(Ranjitkar S ,2012)

CT scanning generates 3D reconstructions (models) in voxels for qualitative 3D structural analysis, and the voxels can be converted to coordinates for quantitative morphometric analysis (Rajion ZA, 2006) (Swain MV,2009) (Kapila S,2011) Furthermore, 3D models allow reconstruction of 2D images in various planes for improved viewing of anatomical or pathological features compared with original imaging planes (e.g. sagittal images from original axial slices). In essence, 3D CT has enhanced image analysis capability compared with conventional 2D radiographs. The 3D datasets can also be used for 3D printing of custom made skull implants and periodontal scaffolds in regenerative therapy (Requicha JF, 2013) .However, the observation that significant errors can be associated with replication of anatomical structures (such as foramina, sutures, notches, tuberosities and teeth) emphasizes the importance of referring to original CT or MRI images during surgical treatment (Fasel JH, 2013) . Image quality and data accuracy can also be affected by beam hardening, ring artefacts and other artefacts (e.g. from metallic restorations) that can be partially corrected but with the added risk of image distortion (Schladitz K.,2011) (Vendermeulen D, 2006) (37Sohns JM,2013)

2.3.1 Bones of the Brain Case

The brain case contains and protects the brain. The interior space that is almost completely occupied by the brain is called the cranial cavity. This cavity is bounded superiorly by the rounded top of the skull, which is called the calvaria (skullcap), and the lateral and posterior sides of the skull. The bones that form the top and sides of the brain case are usually referred to as the “flat” bones of the skull.(leon Schlossberg et al 1997)

The floor of the brain case is referred to as the base of the skull. This is a complex area that varies in depth and has numerous openings for the passage of cranial nerves, blood vessels, and the spinal cord. Inside the skull, the base is subdivided into three large spaces, called the anterior cranial fossa**,** middle cranial fossa**,** andposterior cranial fossa (fossa = “trench or ditch”) From anterior to posterior, the fossae increase in depth. The shape and depth of each fossa corresponds to the shape and size of the brain region that each houses. The boundaries and openings of the cranial fossae (singular = fossa) will be described in a later section (leon Schlossberg et al 1997)

2.3.2Cranial Fossae

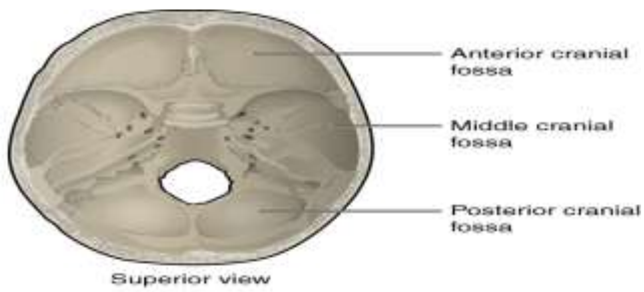

Figure 2.1: Shows The bones of the brain case surround and protect the brain, which occupies the cranial cavity. The base of the brain case, which forms the floor of cranial cavity, is subdivided into the shallow anterior cranial fossa, the middle cranial fossa, and the deep posterior cranial fossa (leon Schlossberg et al 1997)

The brain case consists of eight bones. These include the paired parietal and temporal bones, plus the unpaired frontal, occipital, sphenoid, and ethmoid bones(leon Schlossberg et al 1997)

2.4 Sutures of the Skull

A suture is an immobile joint between adjacent bones of the skull. The narrow gap between the bones is filled with dense, fibrous connective tissue that unites the bones. The long sutures located between the bones of the brain case are not straight, but instead follow irregular, tightly twisting paths. These twisting lines serve to tightly interlock the adjacent bones, thus adding strength to the skull for brain protection(leon Schlossberg et al 1997).

The two suture lines seen on the top of the skull are the coronal and sagittal sutures. The coronalsuture runs from side to side across the skull, within the coronal plane of section). It joins the frontal bone to the right and left parietal bones. The sagittal suture extends posteriorly from the coronal suture, running along the midline at the top of the skull in the sagittal plane of section). It unites the right and left parietal bones. On the posterior skull, the sagittal suture terminates by joining the lambdoid suture. The lambdoid suture extends downward and laterally to either side away from its junction with the sagittal suture. The lambdoid suture joins the occipital bone to the right and left parietal and temporal bones. This suture is named for its upside-down "V" shape, which resembles the capital letter version of the Greek letter lambda (Λ). The squamous suture is located on the lateral skull. It unites the squamous portion of the temporal bone with the parietal bone At the intersection of four bones is the pterion, a small, capital-H-shaped suture line region that unites the frontal bone, parietal bone, squamous portion of the temporal bone, and greater wing of the sphenoid bone. It is the weakest part of the skull. The pterion is located approximately two finger widths above the zygomatic arch and a thumb’s width posterior to the upward portion of the zygomatic bone(leon Schlossberg et al 1997)

2.5Fractures of Skull

The majority of skull fractures results from blunt force or penetrating trauma, and can produce numerous signs and symptoms. The clinical features may be obvious, such as visible injuries and bleeding. There are also subtle signs of fracture, such as clear fluid draining from the ears and nose (cerebrospinal fluid leak indicative of base of skull fracture), poor balance and confusion, slurred speech and a stiff neck.(Leon Schlossbrg,et al,1997)

There are certain areas of the skull that are natural points of weakness:

- **The pterion:** a ‘H-shaped’ junction between temporal, parietal, frontal and sphenoid bones. The thinnest part of the skull. A fracture here can lacerate an underlying artery (the middle meningeal artery), resulting in a extradural haematoma.

- **Anterior cranial fossa:** Depression of skull formed by frontal, ethmoid and sphenoid bones.

- **Middle cranial fossa:** Depression formed by sphenoid, temporal and parietal bones.
- **Posterior cranial fossa:** Depression formed by squamous and mastoid temporal bone, plus occipital bone.

2.6 Types of Fractures

There are four major types of cranial fracture

Depressed – A fracture of the bone with depression of the bone inwards. They occur as a result of a direct blow, causing skull indentation, with possible underlying brain injury.

Linear – The simple break in the bone, traversing its full thickness. They have radiating (stellate) fracture lines away from the point of impact. The most common type of cranial fracture. (Johannes Lang 1999)

Basal skull – Affects the base of the skull. They characteristically present with bruising behind the ears, known as Battle's sign(mastoid ecchymosis) or bruising around the eyes/orbits, known as Raccoon eye's.

Diastatic – A fracture that occurs along a suture line, causing a widening of the suture. They are most often seen in children. (Johannes Lang 1999)

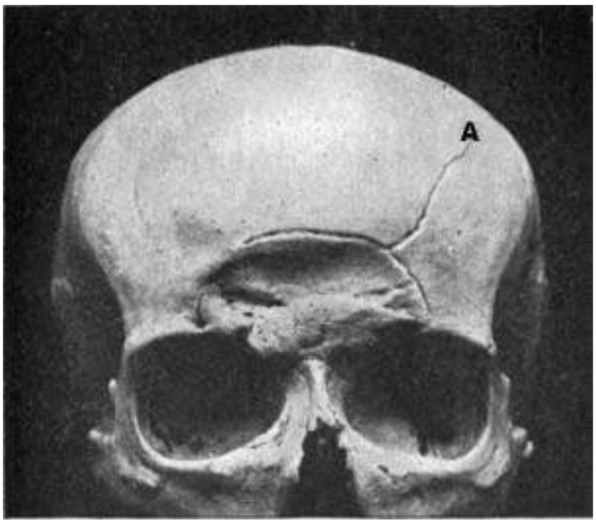

Figure 2.2: Shows depressed fracture of the frontal bone, with linear fracture marked A. (Johannes Lang 1999)

2.7Facial Fractures

Facial fractures are common and generally trauma related, i.e. road traffic collisions, fights and falls. They are often associated with clinical features such as profuse bleeding, swelling, deformity and anaesthesia of the skin. The nasal bones are most frequently fractured, due to their prominent position at the bridge of the nose. (Singh J et al 2006)

A maxillofacial fracture is one that affects the maxillae bones. This requires a trauma with a large amount of force. Facial fractures affecting the maxillary bones can be identified using the Le Fort classification, depending on the bones involved, ranging from 1 to 3 (most serious). .(Singh J et al 2006)

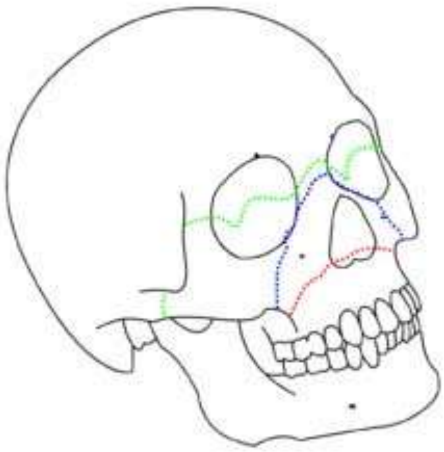

Figure 2.3: Le fort classification of maxillary fractures. (Singh J et al 2006)

2.8 Previous Studies

A study imaging of maxillofacial and skull base trauma by (Altobelli DE,et al ,1993) aimed to explain that CT is image of choice for suspected craniofacial fracture, and after they finished decided that analysis with MIPs is a useful addition to obligatory MPRs.

A study of diagnostic performance of CT, MPR and 3DCT imaging in maxillofacial trauma by (dos santos dt ,et al ,2004) aimed to elaborate that CT imaging of complex maxillofacial fractures is common practice now. Sensitivity and specificity were calculated to measure observer performance. It was found that 3D and CT had a similar performance in fracture detection and both were markedly better than MPR. It was concluded that CT and 3D are comparable in detecting midfacial fractures and both are superior to MPR. 3D reconstructions are superior for localization of complex fractures involving multiple planes.

A study of validity of multislice computerized tomography for diagnosis of maxillofacial fractures using an independent workstation by (fox la , et al ,1995) aimed to explain the CT images of 36 patients with maxillofacial fractures (symptomatic to orbit region).the images were interpreted based on 5 protocols, using an independent workstation. All methods evaluated in this study showed high specificity and sensitivity for the diagnosis of orbital fractures according to the proposed methodology. This protocol can add valuable information to the diagnosis of fractures using the association of axial/MPR/3D with multislice CT.

A study of pediatric skull fracture diagnosis by (Orman G, et al 2015) Aimed to compared the efficacy of combining 2D+3D CT reconstructions with standard 2D CT images in the diagnosis of linear skull fractures in children with head trauma. Authors In this study find that 2D+3D CT in combination showed increased sensitivity in the diagnosis of linear skull fractures in all children and increased specificity in children less than 2 years of age. In children less than 2 years of age, added confidence in the interpretation of fractures by distinguishing them from sutures may have a significant implication in the setting of nonaccidental trauma. Furthermore, 3D CT is available at no added cost, scan time, or radiation exposure, providing trainees and clinicians with limited experience an additional valuable tool for routine imaging of pediatric head trauma.

A study of role of multislice computed tomography and three-dimensional rendering in the evaluation of maxillofacial injuries by (Raju N S, et al 2017) aimed to identify and classify maxillofacial fractures using multislice computed tomography (CT) and identify the advantages of three-dimensional (3D) rendered images over two-dimensional axial images in evaluating maxillofacial injuries. This study conclude demonstrates that Multislice CT with 3D images provides better perception of the pattern of the fracture lines, and the displacement of the bony fragments thus helping in the faster and improved communication of the information to the referring physician. However, the 3D images alone have a limited role in evaluating orbital region fractures and also when there is minimal displacement of the fractured fragment.

A study of Three-dimensional reformations of computed tomography in the assessment of facial trauma by (J.E.Gillespie,2005) were obtained in 15 patients presenting with facial injuries of differing severity. The 3D images were compared with standard radiographs and high resolution CT, including multiplanar reformations, and assessed under the headings of fracture detection, extent and displacement using a simple scoring system. 3D was valuable in severe trauma with multiple fractures, providing a clear demonstration of fraction extent and fragment displacement. 3D was much less useful in minor trauma in which little or no fragment displacement had occurred, and demonstrated fewer fractures overall than either radiography or CT in all categories of facial injury. When used as part of a high resolution CT examination 3D imaging can provide useful information to both radiologist and surgeon in cases of severe facial trauma.

A study of Three-dimensional computed tomography of complex craniofacial fractures by (Massoud, T.F.,1991) Image modalities in the assessment of craniofacial trauma include: conventional radiography, plain tomography, and CT multiplanar reformation from previously acquired axial images. The complex architecture and multiple intricate components of the craniofacial skeleton necessitate accurate three-dimensional understanding of fragmentation patterns, before appropriate surgical stabilization. Three-dimensional computed tomography reformation (3D-CT) has been available for several years. More recently, critical studies of this method of investigation have been undertaken. This article presents a case involving complex craniofacial trauma, which illustrates the potential use and benefit of 3D-CT as a method of fracture assessment.

A study of Classification of midfacial fractures on computed tomography following head injury in a Nigerian population by (Yvonne U Osuagwu1,2013) Head injury is a global epidemic which results in fractures of the craniofacial region. Computed tomography (CT) is the gold standard in evaluating the head injured patient. The aim of this study was to assess the causes of head injury resulting in midfacial fractures and to characterize and classify the observed fracture patterns and associated findings on CT. Patients and Methods: Between 2006 and 2008, 300 consecutive patients with acute head injury were evaluated with a helical General Electric (GE CT/e) CT scan machine. Data reviewed included cause of injury, age and gender distribution, types of facial fractures sustained, and associated intracranial and soft tissue injuries. Results: The modal age group of the patients was the 30 to 39 year age group while the mean age was 32.78 years ± 18.51 standard deviation (SD) with a male: female ratio of 8:3. Abnormal CT scans were seen in 244 (81.4%) of the 300 patients studied. Of the 244 abnormal cases, 79 (32.4%) patients had midfacial fractures. The midfacial fractures were grouped according to the proposed classification. Most of the fractures involved the sinonasal complex (SNC; 47.3%), while the remainder was almost equally distributed in the zygomatico-maxillary complex (ZGMC; 24.4%) and orbital complex (OC; 28.3%). Subgroups were assigned depending on the associated CT findings including soft tissue swelling, cranial fractures, and intracranial abnormalities. Conclusion: Road traffic accidents (RTA) continue to be a major cause of head injury and midfacial fractures followed by falls and assault. We have described the CT findings in midfacial fractures following head injury in the study area and suggest a classification system for categorizing these fractures and associated findings.

A study of Application of three-dimensional computed tomography in craniofacial clinical practice and research by (PJ Anderson,2014) Following the invention of the first computed tomography (CT) scanner in the early 1970s, many innovations in three-dimensional (3D) diagnostic imaging technology have occurred, leading to a wide range of applications in craniofacial clinical practice and research. Three-dimensional image analysis provides superior and more detailed information compared with conventional plain two-dimensional (2D) radiography, with the added benefit of 3D printing for preoperative treatment planning and regenerative therapy. Current state of the art multidetector CT (MDCT), also known as medical CT, has an important role in the diagnosis and management of craniofacial injuries and pathology. Three-dimensional cone beam CT (CBCT), pioneered in the 1990s, is gaining increasing popularity in dental and craniofacial clinical practice because of its faster image acquisition at a lower radiation dose, but sound guidelines are needed to ensure its optimal clinical use. Recent innovations in micro computed tomography (micro CT) have revolutionized craniofacial biology research by enabling higher resolution scanning of teeth beyond the capabilities of MDCT and CBCT, presenting new prospects for translational clinical research. Even after four decades of refinement, CT technology continues to advance and broaden the horizons of craniofacial clinical practice and phonemics research.

A study of Value of high-resolution computed tomography in diagnosis of petrous bone fracture by (TarumiYamakiM.D.,2004) High-resolution computed tomography (CT) was performed on 31 patients clinically suspected of having petrous bone fracture. The location of the fracture was demonstrated accurately in 28 patients (90.3%), whereas it could be diagnosed by plain skull film in only 17 patients (54.8%). The anatomic location of fractures demonstrated by high-resolution CT clearly corresponded to the clinical symptoms and signs.

We have classified petrous bone fracture into five types according to the anatomic levels demonstrated on CT images. The findings indicate that high resolution CT is extremely useful for diagnosing petrous bone fracture.

A study of Interpretation of craniofacial fractures using multislice CT: establishing a protocol by (M.G.PCavalcanti,2004) The purpose of this study was to demonstrate the sensitivity and specificity of multislice computed tomography (CT) for diagnosis of maxillofacial fractures following specific protocols using an independent workstation. The data of CT were processed and interpreted using the following protocols independently of each one: axial, MPR/axial, 3D-CT images, and the association of axial/MPR/3D images. The clinical/surgical findings were considered the gold standard corroborating the diagnosis of the fractures and its anatomical localization. The statistical analysis was carried out using validity test. The association of axial/MPR/3D images added important information in relationship to others CT protocols.

CHAPTER III

CHAPTER III

3. Material and Methods

3.1 Material

3.1.1 Study design

Descriptive study was conducted.

3.1.2 Study area and duration:

The study was conducted in Khartoum state, included hospitals:

- Yastabshiroon Alkhartoum Hospital.
- Altamayoz for Emergency.
- Al Zaytuona Specialized Hospital

3.1.3Study duration:

From March 2017– June2019

3.1.4 Study population

200 patients referred for CT skull examination after trauma and diagnosed with fracture.

4.1.8 Variable under study:

Demographic data, Side of fracture ,Area of fracture, , Type of fracture. Visualization in axial, sagittal, coronal and 3D.

3.2 Methods

CT technique of craniofacial imaging

Patient position

The patient lies supine on the examination couch with their head within the head holder. The head is adjusted so that the enter – papillary line is parallel to the couch and the head is straight .the patient is positioned so that the longitudinal alignment light lies in the midline, and the horizontal alignment light passes through the nasion, straps and foam pads are used for immobilization.

Equipment

- head holder
- immobilization foam pads

3.3 Image interpretation

All images in axial ,coronal, sagittal,3D were interpret to seen the appearance of fractures in each types of image and the percentage were identified.

Figure 3.1: Shows 3D image of skull CT visualized the fracture (author source)

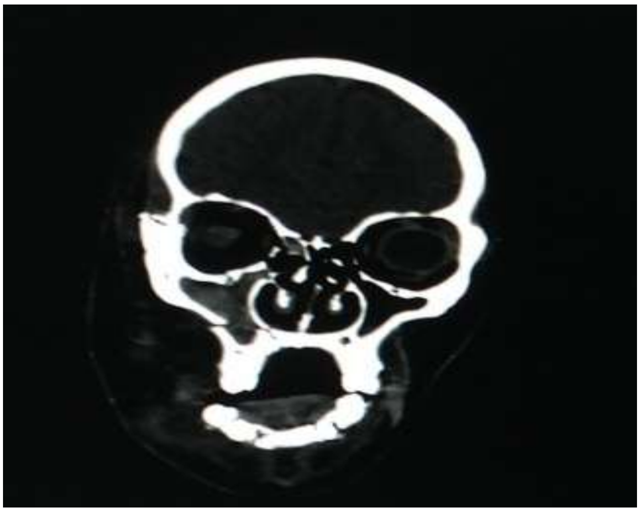

Figure 3.2: Shows MPR image of coronal CT skull that visualized the fracture (author source)

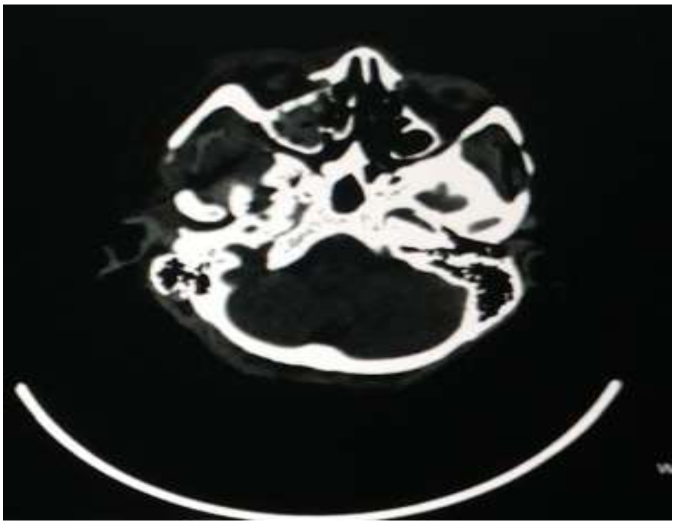

Figure 3.3: Shows MPR image of Axial CT skull that visualized the fracture (author source)

Figure 3.4: Shows MPR image of sagittal CT skull that visualized the fracture (author source)

CHAPTER IV

CHAPTER IV

4. Results

Table 4.1 Shows frequency distribution of patient gender

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	56	28.0	28.0	28.0
	Male	144	72.0	72.0	100.0
	Total	200	100.0	100.0	

Table 4.2 Shows frequency distribution of patient age

Statistics

Age

N	Valid	200
	Missing	0
Mean		34.2350
Std. Deviation		15.39202
Minimum		2.00
Maximum		89.00

Table 4.3 Shows frequency distribution of craniofacial fracture affecting anatomic site

Bone

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Base Of Skull	13	6.5	6.5	6.5
	Facial	57	28.5	28.5	35.0
	Facial+Base Of Skull	3	1.5	1.5	36.5
	Frontal	21	10.5	10.5	47.0
	Occipital	20	10.0	10.0	57.0
	Parietal	45	22.5	22.5	79.5
	Parietal+Frontal	2	1.0	1.0	80.5
	Parietal+Frontal+Facial	1	.5	.5	81.0
	Temporal	27	13.5	13.5	94.5
	Temporal+Frontal	1	.5	.5	95.0
	Temporal+Parietal	1	.5	.5	95.5
	Temporal+Parietal+Frontal	9	4.5	4.5	100.0
	Total	200	100.0	100.0	

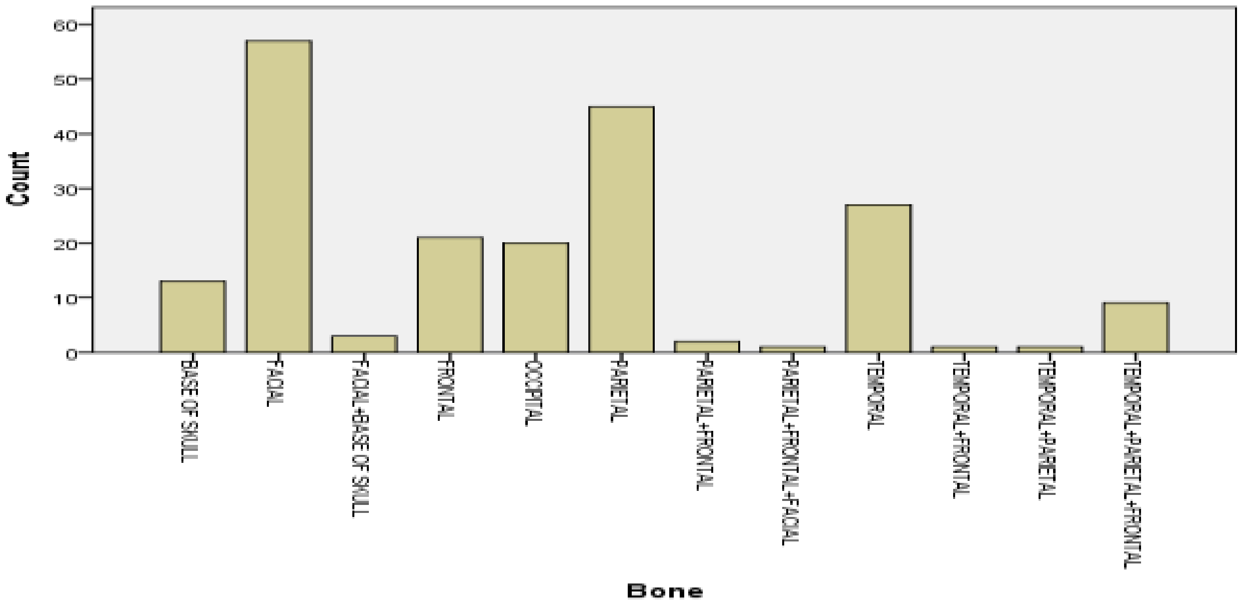

Figure 4.1 Shows frequency distribution of craniofacial fracture affecting anatomic

Table 4.4 Shows frequency distribution of craniofacial fracture according to fracture type

FxType

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Depressed	118	59.0	59.0	59.0
	Linear	82	41.0	41.0	100.0
	Total	200	100.0	100.0	

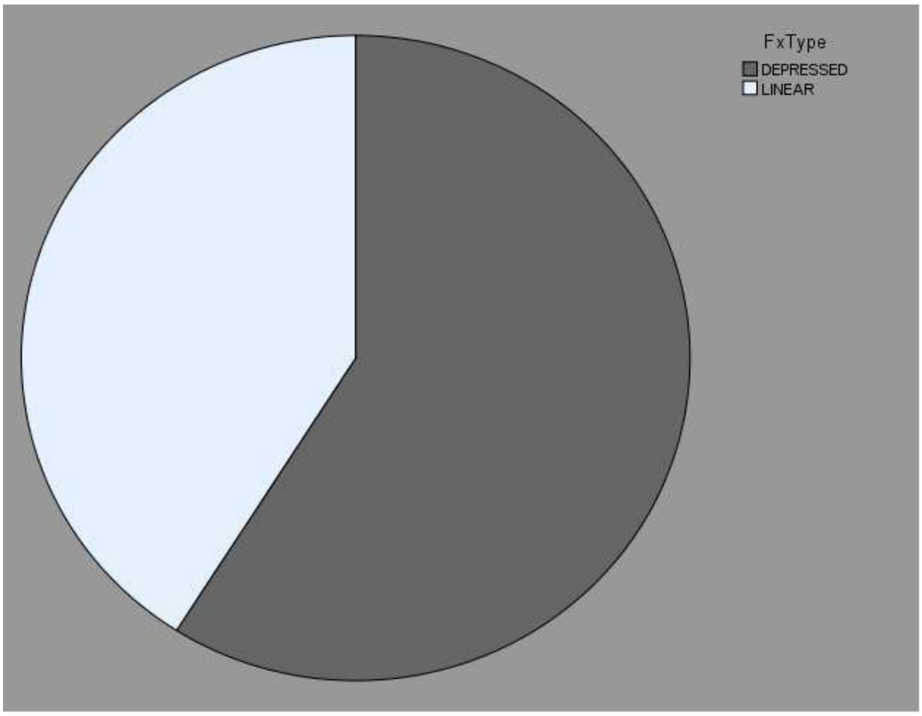

Figure 4.2 Shows frequency distribution of craniofacial fracture according to fracture type

Table 4.5 Shows frequency distribution of craniofacial fracture appeared in axial cut

Axial

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	19	9.5	9.5	9.5
	YES	181	90.5	90.5	100.0
	Total	200	100.0	100.0	

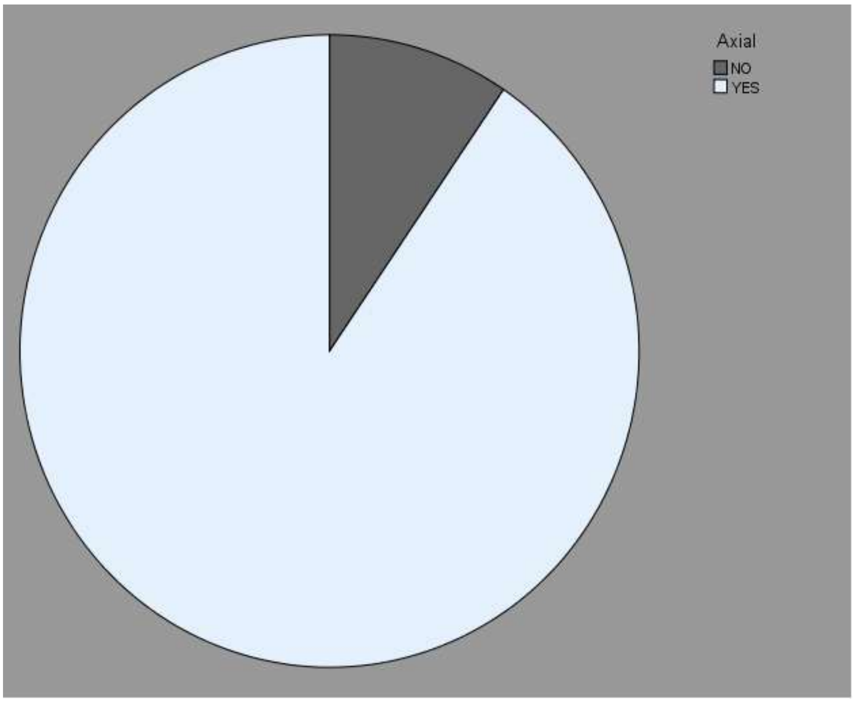

Figure 4.3 Shows frequency distribution of craniofacial fracture appeared in axial cut

Table 4.6 Shows frequency distribution of craniofacial fracture appeared in coronal cut

Coronal

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	50	25.0	25.0	25.0
	YES	150	75.0	75.0	100.0
	Total	200	100.0	100.0	

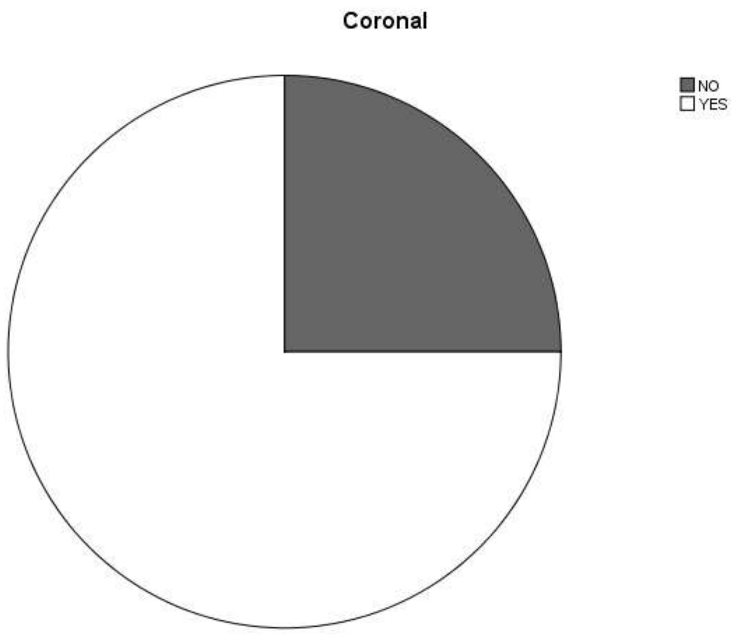

Figure 4.4 Shows frequency distribution of craniofacial fracture appeared in coronal cut

Table 4.7 Shows frequency distribution of craniofacial fracture appeared in sagittal cut

Sagittal

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	42	21.0	21.0	21.0
	YES	158	79.0	79.0	100.0
	Total	200	100.0	100.0	

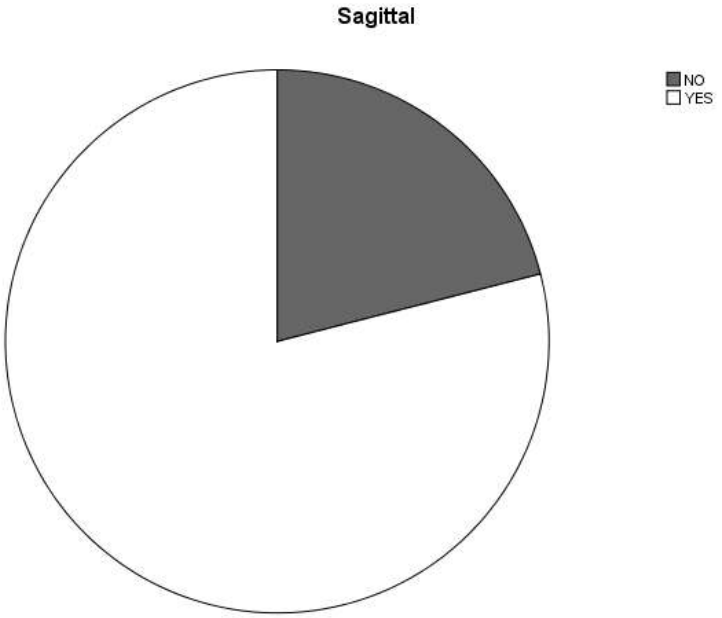

Figure 4.5 Shows frequency distribution of craniofacial fracture appeared in sagittal cut

Table 4.8 Shows frequency distribution of craniofacial fracture appeared in 3DCT

ThreeD

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	30	15.0	15.0	15.0
	YES	170	85.0	85.0	100.0
	Total	200	100.0	100.0	

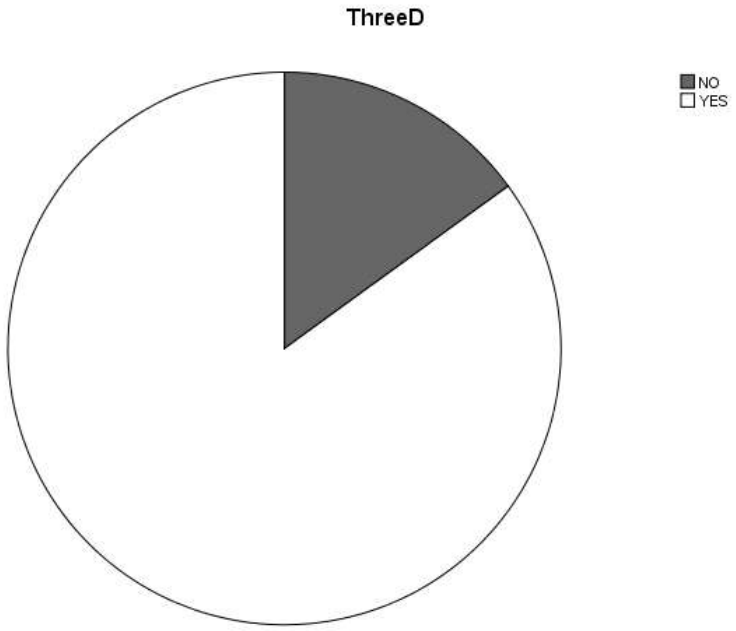

Figure 4.6 Shows frequency distribution of craniofacial fracture appeared in 3DCT

Table 4.9 Shows relation between bone fracture type and appearance of fracture in 3DCT

Count

		ThreeD		Total
		NO	YES	
FxType	Depressed	0	118	118
	Linear	30	52	82
Total		30	170	200

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	50.789[a]	1	.000		
Continuity Correction[b]	47.960	1	.000		
Likelihood Ratio	61.383	1	.000		
Fisher's Exact Test				.000	.000
N of Valid Cases[b]	200				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.30.

b. Computed only for a 2x2 table

Table 4.10 Shows relation between bone fracture type and appearance of fracture in axial cut

Count

		Axial		Total
		NO	YES	
FxType	Depressed	12	106	118
	Linear	7	75	82
Total		19	181	200

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.150[a]	1	.698		
Continuity Correction[b]	.020	1	.887		
Likelihood Ratio	.152	1	.697		
Fisher's Exact Test				.809	.448
N of Valid Cases[b]	200				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.79.

b. Computed only for a 2x2 table

Table 4.11 Shows appearance of fracture in axial cut and 3DCT

Count

		ThreeD		Total
		NO	YES	
Axial	NO	4	15	19
	YES	26	155	181
Total		30	170	200

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.603[a]	1	.437		
Continuity Correction[b]	.193	1	.661		
Likelihood Ratio	.554	1	.457		
Fisher's Exact Test				.496	.312
N of Valid Cases[b]	200				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 2.85.

b. Computed only for a 2x2 table

Table 4.12 Shows appearance of fracture in Sagittal cut and 3DCT

Count

		ThreeD		Total
		NO	YES	
Sagittal	NO	19	23	42
	YES	11	147	158
Total		30	170	200

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	38.126[a]	1	.000		
Continuity Correction[b]	35.183	1	.000		
Likelihood Ratio	31.402	1	.000		
Fisher's Exact Test				.000	.000
N of Valid Cases[b]	200				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.30.

b. Computed only for a 2x2 table

Table 4.13 Shows appearance of fracture in coronal cut and 3DCT

Count

		ThreeD		Total
		NO	YES	
Coronal	NO	22	28	50
	YES	8	142	150
Total		30	170	200

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	43.974[a]	1	.000		
Continuity Correction[b]	40.993	1	.000		
Likelihood Ratio	38.026	1	.000		
Fisher's Exact Test				.000	.000
N of Valid Cases[b]	200				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.50.

b. Computed only for a 2x2 table

Table 4.14 Shows crosstabulation between bone fracture site and appearance of fracture in 3DCT

Count

		ThreeD		Total
		NO	YES	
Bone	Base Of Skull	11	2	13
	Facial	7	50	57
	Facial+Base Of Skull	0	3	3
	Frontal	0	21	21
	Occipital	4	16	20
	Parietal	7	38	45
	Parietal+Frontal	0	2	2
	Parietal+Frontal+Facial	0	1	1
	Temporal	1	26	27
	Temporal+Frontal	0	1	1
	Temporal+Parietal	0	1	1
	Temporal+Parietal+Frontal	0	9	9
Total		30	170	200

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	59.555[a]	11	.000
Likelihood Ratio	47.988	11	.000
N of Valid Cases	200		

a. 15 cells (62.5%) have expected count less than 5. The minimum expected count is .15.

Table 4.15 Shows crosstabulation between bone fracture site and appearance of fracture in coronal cut

Count

		Coronal		
		NO	YES	Total
Bone	Base Of Skull	13	0	13
	Facial	20	37	57
	Facial+Base Of Skull	0	3	3
	Frontal	3	18	21
	Occipital	6	14	20
	Parietal	5	40	45
	Parietal+Frontal	0	2	2
	Parietal+Frontal+Facial	0	1	1
	Temporal	3	24	27
	Temporal+Frontal	0	1	1
	Temporal+Parietal	0	1	1
	Temporal+Parietal+Frontal	0	9	9
Total		50	150	200

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	56.720[a]	11	.000
Likelihood Ratio	59.172	11	.000
N of Valid Cases	200		

a. 12 cells (50.0%) have expected count less than 5. The minimum expected count is .25.

Table 4.16 Shows crosstabulation between bone fracture site and appearance of fracture in axial cut

Count

		Axial		Total
		NO	YES	
Bone	Base Of Skull	1	12	13
	Facial	10	47	57
	Facial+Base Of Skull	0	3	3
	Frontal	2	19	21
	Occipital	0	20	20
	Parietal	6	39	45
	Parietal+Frontal	0	2	2
	Parietal+Frontal+Facial	0	1	1
	Temporal	0	27	27
	Temporal+Frontal	0	1	1
	Temporal+Parietal	0	1	1
	Temporal+Parietal+Frontal	0	9	9
Total		19	181	200

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.827[a]	11	.377
Likelihood Ratio	17.040	11	.107
N of Valid Cases	200		

a. 16 cells (66.7%) have expected count less than 5. The minimum expected count is .10.

Table 4.17 Shows crosstabulation between bone fracture site and appearance of fracture in sagittal cut

Count

		Sagittal		Total
		NO	YES	
Bone	Base Of Skull	13	0	13
	Facial	10	47	57
	Facial+Base Of Skull	0	3	3
	Frontal	1	20	21
	Occipital	4	16	20
	Parietal	2	43	45
	Parietal+Frontal	0	2	2
	Parietal+Frontal+Facial	0	1	1
	Temporal	12	15	27
	Temporal+Frontal	0	1	1
	Temporal+Parietal	0	1	1
	Temporal+Parietal+Frontal	0	9	9
Total		42	158	200

Chi-Square Tests

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	73.564[a]	11	.000
Likelihood Ratio	71.124	11	.000
N of Valid Cases	200		

a. 14 cells (58.3%) have expected count less than 5. The minimum expected count is .21.

CHAPTER V

CHAPTER V

5. Discussion

This study in craniofacial fractures in different bone fractures sites and types, Facial fractures are common and generally **trauma** related, i.e. road traffic collisions, fights and falls. They are often associated with clinical features such as profuse bleeding, swelling, deformity and anaesthesia of the skin. The **nasal bones** are most frequently fractured, due to their prominent position at the bridge of the nose. (Singh J et al 2006) .According to results of this study most bone fracture seen in facial bone (57) (28.5%)parietal bone (45) (22.5%), temporal bone (27) (13.5%), and frontal bone (21) (10.5%), and occipital bone (20) (10%), base of skull (13) (6.5%), temporal+ parietal+ frontal (9) (4.5%), facial+base of skull (3) (1.5%), parietal+frontal (2) (1%), temporal+frontal (1) (0.5%), temporal+parietal (1) (0.5%), and parietal+frontal+facial (1) (0.5%). (**Table 4.3**), This result was consistent with **(Altobelli DE,et al ,1993)** which aimed to explain that CT is image of choice for suspected craniofacial fracture, and after they finished decided that analysis with MIPs is a useful addition to obligatory MPRs. and also consistent with **(fox la , et al ,1995)** aimed to explain the CT images of maxillofacial fractures All methods evaluated in this study showed high specificity and sensitivity for the diagnosis of orbital fractures according to the proposed methodology. This protocol can add valuable information to the diagnosis of fractures using the association of axial/MPR/3D with multislice CT. and also consistent with **(M.G.PCavalcanti,2004)** The purpose of this study was to demonstrate the sensitivity and specificity of multislice computed tomography (CT) for diagnosis of maxillofacial fractures following specific protocols using an independent workstation. And decided that the association of axial/MPR/3D images added important information in relationship to others CT protocols.

There are four major types of cranial fracture: Depressed A fracture of the bone with depression of the bone inwards. They occur as a result of a direct blow, causing skull indentation, with possible underlying brain injury. Linear the simple break in the bone, traversing its full thickness. They have radiating (stellate) fracture lines away from the point of impact.The most common type of cranial fracture. (Johannes Lang 1999). In (**Table 4.4)** shows fracture types distribution and we found that; for depressed fracture type (118) (59%) and for linear fracture (82) (41%). In (**Table 4.9**) shows relation between fractures types and appearance in 3DCT we found that in depressed fractures (118) and in linear fractures (52) *p* value (0.00) which mean there is significance relation between fracture types and appearance in 3DCT. And this result was consistent with **(Dos santos dt ,et al ,2004)** aimed to elaborate that CT imaging of complex maxillofacial fractures is common practice now it was concluded that CT and 3D are comparable in detecting midfacial fractures and both are superior to MPR. 3D reconstructions are superior for localization of complex fractures involving multiple planes. And also consistent with A study of Three-dimensional computed tomography of complex craniofacial fractures by (**Massoud, T.F.,1991**) This article presents a case involving complex craniofacial trauma, which illustrates the potential use and benefit of 3D-CT as a method of fracture assessment.

In (**Table 4.10**) shows relation between fractures types and appearance in axial cut we found that in depressed fractures (106) and in linear fractures (75) *p* value (0.69) which mean there is insignificance relation between fracture types and appearance in axial cut. This result inconsistent with **(Dos santos dt ,et al ,2004)** and (**Massoud, T.F.,1991**) .

On the interior of the skull, the petrous portion of each temporal bone forms the prominent, diagonally oriented petrous ridge in the floor of the cranial cavity. Located inside each petrous ridge are small cavities that house the structures of the middle and inner ears (**leon Schlossberg et al 1997**). In this study temporal bone fracture represents (27) (13.5%) (**Table 4.3**) no. of temporal bone fracture appeared in 3DCT was (26), in coronal (24), sagittal (15) with *p* value (0.00) that mean there is significant relation and in axial (27) with *p* value (0.37) that mean there is insignificant relation. This result consistent with A study of Value of high-resolution computed tomography in diagnosis of petrous bone fracture by (**TarumiYamakiM.D.,2004**) The findings indicate that high resolution CT is extremely useful for diagnosing petrous bone fracture.

3D models allow reconstruction of 2D images in various planes for improved viewing of anatomical or pathological features compared with original imaging planes (e.g. sagittal images from original axial slices). In essence, 3D CT has enhanced image analysis capability compared with conventional 2D radiographs. (**33Requicha JF, 2013**).in this study when evaluate between 3DCT and fracture types, 3DCT with coronal and 3DCTwith sagittal the result was significant with *p* value (0.00). This result was consistent with A study of Application of three-dimensional computed tomography in craniofacial clinical practice and research by (**PJ Anderson,2014**)

CHAPTER VII

CHAPTER VI

6. Conclusion and Recommendations

6.1 Conclusion

This Study conclude that the visible fractures under 3D images was facial bone (50), parietal bone (38), temporal bone (26) and then frontal bone (21), with *p* value (0.00) which mean there is significance relation.

The study showed that fracture type which is better seen in 3D images in traumatic patients was depressed fracture appeared in 3DCT (118) (100%), linear fracture appeared in 3DCT (52) (63.4%) with *p* value (0.00) that mean there is significance relation. also In evaluation the difference between fracture type and axial plane in traumatic patients was found that depressed fracture appeared in axial plane (106) (89.8%), linear fracture appeared in axial plane (75) (91.4%) with *p* value (0.448) that mean there is insignificance relation.

In evaluation between axial plane and 3DCT we found that there was (155) (85.6%) craniofacial fractures appeared in both with *p* value (0.312) that mean there is insignificance relation, but in sagittal and coronal cut there was (147) (93%) with *p* value (0.00) and (142)(94.6%) with *p* value (0.00) respectively that mean there was significance relation.

Based on results of this study and previous studies, we conclude that 3D reconstruction may offer a problem solving option, 3D imaging can provide useful information to both radiologist and surgeon in cases of severe facial trauma.

The study concluded the study of craniofacial fracture, multiplannar reconstrction and 3D increase the effectiveness of visibility and extend of cranifacial fractures.

In evaluation the difference between MPR and 3D images to determining fractures in traumatic patients we found that most depressed fracture appeared in MPR will be clearly appeared in 3DCT, but linear fracture depend on MPR appearance.

In comparison between axial cut in MPR and 3DCT we found that there was insignificance relation.

In comparison between sagittal and coronal cut in MPR and 3DCT we found that there was significance relation.

In comparison between bone and axial cut in MPR we found that was insignificance relation.

In comparison between bone and sagittal,coronal cut in MPR and 3DCT we found that was significance relation.

6.2 Recommendations

3DCT should be added as a routine imaging for head injury patients.

In future studies researcher should use larger sample size for better evaluation.

Specification of type of fracture will be better for easy evaluation.

Specification of bone under study will ease up findings and data acquisition.

APPENDIX

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