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Ground Truth Annotation, Analysis and Release of Data set of Radiographic Images of Bone Fractures

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Abstract- **Bone is the tough, locomotive tissue of the body which is subjected to fractures very often. Advancements in Computer Aided Diagnosis (CAD) have leaded the researchers to develop robust algorithms to reduce human error in assessing different types of pathologies. This paper focuses on the data set release of the plain radiographic images of bone fractures which include both "Ground Truth Annotated" and "Non-Annotated Images". The data was collected from the Radiology Department of Pakistan Institute of Medical Sciences, Islamabad, Pakistan in the form of digital images which were 8,345 in number, out of them 735 images were of bone fracture. The bone fractures were annotated manually to provide "truth" for the spatial location of bone fracture. The type of bone affected, area affected of the bone fractured, type of fracture, potential laterality of the affected bone and x-ray projection had also been identified and reported in the form of a data sheet. These features are expected to help training classifiers for CAD analysis of bone fractures. Frequency analysis of essential features had been performed to accentuate the data. The data set will provide grounds for the research community to manipulate for various CAD operations which may include estimation of precision of the developed CAD operators.**

Index Terms-- **Bone, Fracture, Ground truth, Annotation, CAD.**

I. INTRODUCTION

The human bone is tough, resilient and high stress and strain bearing anatomical structure, which provides site for articulation for various other bones to form movable and immovable joints. Bones also serves as the site for attachment of skeletal muscles. The normal adult human skeleton contains 206 bones [1-2]. The typical long bone is grossly divided into three regions; the epiphysis, which is the broad joint forming part of the bone (proximal and distal), the metaphysis, which is the narrow growth plate containing part of the bone and the diaphysis or the shaft of the bone. Short bones usually do not contain these parts specifically [3].

Bone is a dense connective tissue which is derived embryologically from mesoderm [4]. It is made up of an outer tough and hard cortical and inner soft and spongy medullary portion. It is composed of an outer periosteum and inner highly vascularized endosteum. The periosteum is further composed of fibrous and cellular layers. The endosteum lines the medullary cavity of the bone. The medullary cavity is composed of bone marrow and matrix made up of mainly hydroxyapatite, calcium carbonate and collagen fibers. It is the bone marrow where the synthesis and maturation of red and white blood cells take place [3].

At the articulation site (epiphysis), the typical bone is line with articular cartilage to provide friction free movement at the joint. The bones are held together in place by ligaments. The muscles are attached to the bone by tendons. Together this assembly provides mobility at the joint [5].

The bone serves as the locomotor, blood cell synthesizing house and protector for visceral organs by forming skeleton [3]. The medical condition which leads to loss of continuity in the bone is termed as a fracture. Certain bone fractures are treated as a medical emergency. Fracture can be traumatic, pathological and peri-prosthetic. Fracture results in disruption of periosteum or both periosteum and endosteum, the peri-fracture tissue edema, skin erythema and intense pain [6].

The major types of fractures are: *Closed Fracture:* The closed fracture is the type of fracture that does not lead to the fracture ends breaching the skin barrier. The fracture ends remain inside the body. *Open Fracture:* The open fracture is the type of fracture which causes one of the fracture ends to breach the skin barrier and become in contact with the body's external environment [6].

A bone fracture can also be classified on the basis of; mechanism of fracture, surrounding soft tissue involvement, extent of displacement of fracture ends, presence and amount of fragments, anatomical location and bone affected. There are several bone fracture classification mechanisms which include alphanumeric AO/OTA classification system for long bone fractures, Denis classification system for spinal injuries, Gustilo's classification system for open fractures [7], Allman's classification system for clavicular fractures [8] and classification of scapular [9].

The bone fractures can be detected clinically. The pathological fractures can be provisionally diagnosed by evaluating the patient's history, which may include osteoporosis, arthritis, bone tumors or osteogenesis imperfecta. There will be peri-fracture soft tissue swelling, erythema, and severe pain at the fracture site. The traumatic fractures can also be detected clinically in the same way. The history in the case of traumatic fractures may include fall, road side or vehicle accident. The peri-prosthetic fractures are caused by either Varus alignment of the implant or bone resorption as the result of inflammation at the implant site. The Varus alignment of implant results in fracture of the lateral aspect of the bone. The history of the patient is also very useful in formulating provisional diagnosis of the peri-prosthetic fracture [10]. The clinical evaluation is only helpful in making the provisional diagnosis of the fracture and does not give the absolute clue about the fracture. That is why some more advanced technique in fracture detection is required.

Radiology is the branch of medicine and physics which uses electromagnetic radiations to aid diagnosis for various pathologies which cannot be visualized otherwise.

Plain radiography is the primary diagnostic technique for bone fractures. It is most widely used technique in emergency and traumatic conditions. It has very high diagnostic accuracy for bone fractures. Computed tomography is shows very high sensitivity and specificity for subtle or occult fractures of cranium and short bones. Magnetic Resonance Imaging is found to be very accurate for detecting stress fractures of lower limb.

Despite of high contrast and spatial resolution of CT and MRI, conventional radiography is always a primary means of diagnosis of bone fractures in hospital settings because of certain advantages in terms of time required and expertise for diagnosis relatively apparent bone fractures [3-6].

Plain radiography, since the long time, uses screen film combination as the image detector. This conventional radiography method uses phosphor screens to convert x rays to light. This light is detected by the silver halide crystal containing radiographic films sandwiched between the screens inside the cassette. The latent image is formed on the radiographic film which is then processed in a darkroom which takes about one hour. The developed image is the readable image [5-9].

There is no film in the digital radiography, rather the image receptor is a cassette which is contains selenium, cesium iodide or gadolinium oxysulfide as a phosphor instead of screen. X rays are converted into light by detectors, converted to digital signal, subjected then to thin film detectors or CCDs which lead to the prompt formation of an image. The image does not need any developing chemistry. The conventional or plain radiographic image, once projected, cannot be altered in size, shape, contrast or saturation. The digital radiographs have an edge over conventional radiographs in this regard. The spatial resolution of conventional plain radiography is much better than the digital radiography [6-7].

The images of computed tomography, magnetic resonance imaging and ultrasound are always acquired in the digital format.

Image Processing refers to using various mathematical operations (algorithms) to extract desired information specifically and to manipulate the image generally, by altering its various parameters. The image processing techniques are usually applied on digital images but they can also be applied to analogue images. There are many tools available over the worldwide web for digital image processing. Some of them are listed as: Analyze, ANIMAL, Mango, MATLAB, OpenCV, and Openlab.

II. LITERATURE REVIEW

Most of the image data sets released in radiology are of CT scans and MRI. A 3D volume rendered CT image data set was released by Phillip *et al.* in 2002, featuring bone fractures. The 3D rendering of CT images allow better visualization of bone fractures specially the complex ones [11].

Another dataset of lung nodules was released under the banner of Lung Image Database Consortium by Armato Iii *et al.* in 2004. Six point criteria were introduced to set the inclusion and exclusion criteria for the release of dataset. The artifactual images were also catered to provide a comprehensive data resource to the medical research community [12].

An annotated dataset of lung nodules containing 157 CT images was released by Dolejsi*et al.* in 2009. The data was released in DICOM format and was annotated in XML format. Small nodules were marked by a point and voxels were marked for large nodules. Scanning parameters were also saved in each DICOM file as metadata [13].

A dataset containing cross-sectional high contrast to noise ratio MR images of young, middle age, older demented and non-demented adults was released by Marcus *et al.* in 2007which was composed of images from 416 different subjects. The brain volume was also calculated automatically and the effects of age and Alzheimer's were also reported. Similar study was conducted by releasing Longitudinal MR images of older adults in 2010 [14].

Certain annotated data sets of radiology are also available online such as; http://langlotzlab.stanford.edu/imaging-datasets/, http://www.radrounds.com/profiles/blogs/list-of-open-access-medical-imaging-datasets

None of the data has been found on the release of annotated plain radiographic images for bone fractures till now, up to the best of our knowledge.

III. MATERIALS AND METHODS

The identification of "truth" is very important for digital image analysis and computer aided diagnosis. The work presented in this paper focuses on the identification of the spatial location of the bone fractures. Several other factors are also important to identify, in order to support or accentuate the truth. Those factors include; the bone fractured, the area of the bone fractured, the type of fracture, the size of the fracture, orientation of radiograph and laterality of the affected bone.

Every bone has its unique radiographic anatomy which isolates it from other bones in terms of physical appearance, spatial location, distinctive features, size and articulations.

A typical bone is divided into three parts; proximal, diaphyseal and distal. These parts of a bone have distinctive shapes, sizes and articular facets, different types of fractures along with different dislocation patterns.

As described earlier there are multiple types of fractures. Each fracture has its own properties in terms of fragments, location, size and orientation, which distinguish it from other types.

Right and left bones are symmetrically located. This embryological alignment of bones does not allow the right and left counterparts to be interpreted interchangeably.

The radiographs for bone fractures must be taken into two orthogonal planes; Anteroposterior and Lateral typically. The bone appears differently in both of these planes. The fracture may be visible in one while obscure in another one.

Each of the features mentioned above can strengthen the imbecile CAD systems and can help in training classifiers for automated bone fracture detection.

This study was conducted retrospectively. Digital plain radiographs from September 2016 to June 2017 were collected from the Department of Radiology, Pakistan Institute of Medical Sciences (PIMS), Islamabad. A written approval was granted from the Head of the Department. A total of 8,345 images were obtained of which 735 images contained bone fractures. Since no record of a report was digitally available for these radiographs, presence of a fracture (and selection of a radiograph) was verified by two independent individuals.

Images containing bone fractures were included in the study regardless of the presence of an artifact. However, Images deficient in patient information, imaging parameters and collateral orthogonal scans were not excluded either.

Images containing subtle fractures, which may be misdiagnosed due to absence of clinical correlation, of craniofacial bones, tarsals and carpals were not included in this study.

The data was available in DICOM format which was viewed using MicroDICOM viewer. The patient's data was embedded on the image and DICOM Viewer was unable to remove it. The DICOM image was then converted into JPEG through the inbuilt JPEG converter. In order to maintain patient privacy, the JPEG images were then cropped to remove patient information. The images were then randomly assigned numbers as the file name. To demarcate the fracture, it was annotated by manually drawing a red square around it. Both the annotated and non-annotated JPEG bone fracture radiographs are placed in the dataset for identification of truth and CAD analysis respectively. These labeled/annotated images along with their non-annotated counterparts were placed into respective folders shown in Fig. 1.

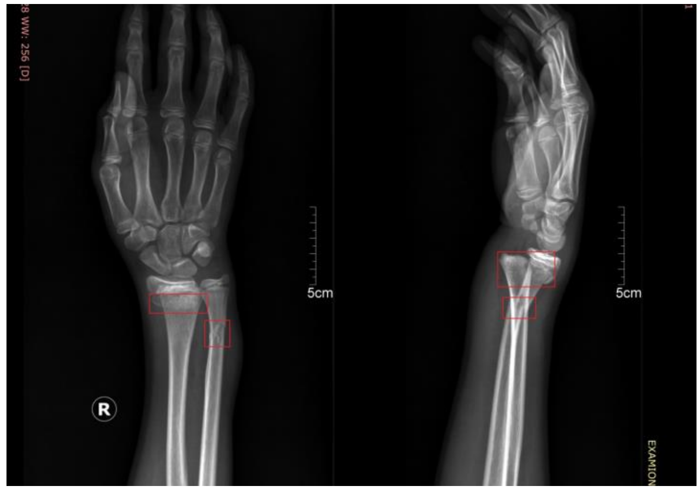

FIGURE 1. An Annotated Fracture of Distal Radius and Ulna of Right Forearm.

IV. RESULTS

Digital images of plain radiographs were collected from PIMS. The images containing bone fractures were separated and were annotated and an data file was created containing several labels including; Type of fracture, anatomical location of the fracture, bone affected, area of the bone affected, potential laterality of the affected bone, size of fracture, gender, age, presence of artifact and presence of implant/ prosthesis.

Transverse fractures were found to be most common types of fractures (34.04%), followed by comminuted fractures (17.36%). Diaphysis of a bone was found to be the most commonly affected area of the bone (53.03%). There were 90.14% of the images without any artifact while 71.69% images without any prosthetic implant. As there are significant images without the presence of any sort of artifact or implant, majority of the images are feasible for CAD operations. Further statistical analysis is not applicable because of the limited approach of the research paper.

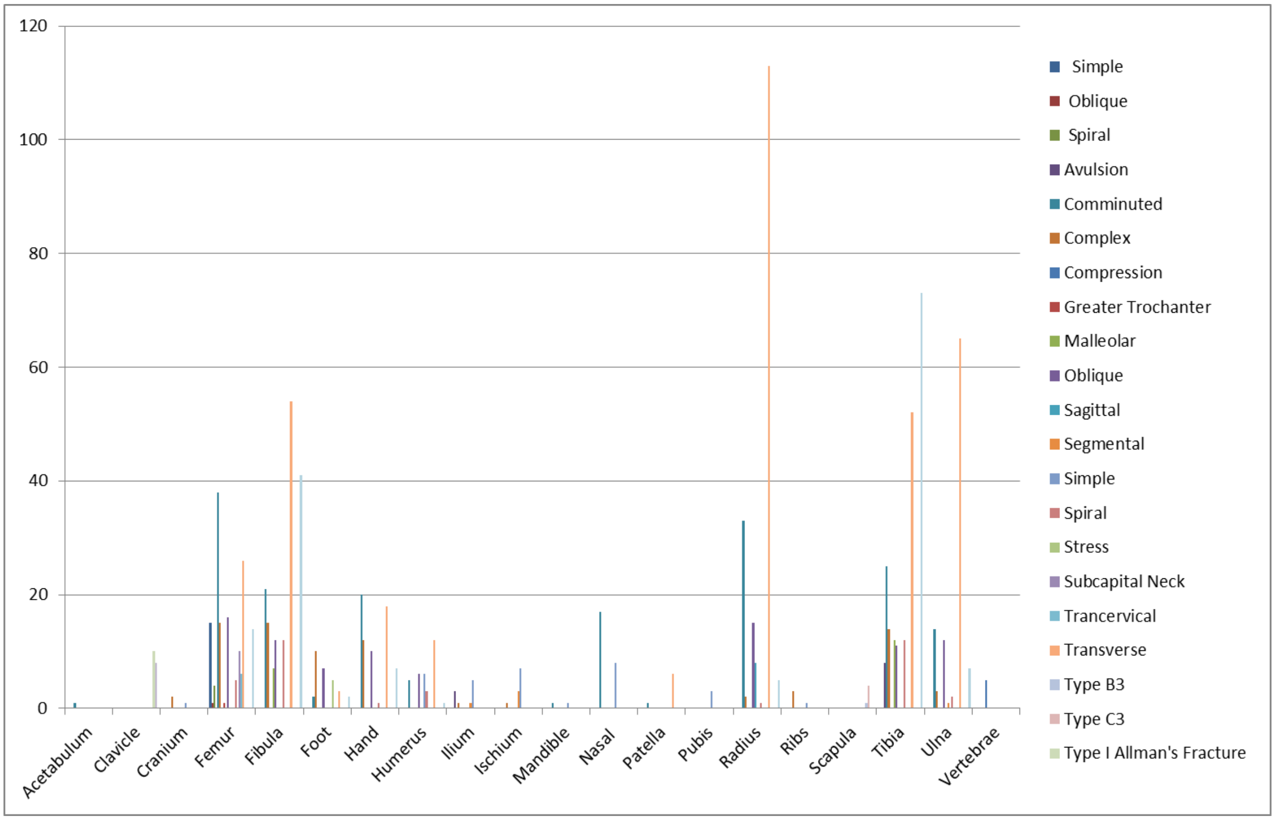

FIGURE 2. Frequency of Type of Fractures vs Affected Bone.

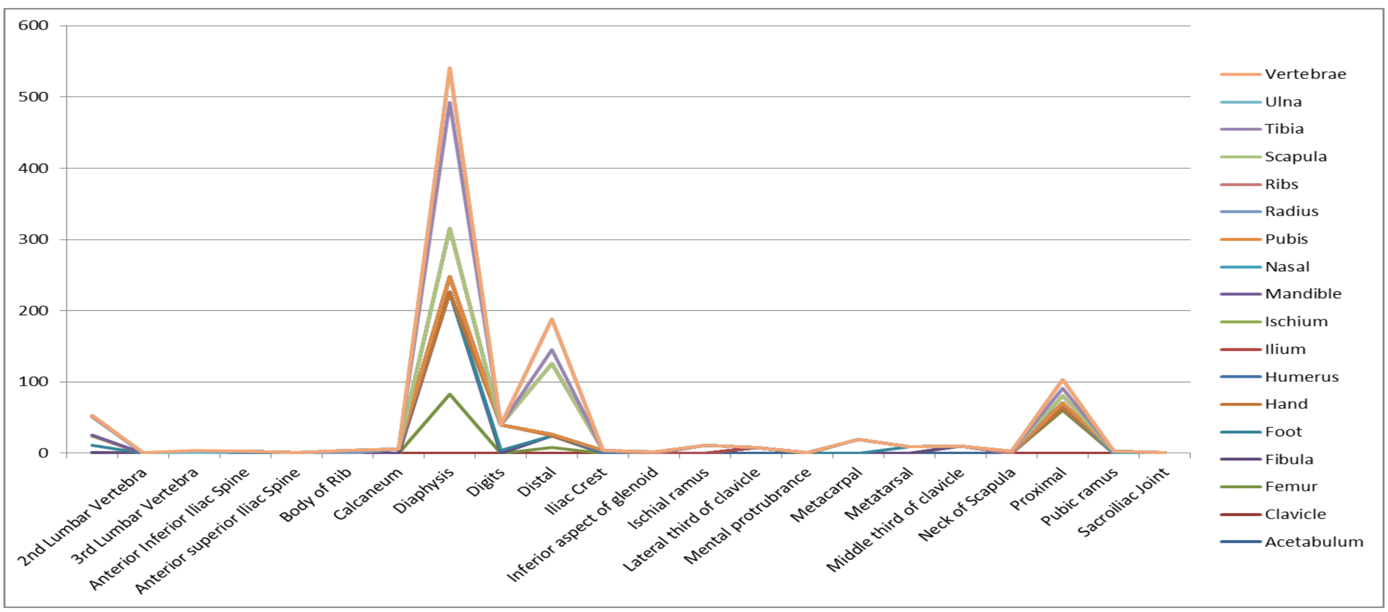

FIGURE 3. Frequency of Affected bone vs Affected Area of Bone

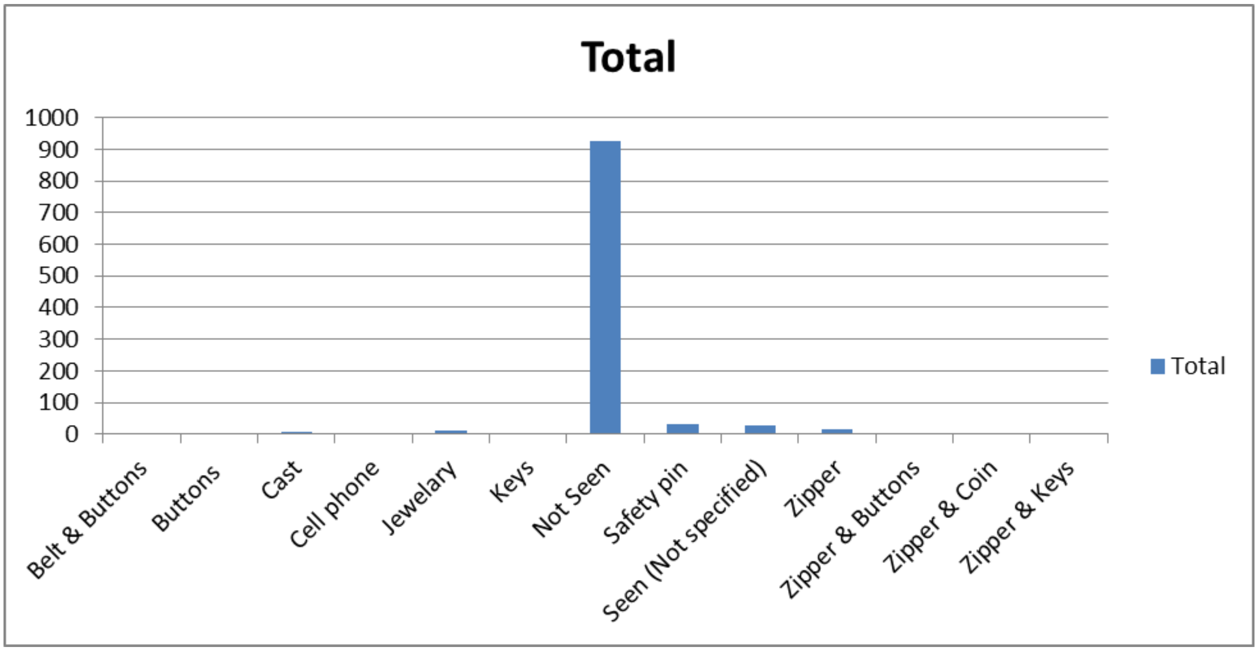

FIGURE 4. Frequency of Type of Artifacts found in radiographic Images

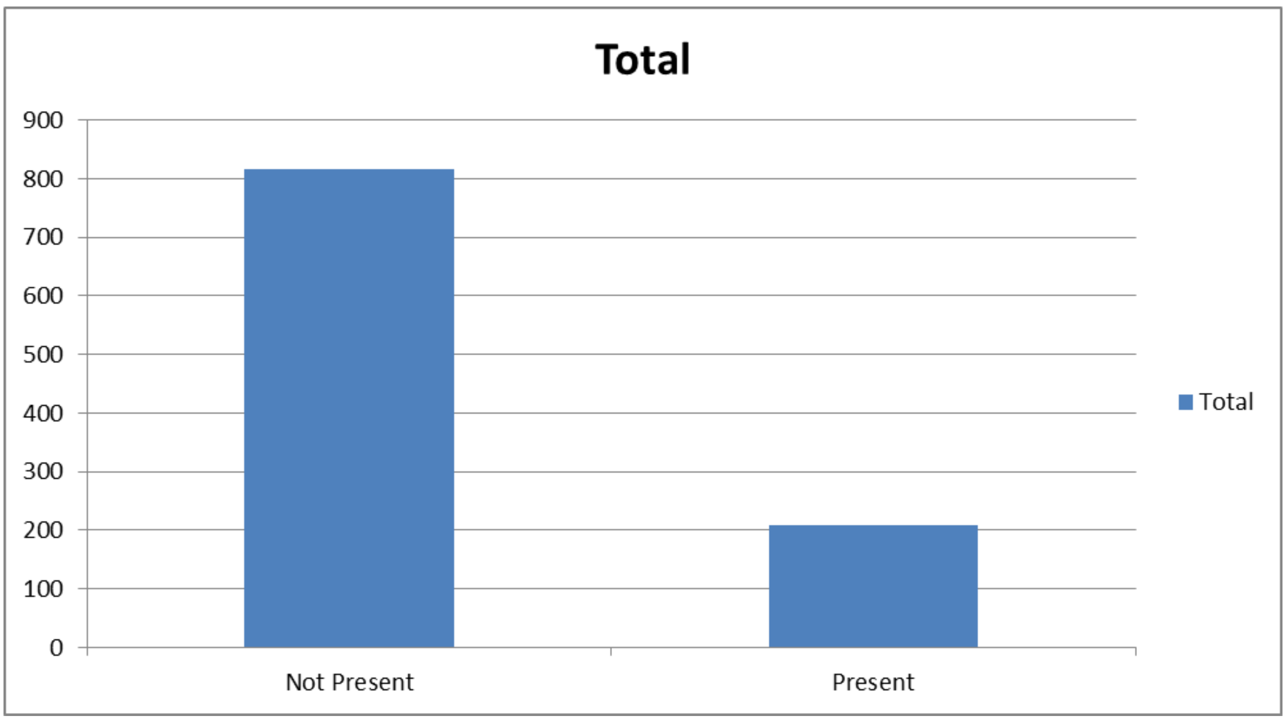

FIGURE 5. Frequency of Presence and Absence of Prosthetic Implant in Radiographic Images

V. DISCUSSIONS

The digital images were retrospectively acquired from Radiology Department of PIMS after the written consent of HOD Radiology. The collected images were then sorted out on the basis of presence of fractures. The DICOM images were then converted into JPEG, cropped to remove patient details, which was not possible otherwise and then were orientated properly. The images were renamed numerically randomly and then were placed into their respective folders, classified on the basis of bone type. Each of 735 images was then annotated manually to specify the fracture. The annotation indicates the “truth”, which is the baseline for CAD analysis of digital images. Type of fracture, anatomical location of the fracture, bone affected, area of the bone affected, potential laterality of the affected bone, size of fracture, gender, age, presence of artifact and presence of implant/ prosthesis were explicitly mentioned in the data sheet created.

PIMS is one of busiest public sector hospitals in Pakistan. The department of radiology is equipped with the radiographic systems of Shimadzu and Toshiba, installed in two X Ray rooms. DR system has been purchased from Colenta which has inbuilt features of teleradiology and digital reporting. The problem arises when the quality of image is taken into consideration. The patient has not been positioned properly for most of the orthogonal scans either for screening or diagnostic purposes.

As mentioned earlier, the images were acquired in DICOM format and are not possible to be released as they contain embedded details of the patients which were irremovable. There were some of the images which did not specify the age, gender and proper imaging factors (kVp and mAs) of the scan. These factors were not possible to identify, even to best guess. Position markers indicating right and left side of the patient were also not present in some of the images. The potential laterality of each image was identified on the basis of best of knowledge of radiologist and author.

The important features to be identified manually, from the perspective CAD are the bone fractured, the area of the bone fractured, the type and size of the fracture and laterality of the affected bone. Each of these are features are expected to play an important role in training classifiers and machine learning in digital medical image analysis. Simulation results are shown in Fig. 2-5. The data can be accessed openly after peer review at the open access data base of National University of Sciences and Technology, Islamabad.

VI. CONCLUSION

JPEG images of bone fractures have been annotated to provide ground truth. Several data sets of medical images have been available online, no data set has been found for bone fractures up to best of our knowledge. The broadness of the subject restricts to analyze fine details during statistical analysis which could be taken into account individually in the future. The data set release along with the feature identification done in this study will prove a major contribution to the research community in the field of Medicine and Artificial intelligence to work upon CAD based diagnoses of digital medical images.

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