X-RAY IMAGE PROCESSING ON BONE FRACTURE, HEALING AND CURE ANALYSIS USING MATLAB

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ABSTRACT

Image Processing based computerized expert system has been developed in the context of fracture treatment of patient. The tibia fracture has been taken into account for various possibilities of the cure analysis. Callus formation along with the Patient tenderness jointly signifies the treatment. The concept of fuzzification between the callus formation between fragment of broken bones and other parameters of patient clinical status have been considered for decision making system. The Callus Formation is identified by edge blurriness and gap filling between cortical gaps of bones. Intensity change has been quantified by portion of normal and broken bone in order to find the healing .Various treatment methods to fracture have been depicted by patient's stiffness, pain, movement and deformity along with the callus intensity change creating fuzzy logic.

Keywords—Artificial intelligence; Biomedical Image Analysis; Decision making

INTRODUCTION

Bones are the Part of our body which gives strength to our body and gives resistance to shock and vibration encountered in critical situations [6]. When the force exerted on the bone is critical limit then bone fracture is done. Bone fracture is the break of bone due to the excessive loading condition. Bone is having some specific density such that it can be seen as whitish component pixels in x-ray and the structure of the bone is analyzed for specific purpose. Various application of analysis of the x-ray of the bone is osteoporosis, bone fracture, etc.[9].

Bones are depicted by the x ray image as a high intensity level and they are differed by the following background on which object is located. The region of interest is to isolate the bone from the background by the edges outside bone should not be taken into consideration [3]. So far as the human body is concerned the bone is encapsulated into muscles. The edge of the bone is indicated by the gradient of the image where the intensity level of pixels undergone through the change.

Many techniques to image feature extraction are based on edges, because analysis carried out through edge detection is insensitive to overall deviation in intensity level [5]. Edge detection highlights image contrast. Contrast detection which is difference in intensity can depict the boundaries of objects within an image as this is where image contrast exists. Human vision can feel the perimeter of an object because the object is of different intensity to its surroundings. Essentially, the boundary of an object is a step change in the intensity levels. The edge is at the position of the step change. To detect the edge position we can use first order differentiation, since this emphasizes change; first order differentiation gives no response when applied to signals that do not change.

Bone healing is the part of recovery of the fracture which takes some amount of type which is based on type of trauma, crack intensity, patient’s age, sex and plenty of factors[7]. But the thing used to detect the recovery is common which is done through callus formation between two fragments. Callus can be considered as a kind of object in respect of image processing which is formatted through initial immobilization of bone and bone tissue formation after rehabilitation.

Bone healing can be detected by haziness of crack and gap filling by callus formation[12]. Haziness in crack is having problematic measure so that the gap filling may be good aspect of identifying the bone healing bone callus can be made confined by edges so as to effective depiction of healing of bone.

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Fracture Healing:
A broken bone is called a fracture. In order for a fracture to heal, the bones must be held in the correct position and protected. Soon after a fracture occurs, the body acts to protect the injured area, and forms a protective blood clot and callus around the fracture. New threads of bone cells start to grow on both sides of the fracture line. These threads grow toward each other. The fracture closes and the callus is absorbed. Depending upon the type of fracture, this healing process may take up to a year.

Soft Callus: Pre formation of hard callus which is created within one to two weeks of the fracture treatment. It cannot be shown in x ray but it can be shown in ultrasound.

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Hard Callus: Rehabilitation in bone after tissue get reconnected. It can be seen in x ray. It is done after formation of soft callus.

Sometimes wrong alignment in fracture treatment can cause serious problems like inability to move the body parts and some gripping problems can occur. Healing can be measured by the callus formation within the crack.

Bone Healing:

Bone healing is divided into two parts [g]:

1. Primary Bone Healing
2. Secondary Bone Healing

Former one is also known as direct or cortical healing and later one is known as indirect or spontaneous healing. Both of these are very complex processes that involve the coordination of a sequence of many biological events. Both of these are very complex processes that involve the coordination of a sequence of many biological events.

Primary Bone Healing:

Primary bone healing needs rigid stabilization with or without compression of the bone fragments.

Gap Healing

There are two stages of Gap healing,

I. Initial bone filling

II. Bone remodeling.

In the first stage of gap healing, the width of the gap is filled by direct bone formation. An initial scaffold of woven bone is laid down, followed by formation of parallel-fibered and/or lamellar bone as support [28, 29].

Contact Healing

In contrast to gap healing, contact healing occurs where fragments are in direct apposition and osteons actually are able to grow across the fracture site, parallel to the long axis of the bone, without being preceded by the process of transverse bone formation between fracture ends [27-30]. Under these conditions, osteoclasts on one side of the fracture undergo a tunneling resorptive response, forming cutting cones that cross the fracture line. This resorptive cavity that develops allows the penetration of capillary loops and eventually the establishment of new haversian systems. These blood vessels are then accompanied by endothelial cells and osteoprogenitor cells for osteoblasts leading to the production of osteons across the fracture line [21]. The result of normal contact healing will also eventually lead to regeneration of the normal bone architecture.

The biology of bone fracture repair is a very complex process that leads to the regeneration of normal bone architecture. Primary bone healing occurs when there is rigid stabilization of the fracture site and the fracture callus is inhibited. Gap healing and contact healing are both considered to be primary bone healing processes. Secondary bone healing occurs when there is no rigid fixation of the fractured bone ends, which leads to the development of a fracture callus. This process is a little more complicated and consists of an inflammatory phase, a reparative phase, and a remodeling phase. Normal fracture repair is orchestrated through the expression of many different genes, which are turned on and off at very specific times throughout healing.

Secondary Bone Healing

Secondary fracture healing which is the most common method is characterized by spontaneous fracture healing in the absence of rigid fixation of the fracture site. The complete process has been depicted as having three to five phases [9, 15]. The biology of bone fracture repair is an organized pattern for repair and perhaps is best elucidated when viewed in histological sections [9, 16]. Fracture repair can be easily divided into three phases, each characterized by the presence of different cellular features and extracellular matrix components. The stages of healing are depicted below [9, 17].

I. Inflammatory phase

II. Reparative phase

III. Remodeling phase

It is important to note that these three phases overlap one another and in effect form a continuous healing process.

Inflammatory Phase:

An injury that fractures bone damages not only the cells, blood vessels, and bone matrix but also the surrounding soft tissues including muscles and nerves [18]. Immediately following the injury, an inflammatory response is elicited, which peaks in 48 h and disappears almost completely by 1 wk. post fracture. This inflammatory reaction helps to immobilize the fracture in two ways: pain causes the individual inflammatory phase to protect the injury and swelling hydrostatically keeps the fracture from moving [10]. Recent evidence also suggests that the hematoma serves as a source of signaling molecules that initiate cellular events essential to fracture healing. This whole process creates a reparative granuloma and is referred to as an external callus [17].

Reparative Phase:

The reparative phase occurs within the first few days, before the inflammatory phase subsides, and lasts for several weeks. The result of this phase will be the development of a reparative callus tissue in and around the fracture site, which will eventually be replaced by bone. The role of the callus is to enhance mechanical stability of the site by supporting it laterally. Osteocytes located at the fracture ends become deficient in nutrients and die, which is observed by the presence of empty lacunae extending for some

Remodeling Phase:

The remodeling phase is the final phase in fracture healing and begins with the replacement of woven distance away from the fracture [12].bone by lamellar bone and the resorption of excess callus [18,20]. Although this phase represents the normal remodeling activity of bone, it may be accelerated in the fracture site for several years [26]. Remodeling of fracture repair after all woven bone is replaced consists of osteoclastic resorption of poorly located trabeculae and formation of new bone along lines of stress [27]. The result of the remodeling phase is a gradual modification of the fracture region under the influence of mechanical loads until optimal stability is achieved, where the bone cortex is typically similar to the architecture it had before the fracture occurred [10].

PROCEDURE FOR BONE FRACTURE TREATMENT

Below is the generalized procedure for the bone fracture treatment adapted by the modern orthopedic surgeons. The treatment is based on decision making by radiology and other generalized treatment

A. *Manual by the doctor*

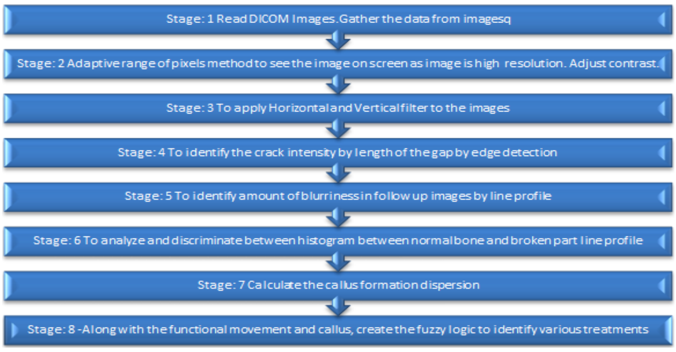
1. Initially Doctor examines the trauma and decides the particular location for treatment
2. Radiological Imaging techniques like X-ray to be used for bone displacement
3. Immobilize the bone by casting
4. Followed up within one month by the radiological imaging technique
5. Discriminates between the bone fragments and normal bone by comparing the gap filling
6. Checkup clinical parameters like patient's pain, movement, deformity, tenderness
7. Based on the above two steps they apply their logical decision based on the generalized treatment procedure.

Following is the treatment method proposed by the computerized automatic guided procedure for bone fracture treatment.

B. *Generalised treatment based on computerised decision making*

- Load the Image
- Preprocessing the Image :
  - Filtering the Image
  - Identify the defect
- Post processing with Image :
  - Quantify the amount of blurriness in defect
  - Along with the functional movement create fuzzy logic to cure analysis

GUI based on above methodology is implemented through below described procedure:



SIMULATION RESULTS FOR GUI

Here the results of various image processing tasks are shown which is inhibited by GUI.

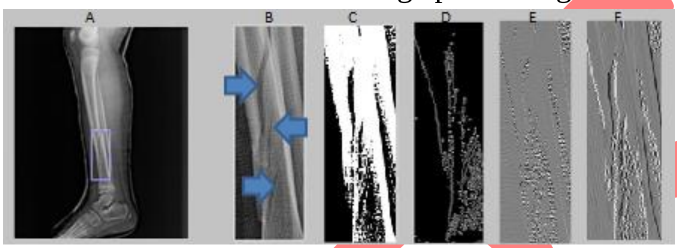
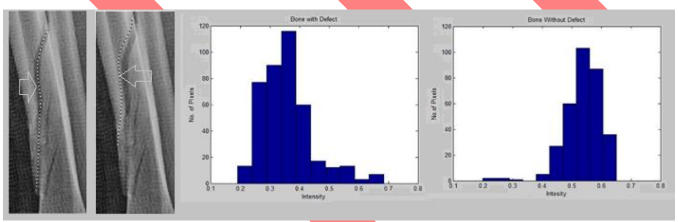


Figure A depicts the source image and Figure B is showing the number of cracks which can be manipulated by thresholding in Figure C , edge detection in Figure D and through horizontal and vertical filter respectively in Figure E and F.

Intensity dispersion and calculation of healing through radiological is depicted by following way



The left portion of above figure contains maximum pixels in the range of (0.25) to (0.45) intensity while the right portion of figure is having maximum pixels in the range of (0.45) to (0.65). The process of quantifying callus is done by mean of intensity dispersion of left portion by mean of intensity dispersion of right portion.

Calculation of Mean Intensity:

Broken bone line; Mean [zdata] = 0.3524

Normal Bone line; Mean [zdata1] = 0.5597

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Mean ratio = 0.3524/0.5597 = 0.6295

For the same procedure to be followed, three cracks have been quantified in terms of their intensity variation and their mean ratio is 0.7329 and 0.6337 respectively. The average of them is 0.6654. Total percentage healing in radiological point of view is 66.54 %.

Creating Fuzzy logic for automatic guided treatment procedure:

Fracture healing is not evaluated as far as only radiograph is concerned but also there are some clinical parameters that are well enough to prescribe the next suggestion to patients [6]. The fuzzy wise logic has been depicted below in order to depict the type of the treatment that patient has to undergo through. Various parameters include patient's pain, deformity, tenderness and motion. There are other factors also that help to make decision which treatment to be prescribed to patient, it includes patient's sex, age, type of injury, location of body etc. which is helpful to compare whether the generalized rule has been deployed in fuzzy tool which have been depicted above. Generally adult people have less tendency to heal fracture in less time compared to the small children this is due to the initial osteoblasts and other cell regeneration in early stages of their rehabilitation. The input to the callus is from the analyzed post fracture image after 4-6 weeks in which callus intensity change is quantified. It is divided into low [up to 25-30 %], medium [up to 50-65 %] and high [more than 65%] he pain, deformity, motion and tenderness have been quantified into none, low, medium and high in linguistic terms as it is input by the physician or clinical person. It is manually input by the user. Output is divided into four groups which comprises cast inhibition, cast reformation only in the case of injury where bone has been healing in wrong way as it is suggested by deformity, complete cast removal and splints or other intermediate treatment where half or more healing is done. Mf3: Remodeling Stage: - The patient should be given instructed to move freely with certain amount of weight bearing, some physiotherapy exercises to be prescribed in order to reduce stiffness of joints if needed.

Fuzzy rules have been depicted so far as generalized treatment of healing fracture is concerned. [IV]

Callus	Pain	Movement	Stiffness	Deformity	Treat-Out
Mf1	Mf3	Mf1	Mf1	Mf1	Mf1
Mf3	Mf1	MF2	Mf2	Mf1	Mf2
Mf3	Mf1	Mf3	Mf3	Mf1	Mf3
Mf3	Mf2	Mf3	Mf1	Mf1	Mf1
Mf3	Mf1	Mf2	Mf3	Mf1	Mf3
Mf3	Mf2	Mf1	Mf2	Mf1	Mf2
Mf3	Mf3	Mf1	Mf1	Mf1	Mf2
Mf1	Mf2	Mf2	Mf2	Mf1	Mf1
Mf2	Mf2	Mf2	Mf2	Mf1	Mf2
Mf2	Mf3	Mf1	Mf1	Mf1	Mf1
Mf2	Mf2	Mf1	Mf2	Mf1	Mf2
Mf2	Mf1	Mf3	Mf1	Mf1	Mf2
Mf1	Mf3	Mf2	Mf1	Mf1	Mf1

Table 1 : Fuzzy logic relation

So far as deformity is concerned the factors that will be affected by the callus formation and pain involved in movement of the bone, because stiffness seems fine sometimes but movements are restricted due to the wrong directional callus formation. Fuzzy rules have been depicted so far as generalized treatment of healing fracture is concerned. [g]

These fuzzy rules can be deployed into the graphical user interface.

Treatment output: The patient should be given normal movement of leg with some angular constraints in order to make callus formation comparatively faster than normal cast steadiness.

CONCLUSION

Callus is identified by the intensity blurring but the amount of healing has to be done with comparing normal bone intensity as well as patient's tenderness, pain, deformity. Callus formation is quantified by comparing normal bone intensity and broke bone intensity line profile. Fuzzy relations amongst clinical parameter have been established. The Treatment analysis provided possibility of the type of treatment the patient has to undergone through. Fuzzy logic based expert system make assistance in decision making of treatment prescribing.

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