

A Review Paper on Bone Fractures and Its Biomechanics

Payal M. Deoghare*

Department of Forensic Science, Lovely professional University, Punjab, India.

ABSTRACT

Bone is hard tissue of living organism. It has anisotropic properties due to which it shows different results at different areas when load is applied on it. Mechanical properties which are mainly considered during testing of biomechanics of bone trauma are stress, strain, shear strain, stiffness, force, displacement and deformation in it. Various tests are performed on the cortical and trabecular bone to examine the biomechanics. Antemortem, perimortem and postmortem fracture can be distinguished based on the changes in bone and the changes in appearance of fractures.

Keywords: Biomechanics; Antemortem; Perimortem; Postmortem; Bone mineral density; Bone fragility; Bone fracture

INTRODUCTION

Bone is the hard tissue of living organism. It is composed of both organic and inorganic components due to which it shows differences in mechanical properties which help in examination of biomechanics of bone trauma. Factors considered for biomechanics can be external or internal factors. Force, magnitude of load and displacement are considered as external factors whereas geometry, stiffness, bone mineral density, etc. are considered under internal factors. Certain experiments were conducted on mandible, cortical and trabecular bone of the body. Cubic shape of bone is mostly sectioned for experimental purpose. [1] Two types of loading mechanism is performed in the test such as cyclical loading and constant loading. Mostly constant loading is preferred in which load is increased until the bone breaks. Main principle of fracture is increase of strain on bone exceeds force or in other terms fracture occurs when the capacity of the bone to absorb energy exceeds [2].

Further, for forensic analysis, it is necessary to differentiate between antemortem, perimortem and postmortem fractures. Antemortem fracture is induced prior to death, perimortem fracture is induced near or round the time of death and postmortem fracture is induced after death. Thus, differences can be observed on the basis of color change, fracture edges and fracture angle [3]. Also changes in the bone structure can be used to distinguish antemortem fracture. But, sometimes it becomes difficult to distinguish between perimortem and postmortem fractures because of external factors such as physical weathering, chemical weathering, soil acidity, exposure to sun, presence of other microorganism around the bone, etc.

Literature Review

Wescott in his research discusses about the application of biomechanics in bone trauma. Biomechanics is the application of laws of mechanics to the biological tissue. Trauma is an action which causes injury or shock to a living tissue which can be due to any accident or violence. Biomechanics of bone trauma includes examination in both the terms external as well as internal. Internal examination includes materialistic properties such as elasticity, stiffness and density whereas external examination involves time, direction of force, and magnitude of force. These factors result into injury of bone [4]. Bone injuries involve breakage or fracture or dislocation of joint. Fracture mechanisms are classified into direct, indirect, stress or pathological. Factors that can cause trauma can be mechanical, thermal and electrical. The degree of trauma is determined by the size of impact by any of the above factors and its magnitude along with the time period. The Goal of trauma examination is to determine the cause and manner of death. The examination of bone is more preferred in both skeletonized and non skeletonized body because it gives detail information regarding trauma. Bone has both organic and inorganic components. So it has mechanical property such as tension and compression due to organic and inorganic component respectively. Water present in bone provides resistance to fracture. The percentage of components changes in bone during life, so its mechanical properties changes according to physical properties. Stress and strain are calculated on small cubic piece of bone to avoid any geometric errors. Any change in dimension is due to strain and when strain exceeds stress it causes fracture. When the strain forms an angle then it is termed

*Correspondence to: Payal M. Deoghare, Department of Forensic Science, Lovely professional University, Punjab, India, Email: payaldeoghare106@gmail.com

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as shear strain. The more the resistance of bone to stress greater will be the hardness of bone. Many different ratios are applied such as young's modulus, poisson's ratio, shear modulus, etc. Bones which are more prone to breakage are resistant to compression stress where as ductile bones are resistant to tensile stress. More the elasticity of bone less will be the chances of fracture. Thickness also plays a vital role. Like in skull there are many region of thickness, due to which horizontal bending is caused in case of fractures. Cracks are radiated towards the area which has less thickness. Further, different fracture types were illustrated by him [5].

Zapata has done his research on the mandible of dog. The study of mandible of dog was done by two different models for the examination of bone transport distraction osteogenesis (BTDO). Distraction osteogenesis is a technique used in surgery in which the bone is sectioned using corticotomy and then its length is increases to overcome the lack in growth of bone. Pre-preparation was done before testing the mandible. The mandible was stored at -20°C . Further, chemicals and material were used for performing the test. Strain was applied on the first molar and incisor by applying the load. FEM technique was used for the biomechanics of mandibular bone as it divides the complex structure of mandible into simpler structure of mandible. This allows defining the geometry, mechanical properties and loads on mandibular bone and then generates output in terms of stress, strain and deformation in the bone. A mandible of dog has corticle, cartilage, trabecular bone and teeth. BTDO process has three stages in which at first stage, complete mandible was created without muscles, at second stage bone was extended to 5cm to create deformation and aligned with BTRP device and at third stage mandible was modeled without device and new bone tissue which is similar to the model that obtained after BTDO process. Vertical deformations, stress and strain were observed in the mandible. Vertical deformation was observed in whole mandible but more on the area (incisal and first molar) where load was applied. Deformation was similar in whole mandible in case of incisal load but different for the three stages whereas deformation was similar n whole mandible in case of first molar load in all the three stages. Both molar and incisal displacements were observed. Stress was similar as well as symmetric in all condition [6].

Wieberg et al. has pointed out the differences between the events of occurrence of trauma. It can be ante mortem, perimortem or postmortem. Antemortem trauma means trauma which occurs before death, Perimortem trauma is defined as trauma which occurs around the time of death and Postmortem trauma means trauma which occurs after death. Characteristics of Antemortem trauma are resultant healing of the bone with time. The terms that are used to differentiate between the characteristics of perimortem and postmortem fractures are "fresh bone" and "dry bone". The experiment was documented in three parts for 5 months. Firstly, macroscopic changes were observed after every 28 days. Secondly, comparison was done between bone moisture content and fracture morphology and at last correlation was obtained for all the terms i.e perimortem and postmortem [7]. To analyze the characteristic whether it is perimortem or postmortem, three parameters are considered- color change, fracture morphology and microscopic appearance. Color change can be due to body fluids or external environment. Cross section of bone is taken. If similar color change occurs on cortical bone surface and fracture surface, then the fracture is before postmortem period. If color change is not similar on the cortical bone surface and fracture surface, then the fracture is to be considered as postmortem changes. Fracture

morphology can also give idea about the occurrence of trauma whether it was on fresh bone or dry bone. Fresh bone has high tensile strength as compared to dry bone. Concentric, circular or irregular fractures are observed when the bone is fresh. Fractures which show oblique transverse cracks and unclean cracks are said to be occurring at the time of perimortem interval. Transverse fractures are mostly associated with dry bone, spiral fracture occur in fresh bone and it is the result of tensile shear failure along a helical path. Fresh bone fractures have smooth surface while dry bone fractures have rough, jagged surface. Fracture angle is one of the parameter considered during analysis. Angle more than 90° and less than 90° are associated with fresh bone whereas angle equal to 90° is associated with dry bone. These differences in the result of parameters considered for dry and fresh bone is due to drastic change in the composition of dry bone. Bone moisture content decreases at high rate for the starting few months after death and then goes on drying for around 5 or more months. Hence, bone moisture content has correlation with fracture angle, fracture surface and color change.

Nicholas P. et al. discusses about the interpretation of perimortem trauma in case of burned skeletal. It is difficult to interpret the perimortem trauma if body is burned. Bone is composed of collagen and hydroxyapatite which provides tensile strength and compressive strength respectively. Heat causes dehydration of collagen due to which the elasticity of bone is lost which causes deformation of bone. Fractures induced on bone due to heat is classified into five types longitudinal, curved transverse, straight transverse, patina and delamination. Patina is present mostly in the epiphyseall region and delamination cause removal of layers of bone. Traumatic fracture occurs when load is applied on a particular area and stress over that area exceeds tensile strength of bone. Direction and propagation rate of fracture is influenced if fresh bone due to its discontinuous structure. Slow propagation produces rough fracture surface whereas fast propagation produces smooth fracture surface. Strain in unheated bone is similar throughout the surface whereas this property is not present in heated bone because of dehydration of bone. Sharp force trauma induced by knife, saw or cutter is clearly visible in the traumatic fractures whereas in heat induced fractures more superficial cuts are visible and they are not influenced by the direction of propagation of fracture. Bones affected by gunshot show high degree of fragmentation before burning. Pre burning radiographs shows spattering of minerals present in bone which is not visible in post burning radiographs.

Konstantinos Moraitis et al. have given brief about the blunt force trauma and according to him blunt force injuries are divided into abrasion, contusion, laceration and skeletal fractures produced by blunt instruments. In long bones, blunt force trauma shows variety of fracture patterns due to both external and internal factors. External factors include magnitude, direction, magnitude of loading and time period for which the force was applied. Internal factors include geometry of bone, density of bone, stiffness of bone, strength and fatigue of bone and ability of the bone to absorb energy and release energy. Fracture caused due to direct force is divided into tapping, crush and penetrating depending upon the intensity of force applied. Antemortem injuries are recognized by the healing of fractures. First macroscopically healing characteristic shows porosity near the fracture ends. Second characteristic is remodeling or rounding of sharp edges of fracture (this occurs 1 week prior to death). Third characteristic is the presence of bone callus. Radiographs shows that sharp edges are found when fractures are recent, blunt edges are found when

fractures are 1 week older, fracture healing is not visible until 2 weeks after injury, and fracture gap is visible after 4 to 6 weeks. After this, bone density increases due to deposition of new cells and resulting into demarcation of margins of fracture. However, healing time is affected by the bone condition, if any infection is present, area where fracture is caused, etc. Perimortem trauma is helpful in reconstruction of events. Fresh bone has more collagen, thus, it has more tensile strength. Perimortem trauma can be differentiated from postmortem trauma by the parameter fracture angle and fracture edges. Obtuse angle and acute angle of fracture angle occurs in fresh bone and right angle fracture angle occurs in dry bone. Fracture edge in fresh bone is smooth and symmetric in color whereas fracture edge in dry bone is rough and asymmetric in color. Visible characteristics of perimortem trauma persist upto weeks or month after death. If body is present in the area of more water, then bone damage persist for longer period. In buried skeletal remains, postmortem fractures may occur due to pressure created by surround soil. Degree of Bone damage under soil depends upon the bone structure. Demineralization of bone due to acidity of soil causes increase in postmortem fractures. Bone weathering which occurs due to physical and chemical factors changes the appearance of color and fractural edges. Bone appears whiter due to exposure to sun.

According to Turner, bone fragility refers to the chances of bone fracture. Fracture can occur due to various reasons such as load on the bone, porosity of bone and weakness of bone. Diseased person such as person suffering from osteoporosis and osteomalacia, can suffer bone fracture in daily life due to normal activities also. Fracture to the bone can occur when the energy affected exceeds the mechanical energy which bone can absorb. Traumatic bones are also considered as fragile when the energy absorption is less for that bone due to more brittleness. The biomechanical definition of bone fragility involves four elements- brittleness, strength, stiffness and work to failure. These parameters are considered during execution of the test in which bone is heavily loaded until it breaks. Bone strength is calculated as the height if curve and work to failure as the area under curve. Brittleness is calculated as the reciprocal of breadth of curve. Diseased skeletal is more fragile as discussed earlier because it absorbs very less energy resulting into stiff and brittle bones which causes fracture. Heavy loads on bone can result bended long bones which can be easily observed in ricket patients. Bone fragility can be reduced by increasing the bone mass and improving tissue properties. This can be achieved through various treatments such as drug with fluoride content, drug with high calcium amount, strong inhibitors of bone resorption such as bisphosphonates, etc. Genetically also, bone fragility can be caused. Bone mineral density, bone porosity is affected.

Lespessailles et al. in their research have discussed about the Evaluation of macrostructural bone mechanics. The quality of bone tissue depends upon the biomechanics of bone and he structure of bone. To check the relevance of biomechanical tests, certain parameters are considered to find correlation between them such as bone density and bone geometry. Bones which have anisotropic property will have different ultimate force, different ultimate displacement and stiffness. For experimental purpose either cyclical loading or constant loading is applied. In Torsional testing, measurement of shear stress is done which is applied on the bone during it mobility. Loads due to trauma are deviated from

the main loading axis which causes fracture of bone. Failure stress can be predicted using deformation at failure and Bone Mineral Density parameter. For examination of bone structure, magnetic resonance imaging, micro computed tomography and histology techniques are performed. MRI scan gives better relation between torsional stress and stiffness of bone. Tensile and compressive tests are performed to evaluate failure stress. This test is used for trabecular bone. Bones with definite shape are needed for this test. During bone compression, collapse between the bone structures takes place. Trabecular bone shows different result with tensile and compression tests. Another test performed on bone is bending test. It is classified into three- three point test, four point test and cantilever test. In three point test, bone is held along the horizontal axis, and force is applied ay the mid pint in the perpendicular direction. Load is increased until the bone breaks. In four point test, the bone is held by the two holders, and two equipped device apply compressive force. This test is performed to know the site of bone with highest fragility. In cantilever test, the bone is fixed at one end and the force is applied on another end which is free.

Summary

Bone is fragile in nature. It breaks when heavy load is applied on it. The tensile strength and compressive strength of bone varies depending upon its mineral constituents. Stress, strain, shear strain, Torsional force are calculated for biomechanics of the bone trauma for different tests. Further, different types of bone fracture show different morphology both macroscopically and microscopically. Heat induced fracture and traumatic fracture is distinguishable. Antemortem, perimortem and postmortem fractures are distinguishable on the basis of three main parameters- color variation, fracture edges and fracture angle. But, this can be affected by the external environment also. Certain correlations can be obtained between two parameters such as correlation between Torsional force and bone mineral density. Hence, bone is anisotropic due to which its mechanical properties changes from one area of the bone to other area.

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