TESTING OF CALLUS FORMATION STRENGTH AFTER BONE FRACTURE HEALING FOR RATS

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ABSTRACT

In this study, callus formation strengths of the rat femurs are examined after bone fracture healing using the computer aided finite element methods. The rat femurs are modeled using computed tomography (CT) images using both MIMICS R12 and GEOMAGIC software for finite element applications for which ANSYS Workbench is employed. The mechanical properties of rat femurs are obtained using the three-point-bending tests and input to the computer based finite element modeling processes. These rats are subjected to the traumatic brain injury (TBI+) previously and their femurs were isolated from the whole body and fractured experimentally. The finite element based results are compared with the three-point-bending test ones.

Key words: Rat, femur, bone fracture healing, finite element analysis, Traumatic brain injury
1. INTRODUCTION

Fractures, not only along the bone or soft tissue affecting the environment, deterioration of bone refers to the anatomical integrity. Fractures, in the direction of force, the bone strength, fracture lines, the degree of trauma, the anatomical region where, according to the skin and surrounding tissue damage is divided into various types.

Fracture healing is differences to the other tissues, bone scar tissue without form and function closest to the original as a way to repair itself is formed. This repair process is quite complex and at the same time have occurred fairly regularly steps. Primary fracture healing, rigid fixation was performed in cases but is less than the secondary type. The secondary fracture healing, non-anatomic reduction and rigid fixation of non-spontaneous, and consist, constitute the great majority of fracture healing [2].

In the literature to determine the strength of bone fracture healing was examined by biomechanical studies are common. Also, in the literature, questioned a number of studies fracture healing with TBI, although mechanical factors in the healing process, investigating TBI's critical role in a small number of studies was found. In this study, TBI⁺ (Traumatic Brain Injury) group in the rat's femurs of the biomechanical properties of experimentally determined. The mechanical properties obtained, by computerized simulation has been used in the experiments. Computer-aided simulation results of stress and strain values obtained from the experimental values are compared.

2. EXPERIMENTAL STUDY

In this study, as specimens of 16 pcs, 3-3.5 months old, weighing 200-300 g male Albino Winstar rats as a result of fracture healing (rat) the definition of the mechanical properties of femurs were obtained by experimental studies. Rat's femurs fractured under control seen in Figure 1, the application process with standard closed fracture mechanism and Einhorn and Bonnarens [3] methods' has been established. Broken femurs of TBI under the influence of one month in time recovery at the end of anesthesia below were sacrificed, femurs be removed tissue to be free from the femurs were obtained. Removed the rat femurs in vitro for the definition three-point bending test of material mechanical properties.
Identification of mechanical properties of femurs, the manually controlled three-point bending test setup was created and shown in Figure 2. A software was developed for the three-point bending test data identification. In Figure 2, three-point bending tests are subject to the femur to the fixed jaw is placed on availability. Femur of both direction anterio-posterior (AP) and medio-lateral (ML) position crushing process has been bending load were obtained. Experimental bending process, the rat right and left femurs were applied in Figure 3, as seen in the broken femurs and the average stress-strain graphs were obtained. The experimental results of studies as shown in Figure 3, rat femurs after fracture-healing structures average elasticity modulus 0.254 GPa, and nearly extended the amount of 0.8% as was obtained. The elastic modulus 0.9 GPa, and nearly extended the amount of 1.5% as was obtained for the healthy bone structure.
3. 3D MODELING OF RAT FEMUR

Three-point bending test were applied on rats, simulated by computer aided software. To do this, 3D solid model of femurs were obtained with software for the experimental rats fracture healing results achieved. Femur's solid models of the experimental rats, the femur and other skeletal structures, obtained with Computers tomography (CT) images are used seen in Figure 4. CT images of rats have taken in the device that in Kocaeli University Medical Faculty Toshiba Aquilion CT scanner in the radiology department. CT images of rats and 512 x 512 pixel resolution of 0.5 mm intervals were obtained by scanning. Images has been recorded in "DICOM" format and imported MIMICS 12 software with 3-dimensional (3D) solid model was issued. GEOMAGIC software was completed with the arrangements of femur models surface.
4. FINITE ELEMENT ANALYSIS OF RAT FEMUR MODEL

After CT scan, 3D solid models of rat femurs were achieved aided with the MIMICS 12.01 software. Obtained from solid models were transferred finite element based software called ANSYS. Finite element model was used to create the MIMICS FEA module. The finite element model of femur modeling procedure shown in Figure 5.

![Figure 5. Flow chart for 3D Femur modeling](image)

Rat femurs' 3D model transferred in ANSYS environment as shown in Figure 7, by computer three-point bending test simulation was conducted. 3D volume model obtained femur geometry, healing fracture region's and the intact tissue region as in Figure 6 a as shown in the three regions are divided. Three-point bending test, the rat femur shown in Figure 6 b, the fixed points A and C, bending strength of 100 and 150 N was applied ob point B. Material properties obtained from three point bending test is defined by experimental values.

![Figure 6. 3D model of rat femur and loading and boundary conditions of FEA simulation](image)

Finite element model used for the preparation of 10 node tetrahedral elements and volumetric mesh and 98,713 nodes were obtained. The simulation and experimental stress values ($\sigma$) and deformation results were compared. Three point bending test simulation procedures were
performed in ANSYS environment for rats' femurs shown in Figure 6.b. Under 150 N force in the formation of elastic material defined by the material properties of approximately 0.3 mm deflection and maximum stress were obtained at approximately 4.14 MPa. Figure 7 shows finite element simulation of three-point bending test results of rat femurs. As shown in Table 1, the finite element simulation results and experimental results are close to each other.

![Figure 7. 3P Bending test FEA results](image)

<table>
<thead>
<tr>
<th>Experimental</th>
<th>FEA Simulation</th>
</tr>
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<tbody>
<tr>
<td>Stress (MPa)</td>
<td>Deformation (mm)</td>
</tr>
<tr>
<td>3-Point Bending Test</td>
<td>14.123</td>
</tr>
</tbody>
</table>

5. RESULTS

In this study, rats were obtained from subjects belonging to the femur by using 3D solid modeling, computer-aided finite element method with a three-point bending (breaking) test is simulated. Femur solid models are successfully transferred to computer interface. Femur material values which is necessary for finite element analysis, calculated before from the experimental work through successfully defined and entered in ANSYS environment. Forces and deformations were obtained from computer-aided simulation values are compared with previous experimental results have been obtained and the approximate value of the overlapped. Çömlekoglu et al. [5] in order to determine the quality of osteoporotic rats femurs realized by biomechanical studies, finite element simulation results and experimental results were explained. Biomechanical test results were parallel with FEA results.

The findings and comparisons of this study showed that, finite element analysis results are useful for bone characteristics and strength of determinations. These results are correct as to obtain finite element simulation to be considered to be the most important detail of bone mechanical properties and the installation of boundary conditions biomechanics experiments, exact definition.
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REFERENCES