Computational Stress Study of Femoral Interlocking Nails using Finite Element Method (FEM)

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Abstract:
In this paper, we calculated amount of maximum stress exerted on femoral interlocking nails. These are the orthopedic implants used to heal the fracture of femoral bone. The failure or fatigue limit plays the vital role for overall performance of an object, which also applies in the case of femoral interlocks. The various activities performed by a human being leads application of different loads on femoral bone as well as on interlock. The stresses induced after the intramedullary nailing treatment is identified initially. Mostly these stresses induced will be compression and shear stresses. Because of this stresses there is a risk of failure for the rod and nails provided in the femoral bone. The femoral bone is one of the major supporter for the human body. After the treatment the nails provided need to be held rigid to the maximum limit for the proper motion of the body and healing of the bone. It should posses certain mechanical properties to function in that environment. We designed the sample model of these interlocks under Autodesk fusion 360 CAD interface and calculated the maximum stresses induced in this interlocks under different boundary conditions using Ansys software. At, last we compared the obtained results graphically.

Keywords: Fatigue limit, Fracture limit, intramedullary nailing, femoral bone, CAD.

I. INTRODUCTION

1.1. Biomechanics literature
Nowadays, Biomechanics become most challenging field in mechanical engineering. Usually It deals with, how muscles, bones, tendons, and ligaments work together to produce movement. The topic is specifically focusing on the mechanics of movement. Like a conventional mechanics, this biomechanics also includes concepts of dynamics, kinematics, kinetics and statics. Dynamics includes the studying of systems that are in motion with acceleration, whereas kinematics includes the effects of motion patterns. The kinetics refers motion cause and whereas statics refers the concept of equilibrium.

1.2. Femoral Interlocking nails
Femur is the longest bone also known as thigh bone which forms by a ball and socket joint with the hip and it extends from hip to knee in the human body. Femoral bone has the ability to resist upto 900 kilograms (approximately).

The function of this bone is for transmitting the motion and load carrier. It helps the human body for certain functions like standing, walking and running. It bears heavy loads. Accidental or stress fractures are most common bone failures occurs due to old-age, high fatigue working and heavy force application.

The fractures in femoral bone can occur in three ways namely femoral shaft fracture, proximal femur fracture, supracondylar femur fracture. These fractures can also be communities, straight horizontal also. When these fractures occur the person cannot bear the pain. Since it provides a huge damage to the human and inability to perform articulated activities.

It will resemble in blood clots and change in pressure level of the blood, provides pains to the muscular system in the body.

The skin protecting the bone may damage in some cases. The fracture can result in overall damage to the body. The fracture occurs like heavy impact loads, small cracks, partial breakage, full breakage of the bone. From this it can lead to constraining articulation activites, weakening of muscles, pain. This pain lasts for long period of time.

There are chance of certain risks like infection, paralysis, chronic pain, disability, anemia at the time of fracture. The fractures can be healed by various methods such as non surgical treatment, intramedullary nailing and external fixation. In non-surgical treatment the bone is given time for self healing by certain prescription, advised by the doctor. In the intramedullary nailing, a rod of less diameter than canal of the bone is inserted into it.

The rod can be made of alloys of titanium, grades of stainless steel and even polymers. For stability of the rod nails are provided at the top and bottom of the rod. In external fixation the screws are placed at the fracture site.

The screws ate placed at the top and bottom of the fracture region. These are supported by a rigid frame for a good position of the bone. But it is a short time treatment and done when the person has multiple fractures. The screws are inserted into the bone.

The rod being inserted need to possess elastic nature and should be strong enough. The material used in manufacturing of this rod need to resist corrosion and have toughness value rich in nature. In this intramedullary nailing, the rod inserted will be removed after healing of the bone.

Time for healing can range atmost one year. It this period of time the nails and rid placed shouldnt infect the person. There should be ready enough to be inactive when there is a flow of blood.
II. METHODS

Finite element method is one of the computer aided engineering (CAE) tool which helps us to give a result of structural behavior. We designed an inter-lock implant under Autodesk fusion 360 software and analyze its behavior using ansys software. The dimensions of the Inter-lock are shown in figure-1 below.

There are two compressive stresses are acting on this implant, one stress is in the form of crushing which is exerted by femoral bone. The other compressive stress is in the form of direct compression which is exerted by body weight.

These compressive stress regions are visualized using ansys software under different conditions. The Interlock is created and meshed using tetrahedral mesh elements. The boundary conditions (case-1) of the interlock with mesh and constraints are shown in figure-3 below.

We fixed all the body part and proximal end and applied a load of 5KN on distal top surface. The amount of stress region with these boundary conditions are shown in figure-4 below. Since, the body is also fixed, the amount of compressive stresses acting on interlock is minimum across the body. The more stresses are acting only on top part.

The stress region of interlock when it is exerted with a compressive force of 10KN is shown in figure-5 below.

In the case-2, we consider the interlock design with boundary conditions of fixed free. In this case, we only fixed the proximal bottom part and analyzed the stress region again with compressive loads of 5KN and 10KN. In this case, we neglect the effect of crushing by bones on interlock. The stress region of interlock when it is exerted with a compressive force of 5KN and 10KN in the case-2 are shown in figures 6 and 7 respectively.
In the case-3, we consider body of the interlock design is fixed and analyzed the stress region again with compressive loads of 5KN and 10KN. In this case, we neglect the effect of distal and proximal end compressions.
III. RESULTS AND DISCUSSIONS

The simulated results obtained using computational analysis is shown in table-1 below.

Table.1. Values of maximum stresses at different boundary conditions

<table>
<thead>
<tr>
<th>Boundary conditions</th>
<th>Maximum stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>When body and proximal end is fixed at 5KN</td>
<td>67.31MPa</td>
</tr>
<tr>
<td>When body and proximal end is fixed at 10KN</td>
<td>134.7MPa</td>
</tr>
<tr>
<td>When only proximal bottom part is fixed at 5KN</td>
<td>1594MPa</td>
</tr>
<tr>
<td>When only proximal bottom part is fixed at 10KN</td>
<td>3188MPa</td>
</tr>
<tr>
<td>When both proximal bottom and top part is fixed at 5KN</td>
<td>208MPa</td>
</tr>
<tr>
<td>When both proximal bottom and top part is fixed at 5KN</td>
<td>518.1MPa</td>
</tr>
</tbody>
</table>

The analysis was carried out to study the behaviour of femoral interlock during static loading. The loads (5KN and 10 KN) were applied on the interlock under different boundary conditions in static condition. The analysis results showed that, the maximum stress induced in interlock was 1594 MPa and 3188 MPa respectively at above said loads. The graphical representation of these applied and maximum stresses are shown in figure-10 below.

During our analysis, we assumed that the material of femoral interlock is stainless steel. We mentioned few mechanical properties of stainless steel.

3.1.Material of interlock used in this study

The implant material need to have biocompatibility. Stainless steel consists of many variations due to change in carbon content and other elements. These don't corrode easily with liquids due to the presence of chromium. It forms a resistant layer over the surface of the steel which is self healing. They posses high strength and also toughness at high temperatures. It's quality , resistance to temperature , impact strength varies among grades. It depends on the application used. These also have tensile strength and creep at high temperatures. When there is change in temperatures the intermetallic phase changes which will result in strong corrosion resistance. At the time of heat treatment process through the process of annealing at the temperature of 1100K there is a formation of face centered and body centered crystals. Through alteration of structure, the required properties are evolved. This determines the performance of stainless steel. This stainless steel has more advantages and type of grade is based on the application required.

IV. REFERENCES

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