Effects of Fibula and Talus on the Tibial Stress Distribution

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Summary

In this study, effects of talus and fibula on stress distribution of tibia subjected to body weight in axial direction and torsional loading are examined. The congruent three-dimensional (3D) solid modeling of distal extremities which is consisting of tibia, fibula and talus are generated using the computerized tomography (CT) images. After the modeling processes, these 3D models are converted to finite element models to apply the loading and the relevant boundary conditions to obtain the stress distribution on the tibia. When the body weight and torsional loadings are applied to the tibia alone, the stress distribution is obtained different than the talus and fibula are added to the tibia modeling conditions. As a result of these calculations, it is obtained that the fibula and talus play an important role on the stress distribution of the tibia model.

Keywords: Stress distribution, Tibia and fibula modeling, Finite Element Analysis

1. INTRODUCTION

Tibia, bearing body weight in lower extremity system is one of the most important structures. Fibula, which is situated lateral side of tibia, is a long and thin bone. Although tibia and fibula are almost have the same size, the lower end of fibula is placed more distally. Therefore upper end of fibula is located below the proximal tibia. Fibula is not involved in knee joint structure and tibia coalesce with the distal end of femoral condyles [1]. However, the distal end of fibula participates to ankle joint and lies slightly more distal. The extended part of lower end of fibula is called lateral malleolus. Stress fractures are seen mostly tibia and fibula bones [2,3]. In order to determine this type of fracture using non-surgical or surgical techniques, the effect of fracture character should be determined in adjacent bones [4]. In this study, stress distribution caused by fracture or damage on the tibia due to effect of fibula and talus was examined and compared using finite element analysis (FEA) when tibia, fibula and talus bones were considered as a joint group.

2. MODELING SOLID BONE STRUCTURES

In this study, the computerized tomography (CT) images were used to generate three-dimensional (3D) solid model of tibia, fibula and talus bones. The 3D solid biomodels were created using CT images with the help of
visualization and segmentation software, Materialise's Interactive Medical Image Control System (MIMICS). In order to develop bone structures a reverse engineering software (GEOMAGIC) was used.

The generated tibia, fibula and talus models were exported as a point cloud in MIMICS. The point clouds were transferred into GEOMAGIC for preparing anatomical original geometry. The failure fixing and smoothing on the surfaces of the biomodels was performed in GEOMAGIC. The 3D models were saved as in STL format. These biomodels were assembled as a non-manifold assembly using MIMICS FEA module. The volumetric mesh was generated to the assembled biomodels. Finite element model generated in MIMICS software was transferred to ANSYS Workbench. The material properties for the FEA were given in Table 1.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Elastic Modulus (E, GPa)</th>
<th>Poison ratio (v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tibia</td>
<td>14</td>
<td>0.3</td>
</tr>
<tr>
<td>Fibula</td>
<td>12</td>
<td>0.3</td>
</tr>
<tr>
<td>Talus</td>
<td>17</td>
<td>0.3</td>
</tr>
</tbody>
</table>

3. EFFECTS OF FIBULA AND TALUS ON THE STRESS DISTRIBUTION OF TIBIA

Talus and fibula works together with tibia as a structure clump. Tibia, fibula and talus constitute lower part of knee mechanism. The effect of talus and fibula on tibial stress distribution in consequence of axial and torsion loading was obtained with FEA. In order to perform this calculation, congruent 3D finite element model (FEM) of lower part of the knee mechanism was used. The mechanical connection of fibula and talus with the tibia was described using model in MIMICS transferred to ANSYS Workbench and axial loading was applied with direction to mechanical load-bearing axis of lower extremity. Torsion loadings were also applied as a rotation moment to mechanical axis of body in the same manner. The boundary conditions and loading position is shown in Figure 1a. Four region selected on the tibia and the situation of these region is shown in Figure 1b.

![Figure 1. Tibia-femur-talus finite element analysis loading and boundary condition](image)

In this study, the stress values caused by axial loading and rotation moments were evaluated on four model (only tibia, tibia and talus, the tripartite model (tibia-fibula-talus) and 4-part model occurred with fibula cutting. 250 N, 500 N, 1000 N and 2000 N force applied to surfaces connected with meniscus on tibia plateau. The effect of these forces was investigated on the tripartite model and compared with 4-part model occurred with fibula.
cutting shown on Figure 2a. So the function of fibula would be achieved stress amount on tibia. Under the same conditions, the effects of rotation moment to the tripartite model (tibia-fibula-talus) would determine on tibia plateau. A comparison was performed between whole fibula and cut fibula models due to considering that there is no a function of fibula existence in load bearing. Also displacements on tibia fibula and talus were obtained by FEA (Figure2b).

![Figure 2a](image1.png) ![Figure 2b](image2.png)

Figure 2. The displacement and stress values in finite element analysis

4. RESULTS AND DISCUSSION

The existence of fibula and talus affected stress distribution on the tibia bone. Taking part of undamaged fibula in tripartite model reduces the tibial stresses. The stress values obtained from four regions on the tibia (Figure 1a) are given in Figure 3. It was resulted from FEA that tibia subjected to excessive stresses when only the tibia is affected. Therefore, the tibial stresses are decreased with fibula. As illustrated in Figure 3, it was determined that the tripartite model has less tibial stresses than damaged fibula.

![Figure 3](image3.png)

The results of stress distributions of four regions due to rotational moments are illustrated in Figure 3. It is determined that the tripartite model subjected to less stress distribution in comparison with damaged fibula. As a result, it is pointed out that fibula is playing an important role in load bearing. It can be concluded that the fixation of fractured two-piece fibula is very important during the operation to reduce the tibial stresses.
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References