1. Introduction

The resurfacing operation is a very popular method as treatment of degenerative human hip joint in younger, more active patients, especially those who are active in sport. Too high and too low value of overloading bones is very unfavourable for remodelling phenomenon. The micro-fractures occur in case of overloading (for ex. while sport activity or physical work) and longer overloading results in fractures as well as breaks. The task of this project was creation of numerical models of human pelvis-joint. First model responds to correct physiological state and second one responds to state after surgical operation of resurfacing pelvis acetabulum and femur head. The prosthesis of pelvis acetabulum is press-fit type prosthesis and the prosthesis of femur head is cement prosthesis. The CT photos were used for creating numerical models [1,2]. Method of creating numerical models presented in this work is half-automatic, because there was not possibility of projecting some elements from CT photos - these elements should be created manually.

2. Methods

The way of creation of FEM model which is described consist of few steps:

- Preliminary preparation of geometry human hip-joint based on filtered CT scan data
- Preparation of models of joints surfaces and prosthesis, and collect them into two assemblies: modelphysiologically correct and model after resurfacing operation
- Division model to finite elements
- Assignment of material data
- Assignment of boundary condition and analysis

In the first step the CT data was used for creation of virtual bones. The scan photos were filtered additionally to adjust their quality. Geometry of bones was created in Mimics program of Materialise Company. The CT slices were done with high precision and thickness: 0.347mm for each one. The models of prosthesis and joint surfaces were made in SolidEdge program in next step, and were collected in two assemblies:

- Model after operation of resurfacing which includes femur and pelvis bone (after cutting) and models of prosthesis of femur head and prosthesis of pelvic acetabulum.
- Model before operation of resurfacing which include femur and pelvis (not cutting) and models of joint surfaces on femur head and on pelvic acetabulum.

Prosthesis of femur head was attached by modelling of 3 mm cement layer between implant and femur bone. Cement was not modelled in drilled canal, because in practice doctors do not pour into it the cement. Canal serves only as the leading and positioning one for prosthesis. The implant of pelvis acetabulum was modelled without cement due to the way of attaching which is called ‘press-fit’ and this method does not require to use surgical cement. The pelvis acetabulum should be strictly well-fitted to the shape of implant.

The parts of second model involved pelvis and femur joint surfaces. The femur and pelvis have been set previously. Only joint surfaces should be created. Cooperating surfaces are parts of two spheres with the same centre. It allowed to simulate the real connection in hip joint, which is the spherical joint.

Model was divided by 4 nodes finite elements in MSC Patran system. These are linear elements, but with such numerous elements ( for ex. pelvis physiologically correct -132287 of elements; femur bone after operation - 104659 of elements) with individual material parameters they could simulate the heterogeneity of bones. It allowed to shorten the solving time.

The next step was the material data assignment for every solid. The properties were assigned in Mimics program of Materialise, for femur and pelvis before and after operation. The equation converting mineral density (g/cm^3) to Young’s modulus (MPa) was used to describe our bones by material data. The Keller’s equation was used [3,4]:

\[ E=10.5\rho^{2.57} \]  

(1)

The material’ intervals are shown in table 1. Contact was modelled between:

a) cooperating surfaces of prosthesis (for hip joint after operation);

b) cooperating surfaces of joint surfaces (for hip joint before operation).

The coefficient friction was: 0.001; 0.01; 0.3.
Assignment of this same boundary condition for each models were done. The possibility to displacement in vertical direction was established in joint pubic and in the place where pelvis is connected with spine. The lower part of femur was fixed by taking degrees of freedom in all directions. The 800N force was simulated to pelvis. The model was calculated in MSC Marc program. There were six analysis:
   a) For hip joint physiologically correct with coefficient friction 0.001; 0.01; 0.3.
   b) For hip joint after resurfacing operation with coefficient friction 0.001; 0.01; 0.3

3. Results

The results described in the table 1 show point stresses on particular elements. In case of the model after operation, there is the maximal stress between cement and femur bone. The reason for such stress is probably vertical direction of force influencing pelvis. In case of leaning the assembly pelvis-acetabulum on the part prosthesis-cement-femur the minimal bending of femur occurs. The bend is caused because the lowest part of femur is fixed and the moment occurs. This moment caused the maximal stress between the cement and femur. This is the most dangerous place on the model and can lead to loosening of prosthesis of femur head due to weakening of the cement. In case of pelvic acetabulum after the operation the maximal point stress also occurs but here no cement is used. This result is not as dangerous as in femur case. The result shows also that the coefficient friction does not have influence on the maps of stress in case of static analysis. The map of stress were these same for each element of models’ groups both for hip-joint before and after operations.

<table>
<thead>
<tr>
<th>Model</th>
<th>Max. Stress [MPa]</th>
<th>Young Modulus [MPa]</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femur before operations</td>
<td>30.5</td>
<td>110-20472</td>
<td>Non point stress.</td>
</tr>
<tr>
<td>Femur after operations</td>
<td>27.5</td>
<td>100-20465</td>
<td>Point stress between cement and femur bone.</td>
</tr>
<tr>
<td>Pelvis before operations</td>
<td>88</td>
<td>81-20447</td>
<td>Non point stress in acetabulum</td>
</tr>
<tr>
<td>Pelvis after operations</td>
<td>111</td>
<td>96-20461</td>
<td>Point stress in acetabulum</td>
</tr>
<tr>
<td>Joint surface on acetabulum</td>
<td>13</td>
<td>2000</td>
<td>Point stress (in this same area like in prosthesis of acetabulum model)</td>
</tr>
<tr>
<td>Joint surface on femur head</td>
<td>19</td>
<td>2000</td>
<td>Point stress on joint surface</td>
</tr>
<tr>
<td>Cement</td>
<td>25.2</td>
<td>2000</td>
<td>Point stress on internal side – from femur side</td>
</tr>
<tr>
<td>Prosthesis of femur head</td>
<td>114</td>
<td>200000</td>
<td>Point stress on femur head</td>
</tr>
<tr>
<td>Prosthesis of pelvic acetabulum</td>
<td>67.5</td>
<td>200000</td>
<td>Point stress (in this same area like in joint surface of acetabulum model)</td>
</tr>
</tbody>
</table>

4. Discussion

The studies conducted and show in this article deliver information about hip joint before and after operation of resurfacing. The relationship between coefficient friction and map of stress for walk faze loading (femur’s motion towards pelvis) will be check in the next step of our investigations.

References