Towards Modelling of Trabecular Bone Microstructure

SSIP 2008 Project 20
Outline

• Myths behind Bone
• Need for personalized bone analysis
• Method and Materials
  - Materials
  - segmentation and Mesh generation
  - Finite Element Analysis
  - Elastic property and Direction
• Results and Discussion
Objective

• Hypothesis: there exists a relationship between the direction (orientation) of bone and the forces it endures

• Challenges:
  – Trabecular bone is anisotropic, but how does the arrangement look like
  – Irregular geometry shapes
  – What kind of relationships between the architecture and mechanical properties
Insights of Bone

ACK, Bert van Rietbergen, Finite Element Modeling, The Physical Measurement of Bone, 475-510
Work flow

ROI selection of bone sample

Segmentation

3D reconstruction

meshing

FE model setting

FE solver

FE model setting

Virtual Mechanical Testing
**Experimental data:** tomography of a bone-cartilage sample

- **Data acquired at:**
  - ID17  Biomedical Beamline
  - European Synchrotron Radiation Facility (ESRF)
  - Grenoble, France

- **Technique:**
  - phase-contrast imaging (propagation-based imaging technique)
Meshing

• Divide the volume into elements
  • Surface meshing
    • Triangle shape elements (3 nodes)
  • Volumetric
    • Cube shape elements (8 nodes)
The Materials

• Elasticity
  – Young’s Modulus
  – Poisson Ratio

<table>
<thead>
<tr>
<th>Property</th>
<th>Tissue</th>
<th>Holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young modulus [GPa]</td>
<td>6</td>
<td>0.006</td>
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<tr>
<td>Poisson ratio</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Finite Element Model

• Elasticity Model
  – Geometry
  – Material properties

• A better one: Poroelasticity Model?

\[ F = Ku \]
Preliminary Results (1)
Preliminary Results (2)
Discussion and Future Work

• The deformation of trabeculae seems to be along bone’s direction
• More data and quantitative analysis
• A descriptor of trabecular bone orientation
• Better modelling
  – More complicated but detailed meshing
  – More time for FEM
• Validation – real mechanical testing
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