Introduction

- Osteoarthritis (OA): degenerative disease of all the tissues in the diarthrodial joint leading to pain, limited mobility and joint deformation (Coggon, et al., 2000).

- Cartilage degeneration is caused by elevated stress level in the knee joint (Clements et al., 2001).

- 14.1% of men & 22.8% of women over 45 years show symptoms of OA of the knee (Valkenburg, 1980).

- OA costs £12 billion to the NHS and $185.5 billion to the United States annually (Mathers, at al., 2006).
Meniscal Tears & Partial Meniscectomy

- **Joint injury** - a torn meniscus resulting from a twisting injury (football, skiing) (Englund, et al., 2003)

Four Basic Tears:
- I - longitudinal;
- II - horizontal;
- III - oblique;
- IV - radial
Gap in Knowledge

The link between the proportion and location of the partial meniscectomy and the contact stress within the knee joint during sports activities is not known.
Methodology

MRI scans

3- MATICS Module
Smooth surfaces; non-manifold assembly, Surface geometry

MIMICS Modules
Image processing, generation of 3D structure

CATIA
Smooth edges; Solid geometry

Abaqus FEA Package
Meshing; Boundary Conditions
MRI Scans

- **SPGR sequence**: bones & cartilages
- **CUBE sequence**: meniscus & ligaments
- Voxel Resolution: 0.29 x 0.29 x 0.7mm$^3$
3D Modelling of the tissues

1. Import
2. Livewire
3. Editing

- Femoral Cartilage
- Tibial Cartilage
- Meniscus
- Femur (or Thigh bone)
- Tibia (or shin bone)
- Fibula
Non-Manifold Assembly (NMA)

- NMA algorithm permits elimination of sections between surfaces.
- This ensures that a common border is calculated.
Knee Model

- Surface geometry from Mimics converted to solid geometry in CATIA.
- Rough cartilage edges smoothened for subsequent meshing with hex elements.
# FEA Studies in Abaqus

<table>
<thead>
<tr>
<th>Material Properties</th>
<th>Young's Modulus [MPa]</th>
<th>Poisson's Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bones</td>
<td>1000</td>
<td>0.3</td>
</tr>
<tr>
<td>Cartilage</td>
<td>50</td>
<td>0.45</td>
</tr>
<tr>
<td>Meniscus</td>
<td>112</td>
<td>0.45</td>
</tr>
<tr>
<td>Ligaments</td>
<td>332, 345</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Source: Kubicek, M. and Florian, Z., 2009
- Cartilages and Ligaments were bonded to the bones.
- Frictionless contact were defined between cartilages/cartilages and meniscus/cartilages.
Verification With Cadaveric Study

Boundary and Loading Conditions:
- 300 N axial load
- 12 Nm bending moment.
- Femur fixed
<table>
<thead>
<tr>
<th>BM (Nm)</th>
<th>Force (N)</th>
<th>Pressure (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE</td>
<td>In Vitro</td>
<td>FE</td>
</tr>
<tr>
<td>0</td>
<td>200.16</td>
<td>120</td>
</tr>
<tr>
<td>2.4</td>
<td>247.35</td>
<td>175</td>
</tr>
<tr>
<td>4.8</td>
<td>273.98</td>
<td>205</td>
</tr>
<tr>
<td>8.4</td>
<td>373.52</td>
<td>240</td>
</tr>
<tr>
<td>12</td>
<td>405.29</td>
<td>267.34</td>
</tr>
</tbody>
</table>

**RMS error (N)**: 88.25  
**RMS error (MPa)**: 0.58

**FSE (%)**: 21.8  
**FSE (%)**: 23.1
Intact Knee v/s Meniscectomy

- Tibia fixed (A).
- Axial load (B) applied at the femur.
- Constraints:
  - Translation free in vertical direction only
  - Flexion/extension constrained to sagittal plane
## Results

<table>
<thead>
<tr>
<th></th>
<th>Stress on Medial Tibial Cartilage (MPa)</th>
<th>Stress on Lateral Tibial Cartilage (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact Knee</td>
<td>1.2</td>
<td>0</td>
</tr>
<tr>
<td>Partial Medial Meniscectomy (50%)</td>
<td>1.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Full Medial Meniscectomy</td>
<td>2.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Conclusion

- Our findings show the importance of the meniscus in reducing knee joint contact stresses.

- Important to understand whether dynamic activities impose high level of stress to the articular cartilage.
Ongoing Work

- Modelling different sizes and location of partial meniscectomies for different dynamic activities.

- Modelling the cartilages & meniscus as viscoelastic materials.
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http://www.justgiving.com/Dilen-Carpanen

Thank You

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