Quantifying Compartmental & Sub-compartmental Cartilage Variation in Osteoarthritic Knees

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Declaration of Interest

I declare that in the past three years I have:

• held shares in: **Optimized Ortho, 360 Knee systems**

• received royalties from:

• done consulting work for: **Arthrex, Global Orthopaedics, Depuy**

• given paid presentations for: **Arthrex, Global**

• received institutional support from: **Global Orthopaedics, Smith and Nephew, Zimmer, Arthrex**
Introduction

TKA techniques and alignment strategies require adjustments to resection depths to account for existing osteoarthritic quantities of cartilage

- Cartilage thickness is difficult to measure intraoperatively:
  - Worn and unworn compartments are difficult to quantify and compare

- Incorrect OA cartilage thickness assumptions can lead to under- or over-correction of resection depths

- Kinematic alignment techniques in particular seek to restore native cartilage volume and joint line alignment, and inaccurate measures or estimates of cartilage thickness make this difficult
Introduction

- Cartilage thickness varies across the normal population:
  - Young vs. Old [1,2]
  - Men vs. Women [2,3]
  - Active vs. Inactive [2]
  - Varus vs. Valgus [1,2,3,4,5]

- And throughout the knee joint:
  - Medial vs Lateral [1,2,3,4,5]
  - Distal vs Posterior [5]
  - Contact vs. Non-contact [7]
  - Anterior vs. Posterior Regions [8]

- Few studies have examined variations in cartilage thickness across OA affected populations [5]
Introduction: Limitations of MRI Studies

- MRI measurements have dominated OA cartilage thickness studies [2,3,5,7,11], however they have significant limitations:
  - Poor accuracy when measuring cartilage thicknesses < 2 mm [7,11] making it ill-suited for OA thickness measurements.
Study Aims

Aims:

a. Develop a technique to accurately measure OA cartilage thickness profiles

b. Compare cartilage thickness and its variation with common in use assumptions

c. Identify trends in sub-compartmental cartilage degeneration
**Method: 3D Scanning & Wet Chemical Treatment**

**3D Cartilage Surface**

Resected tissue from 27 TKR was collected and scanned with a high resolution laser scanner (0.02mm accuracy)

**3D Bone Surface**

The resulting bone offcuts with cartilage removed were re-scanned to produce a set of 3D models matched to the cartilage containing models

**30 Hours**

A corrosive chemical treatment bath was used to dissolve the cartilage from the bone
Method: Calculating Cartilage Thickness Profiles

The two sets of 3d models (with and without cartilage in-situ) were then combined and the volume of the bone only model subtracted from the cartilage containing model. The remaining tissue thickness is cartilage only, and gives a highly accurate 3D map of cartilage thickness across the surface of the bone.
Results: Average Medial & Lateral Thicknesses

<table>
<thead>
<tr>
<th>Medial Cartilage</th>
<th>Lateral Cartilage</th>
</tr>
</thead>
</table>

Median, interquartile range, minimum and maximum thicknesses indicated.

Average Thicknesses Indicated:
- Medial Cartilage: 1.1 mm, 1.9 mm
- Lateral Cartilage: 0.6 mm, 1.6 mm

* Indicates p < 0.05
## Results: Healthy Comparison

### Cartilage Thicknesses in Varus Knees

<table>
<thead>
<tr>
<th></th>
<th>OA average cartilage thickness (n=27)</th>
<th>Healthy cartilage thickness (n=112) [12]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial Tibial Well</td>
<td>1.09 ± 0.56</td>
<td>1.7 ± 0.2 *</td>
</tr>
<tr>
<td>Lateral Tibial Well</td>
<td>1.93 ± 0.58</td>
<td>2.2 ± 0.25 *</td>
</tr>
<tr>
<td>Medial Distal Condyle</td>
<td>0.64 ± 0.44</td>
<td>1.9 ± 0.3 *</td>
</tr>
<tr>
<td>Lateral Distal Condyle</td>
<td>1.64 ± 0.45</td>
<td>1.8 ± 0.25</td>
</tr>
<tr>
<td>Medial Posterior Condyle</td>
<td>1.63 ± 0.51</td>
<td>1.7 ± 0.3</td>
</tr>
<tr>
<td>Lateral Posterior Condyle</td>
<td>1.61 ± 0.53</td>
<td>1.6 ± 0.3</td>
</tr>
</tbody>
</table>

* Denotes a significant difference between the OA worn and healthy control cartilage thickness for a given measurement

- Average cartilage thicknesses in the unworn compartments of varus populations are comparable with healthy thicknesses
- There is significant difference of cartilage thickness between the medial and lateral compartments of tibial plateau and the medial distal femoral condyle, but NOT the lateral distal condyle or the posterior condyles in varus knees
Results: Wear Patterns

Typical varus wear patterns show medial wear that is more prominent in the anterior region of the tibia – variation exists.

Femoral patterns demonstrate wear at the distal-posterior junction of the condyle, centred most prominently on the distal.
Discussion & Conclusion

• Cartilage thicknesses in healthy compartments of osteoarthritic knees differ significantly from those found in worn compartments and can be very accurately measured with this technique.

• In varus knees (n=27) there is a significant difference between the thickness of cartilage in the medial and lateral wells of the tibia (p < 0.001) and the distal femoral condyles (p < 0.001) but not the posterior femoral condyles
  • Implication from this and from observed wear patterns – posterior condyles can be reliably used to set joint line in flexion, if access to the posterior medial condyle past the most distal portion is available
  • On the tibia – lateral plateau reliably gives similar reference

• Significant inter-patient variation existed, and reference rules for volume of healthy cartilage to ‘restore’ with kinematic techniques may not be reliable
References


