

The Alignment Index:

A new method to analyse
collagen fibre orientation
distribution in the knee.

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Cruciate ligament preserving implants MUST have “healthy ligaments”



Total knee replacement
with cruciates retained



Partial knee replacement or
unicompartmental with cruciates

Invisible on MRI

How can we quantify ligaments when they are “invisible”?

Conventional MRI

Exploit the **Magic Angle Phenomenon**

Magic Angle $\theta = 54.7^\circ$

$I = \exp(-(3\cos^2\theta - 1)^2)$

Magic Angle artefact

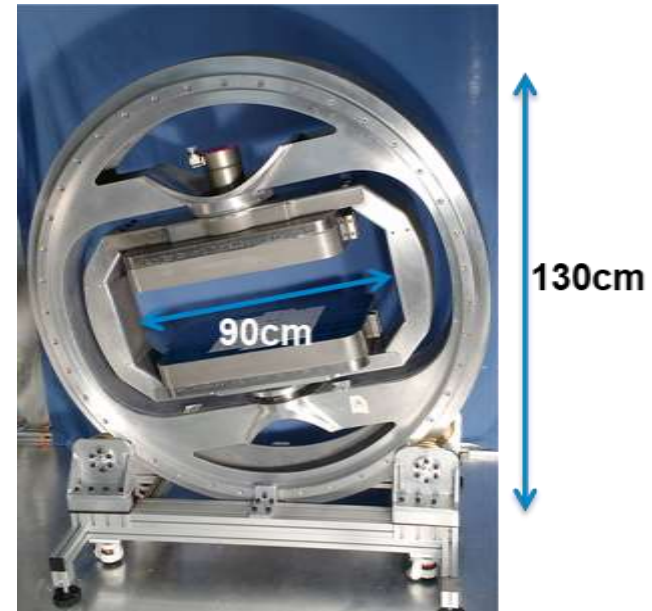
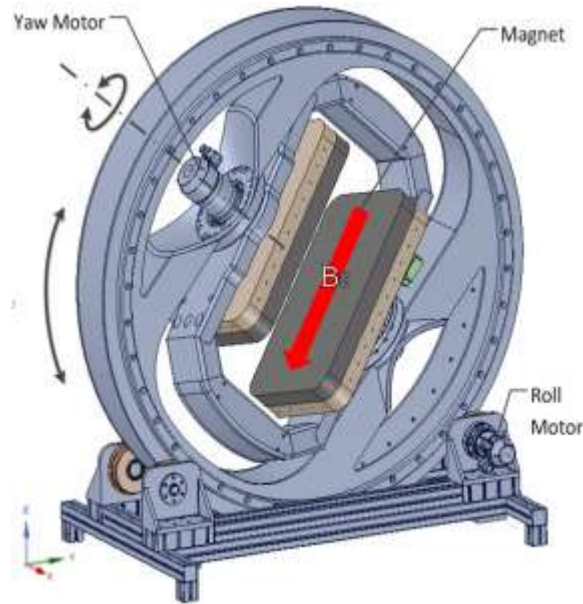
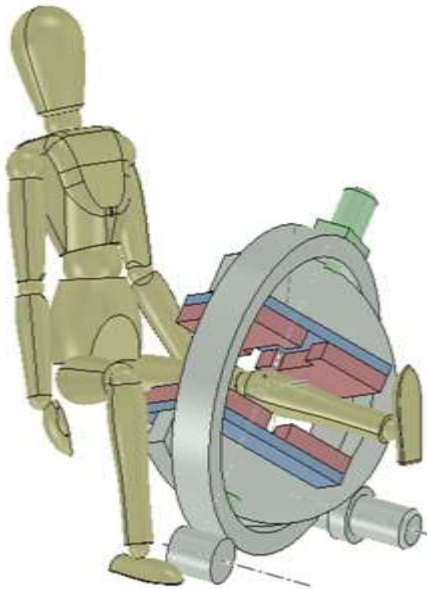
B_0

Angle sensitive MRI

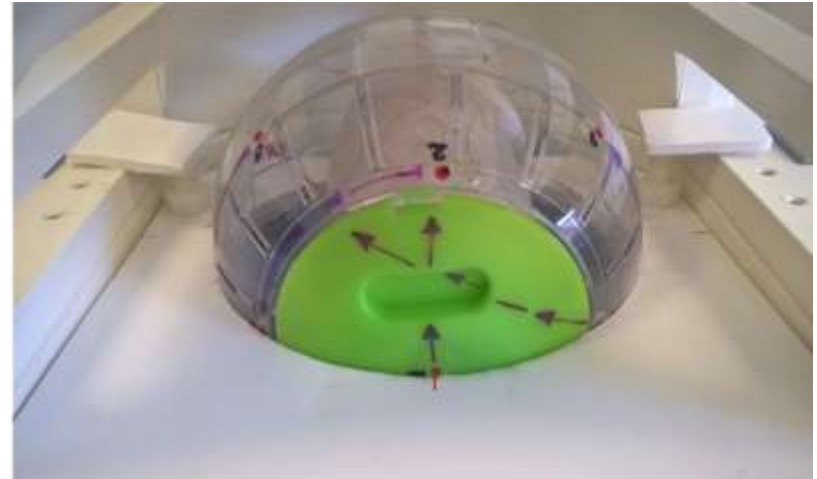
B_0

Magic angle scanner

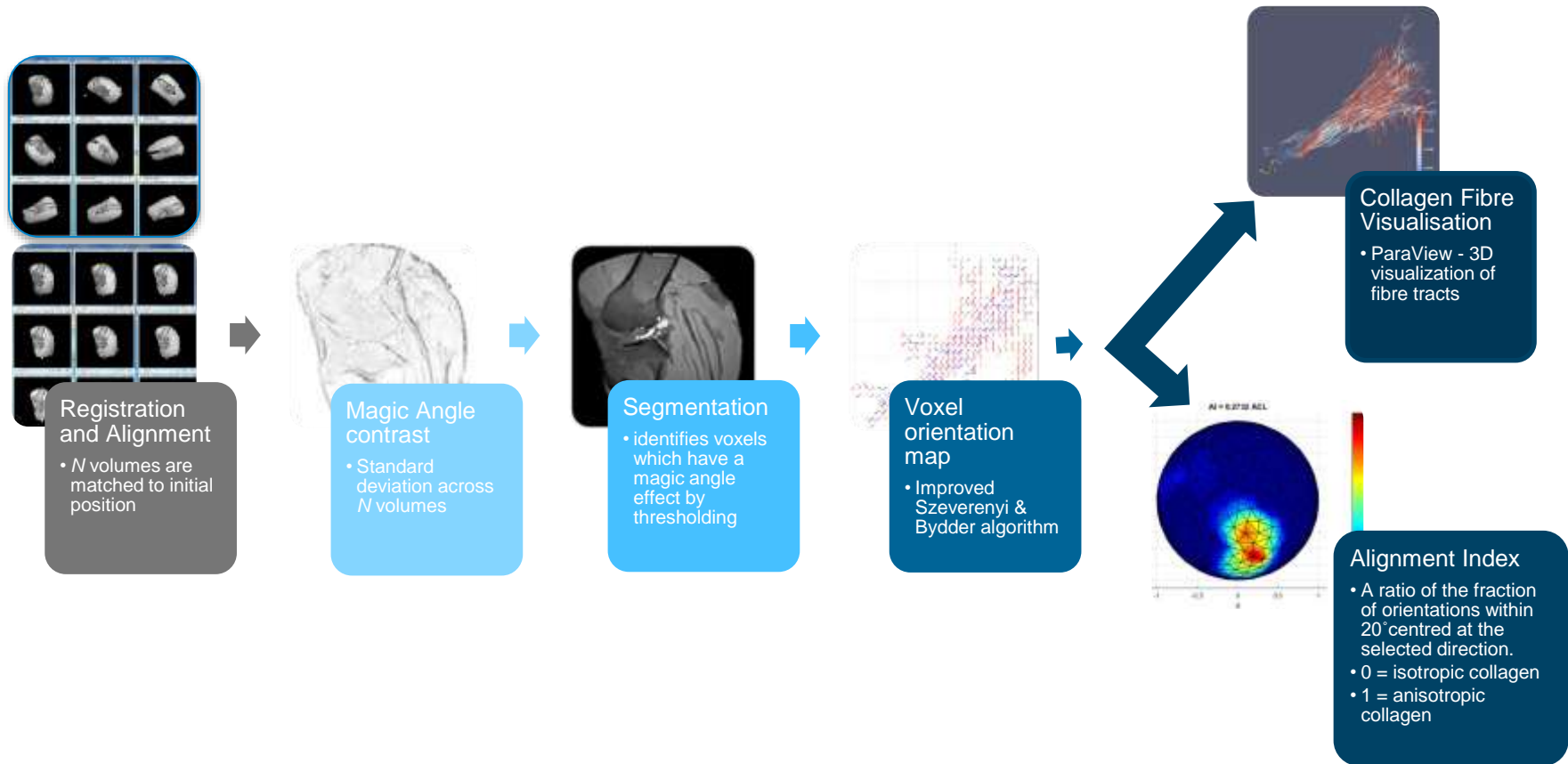
A novel open MRI system from McGinley *et al.* (2016 JMR)



- Siemens Verio 3T
- 12 channel head coil
- 3D 1x1x1mm isotropic sequence optimized for magic angle
- Sphere containing caprine knee
- Sphere was rotated and scanned in 9 directions to B_0



Post Processing



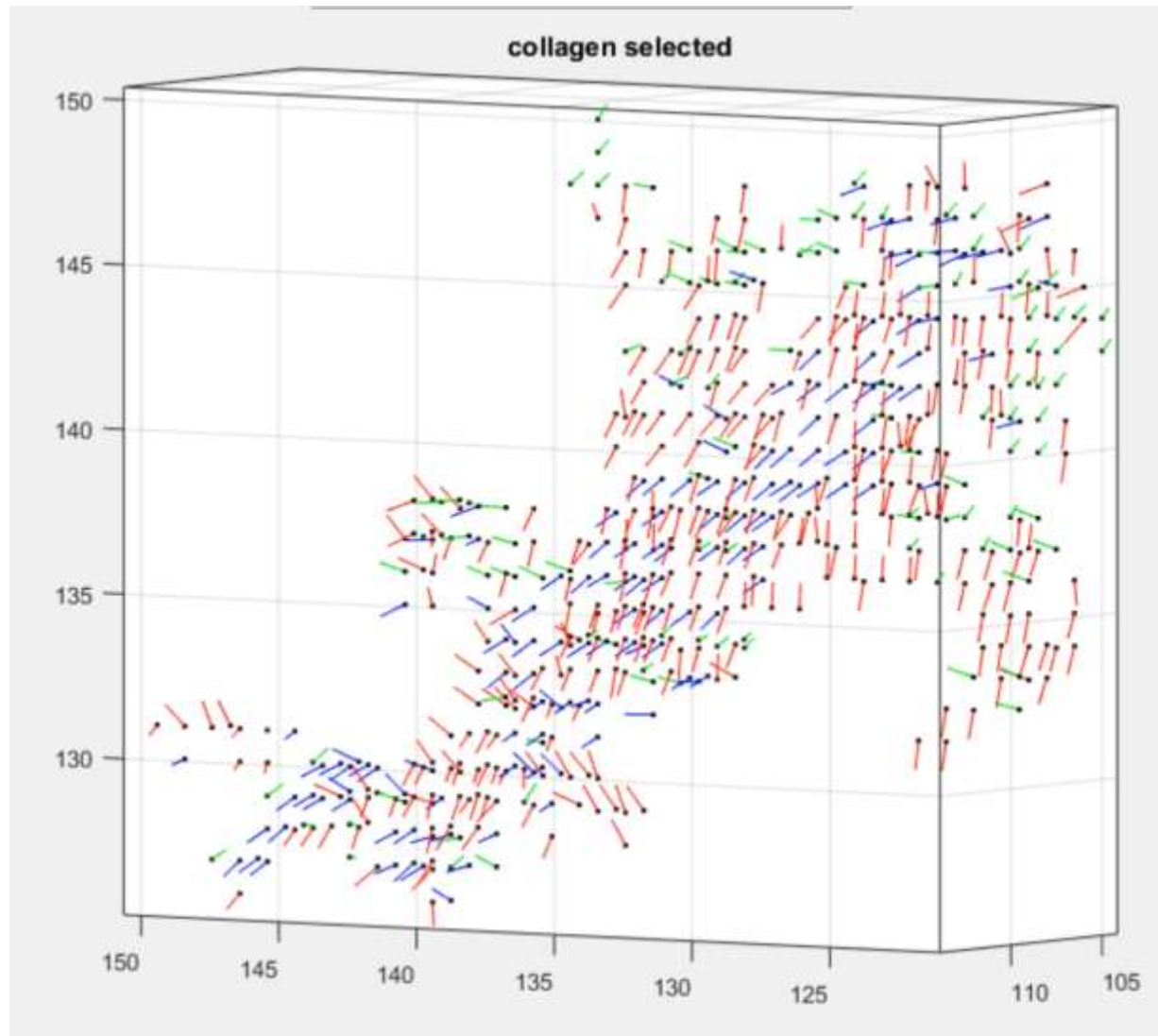
Voxel orientation map

▪ = Voxel

Red = top/bottom (y)

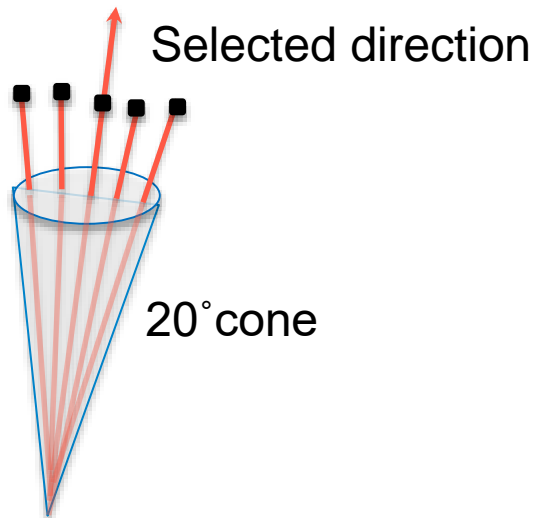
Blue = left/right (x)

Green = in/out (z)

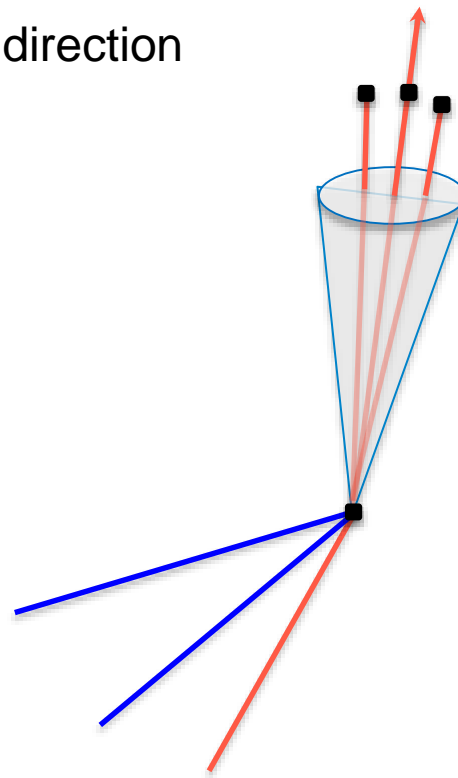


Alignment Index (AI)

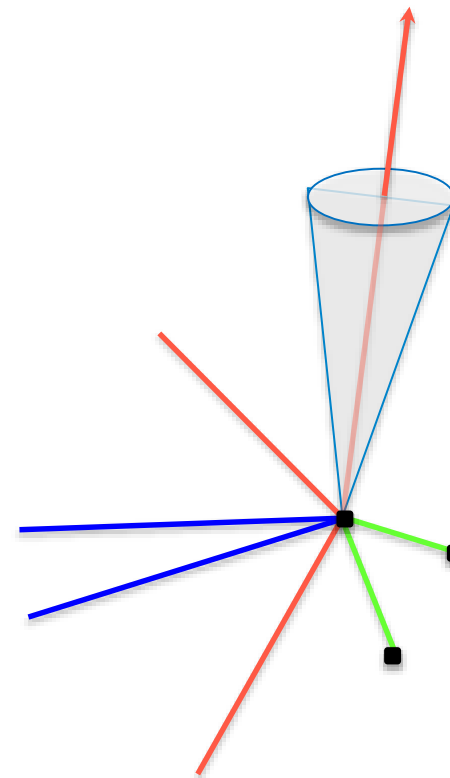
AI = 1 = anisotropic



AI = 0.5

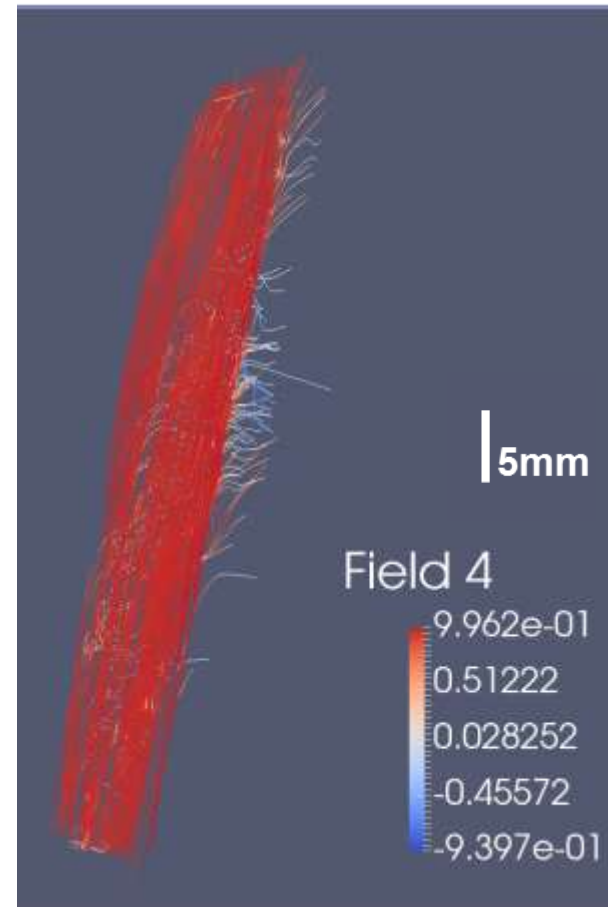
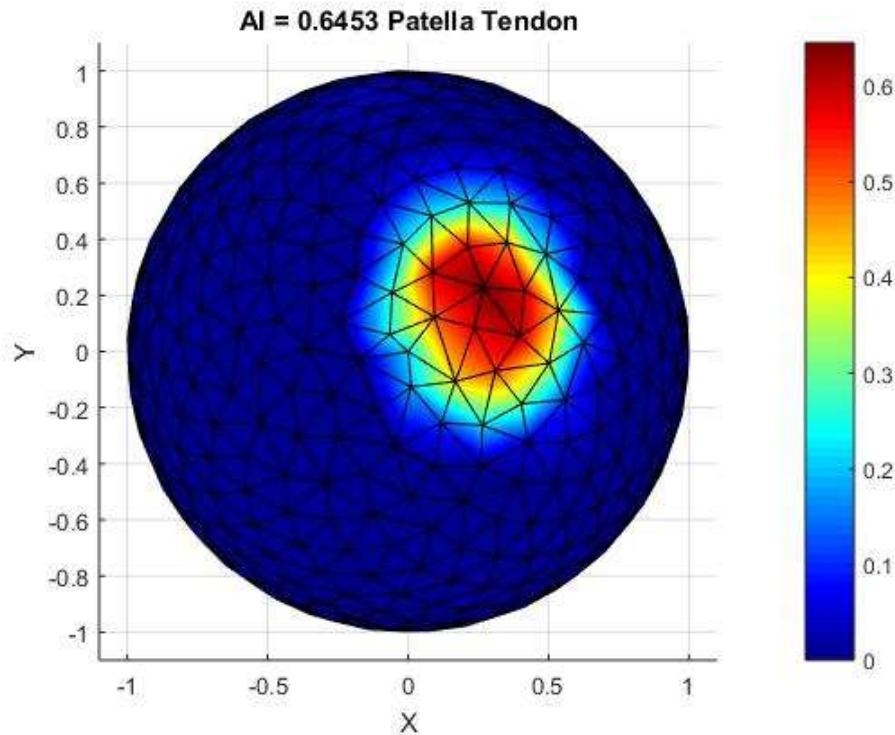


AI = 0 = isotropic



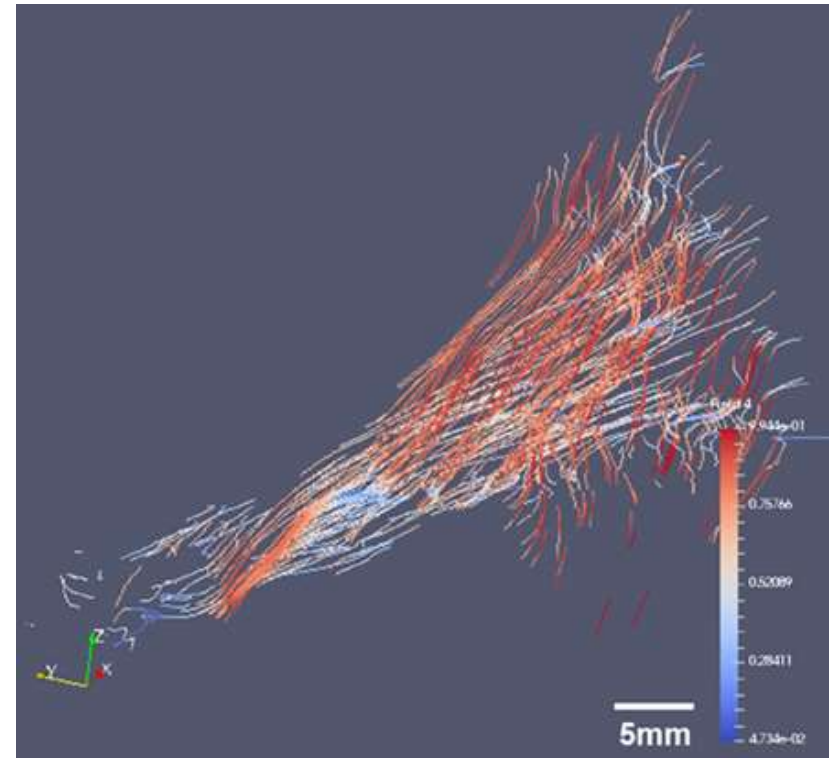
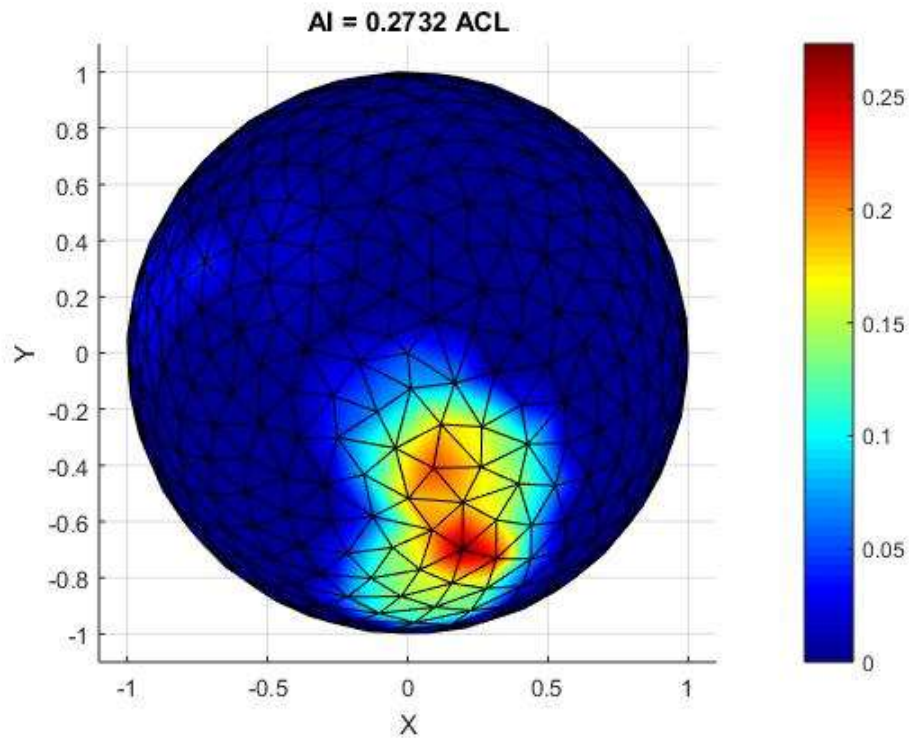
Patella Tendon AI results

Most aligned

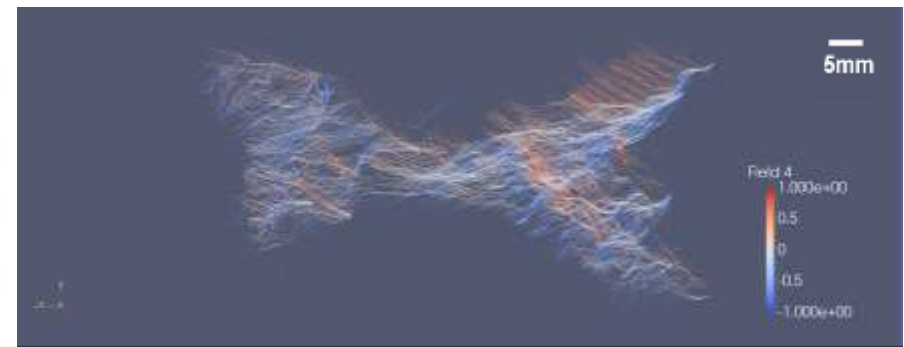
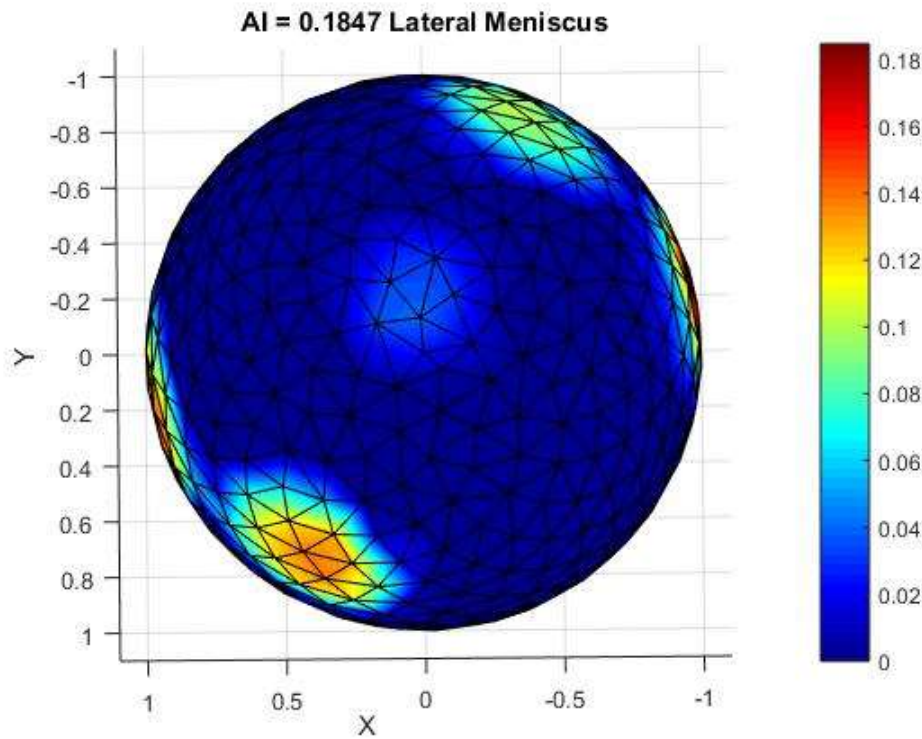


ACL AI results

Two fibre bundles: anterior medial and posterior lateral

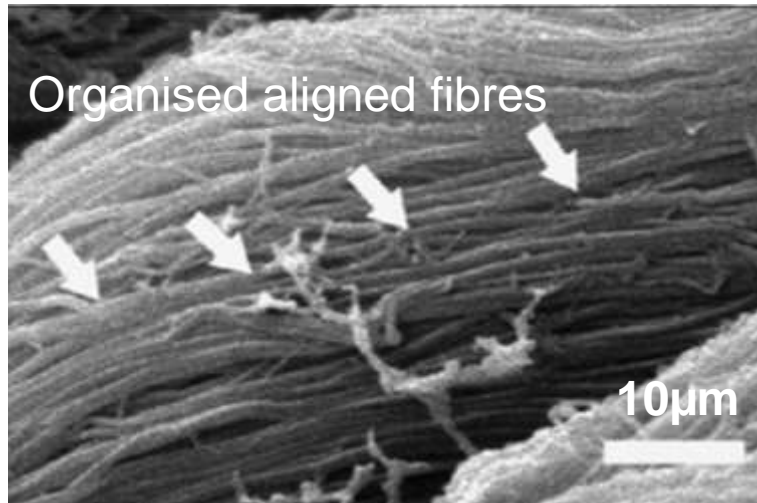


3 fibre groups: vertical, radial and circumferential

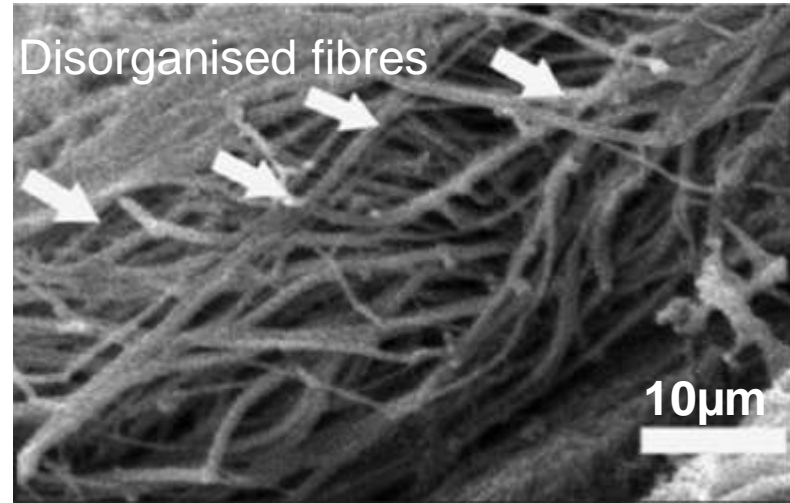


Discussion

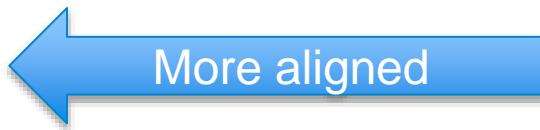
SEM Healthy Meniscus



SEM Damaged Meniscus



1



AI



0

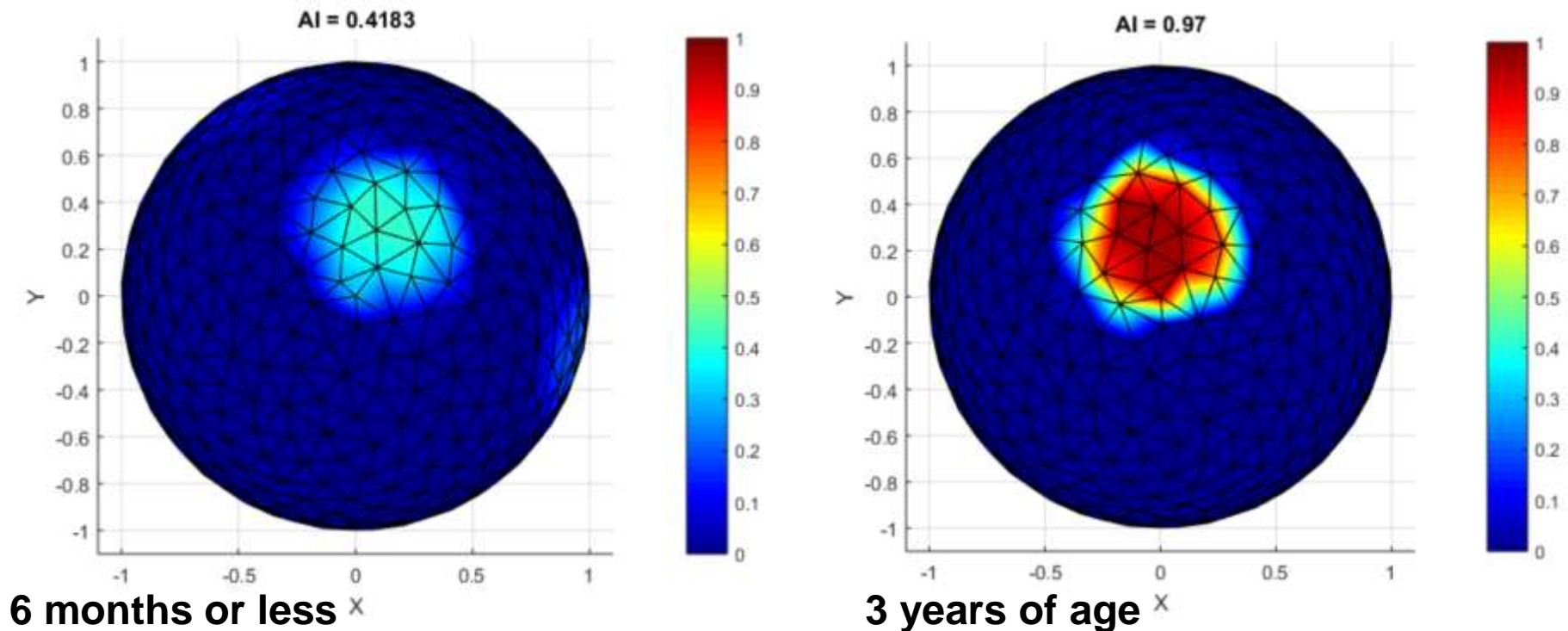
Worsens with damage

Conclusion

The AI can

- improve understanding of collagen orientation distribution
- be a quantitative, non-invasive measure of structural health.

AI demonstrates Patella Tendon alignment changes with age



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