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 unicondylar 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

Angle sensitive MRI

B₀

B₀
Magic angle scanner

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

- 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

Registration and Alignment
- \( N \) volumes are matched to initial position

Magic Angle contrast
- Standard deviation across \( N \) volumes

Segmentation
- Identifies voxels which have a magic angle effect by thresholding

Voxel orientation map
- Improved Szeverenyi & Bydder algorithm

Collagen Fibre Visualisation
- ParaView - 3D visualization of fibre tracts

Alignment Index
- A ratio of the fraction of orientations within 20° centred at the selected direction.
- 0 = isotropic collagen
- 1 = anisotropic collagen

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

AI = 0.6453 Patella Tendon

Field 4

5mm
ACL AI results

Two fibre bundles: anterior medial and posterior lateral
Meniscus AI results

3 fibre groups: vertical, radial and circumferential
Discussion

SEM Healthy Meniscus

Organised aligned fibres

SEM Damaged Meniscus

Disorganised fibres

AI

Less aligned

More aligned

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

6 months or less

3 years of age
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