Imperial College London

Visualization and quantification of collagen fibers in a partially torn ligament using magic angle imaging

Karyn E Chappell, Catherine Van Der Straeten, Donald W McRobbie, Wladyslaw Gedroyc, Mihailo Ristic, Djordje Brujic & Richard Meeson.

k.chappell@imperial.ac.uk

Imperial College London

Declaration of Financial Interests or Relationships

Speaker Name: Karyn E Chappell

I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

Imperial College London

Research motivation

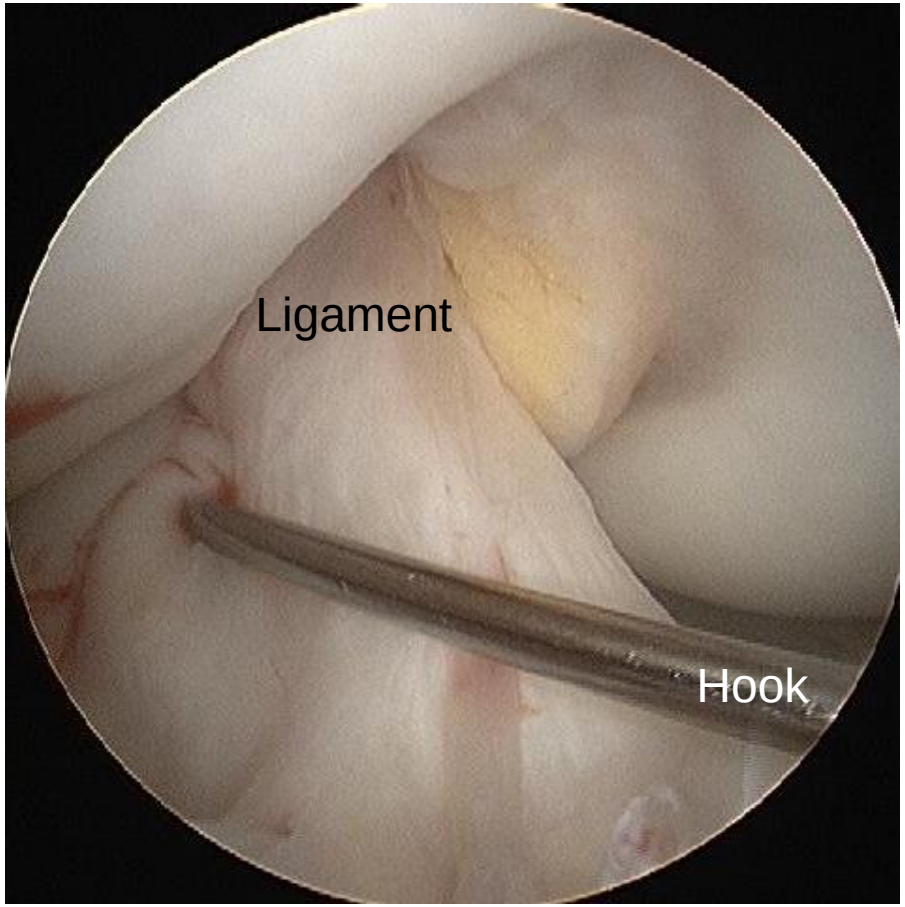
Cruciate ligament preserving implants MUST have “healthy ligaments”

Total knee replacement
with cruciate ligaments retained

Partial or unicondylar knee replacement
with cruciate ligaments retained

Imperial College London

Healthy Ligament?

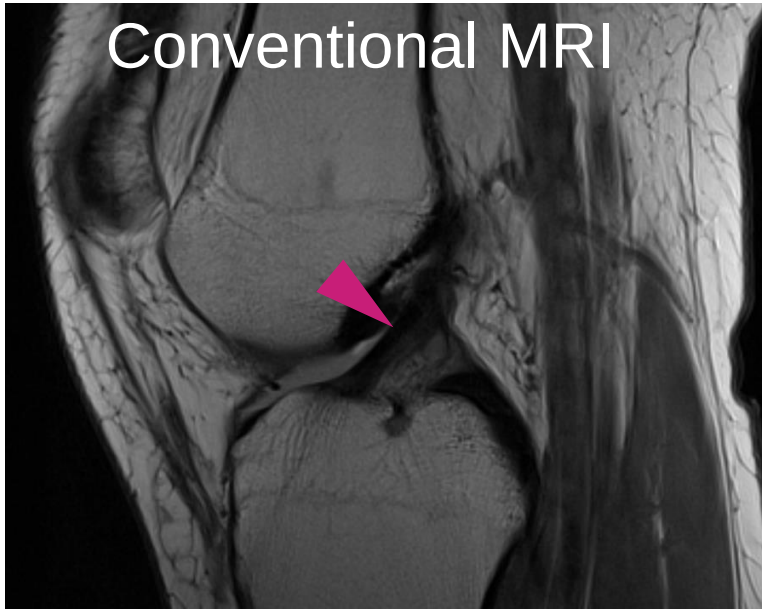


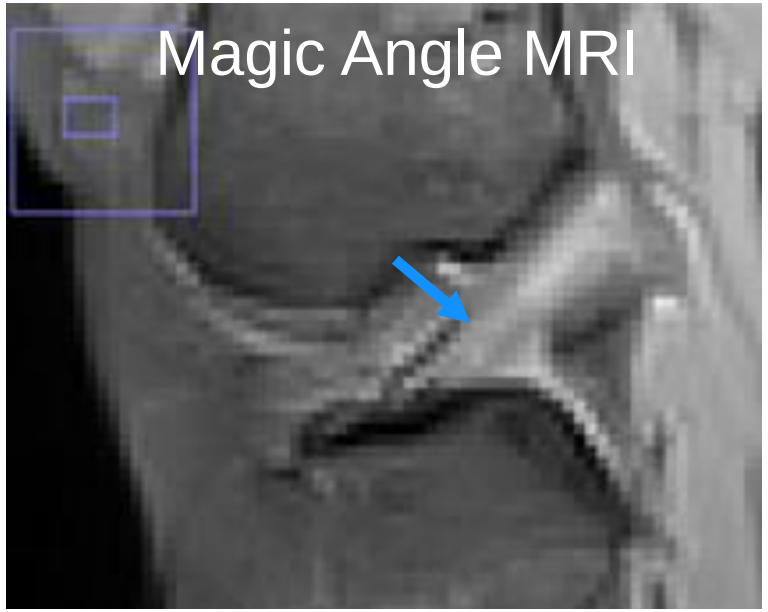
- Hook test
- Invasive
- Subjective

Imperial College London

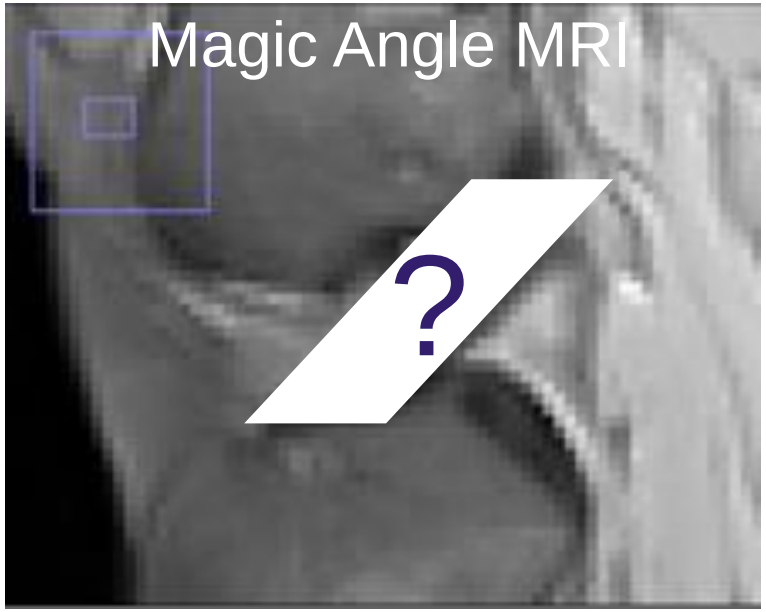
Rationale

How can we measure ligament health with little or no MR signal?





Healthy ligament



? Damaged ligament

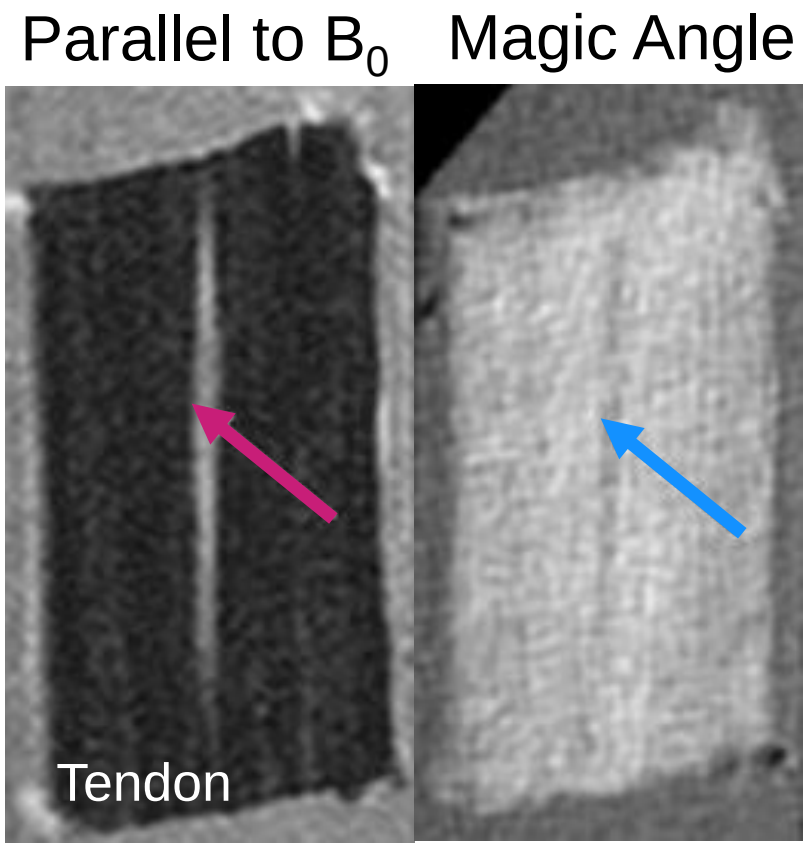
dipolar anisotropy
magic angle effect

Chang *et al.* 2014

Imperial College London

Collagenase Model

- Post mortem tendon
- 0.2mL injected collagenase
- Molecular structure disrupted
- Loss of magic angle effect

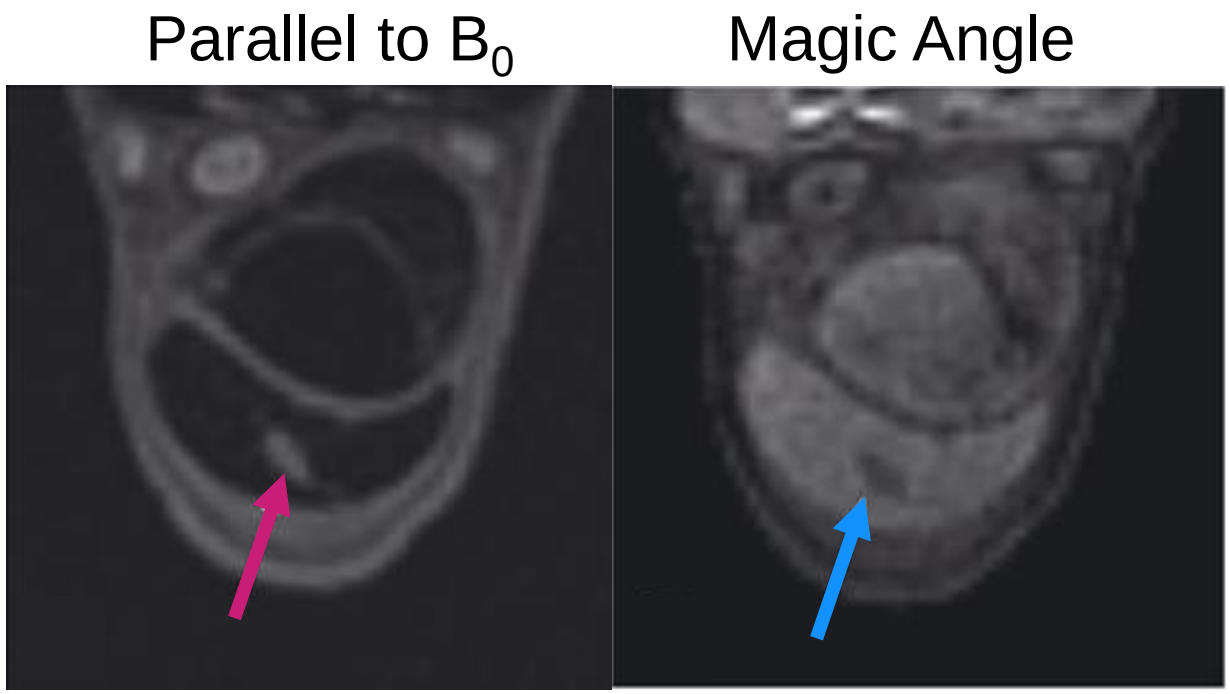


Fullerton & Rahal 2007

Imperial College London

Laser Diode Model

- Post mortem tendon
- Laser induced lesion
- Thermal damage
- Unravelling collagen fibers
- Loss of magic angle effect



Spriet *et al*. 2012

Imperial College London

Spontaneous injury model

Taylor-Brown *et al.* 2015

Imperial College London

Method

- 3T Siemens Verio
- 12 Channel head coil
- 3D T1 FLASH volume in 9 orientations to B_0

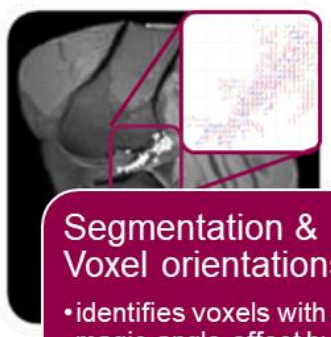
- 10 dog knees
- Vet assessed disease
- Post processing pipeline:

Registration & Alignment

- 9 volumes are matched to the initial position

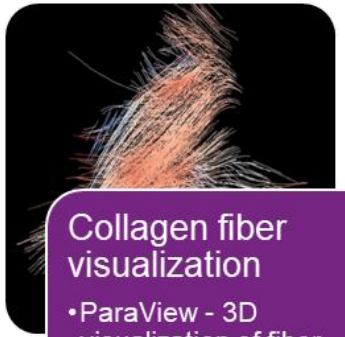
Magic Angle Contrast

- Standard deviation across 9 volumes



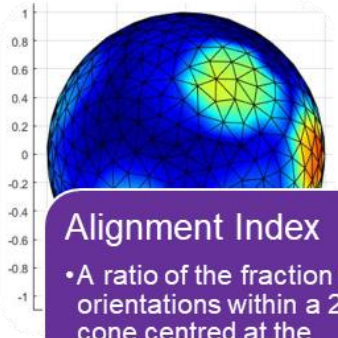
Segmentation & Voxel orientations

- identifies voxels with a magic angle effect by thresholding
- Computes the net voxel orientation map



Collagen fiber visualization

- ParaView - 3D visualization of fiber tracts



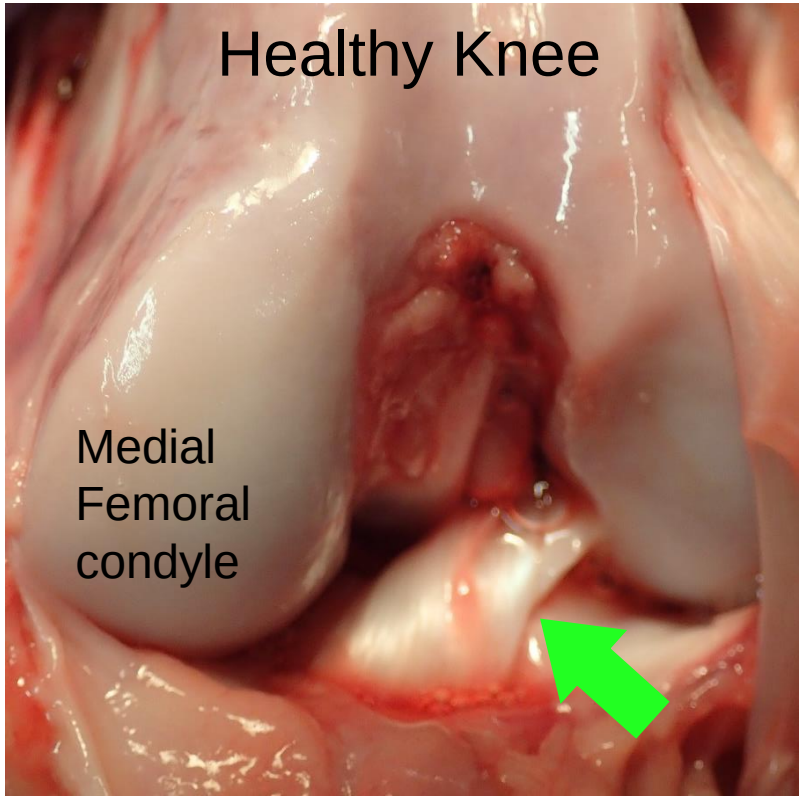
Alignment Index

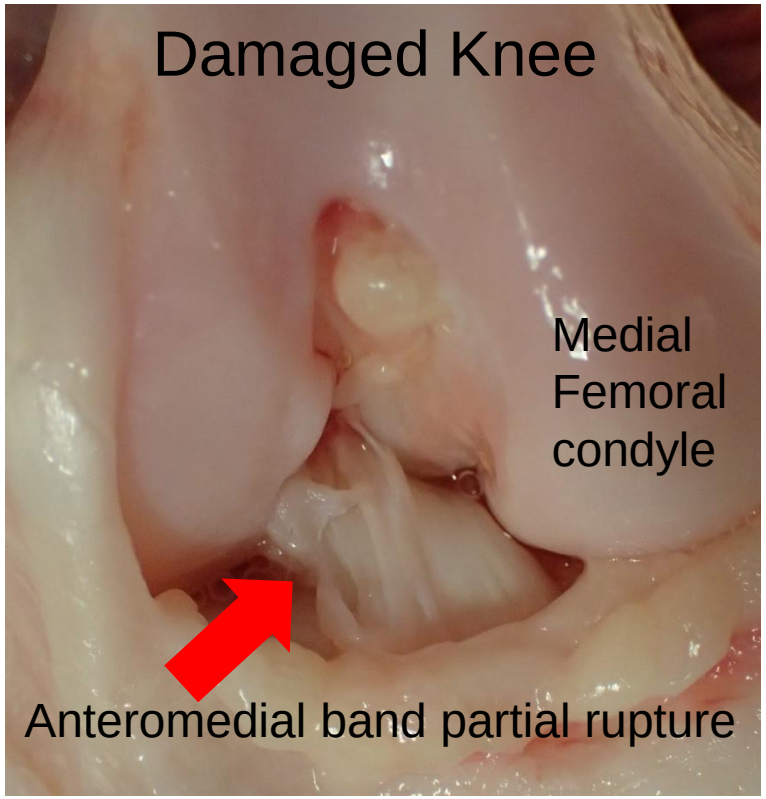
- A ratio of the fraction of orientations within a 20° cone centred at the selected direction.
- 0 = isotropic collagen
- 1 = anisotropic collagen
- AI changes visualized on a hemisphere

Szeverenyi & Bydder 2011 © Karyn Chappell 2018

Imperial College London

Results

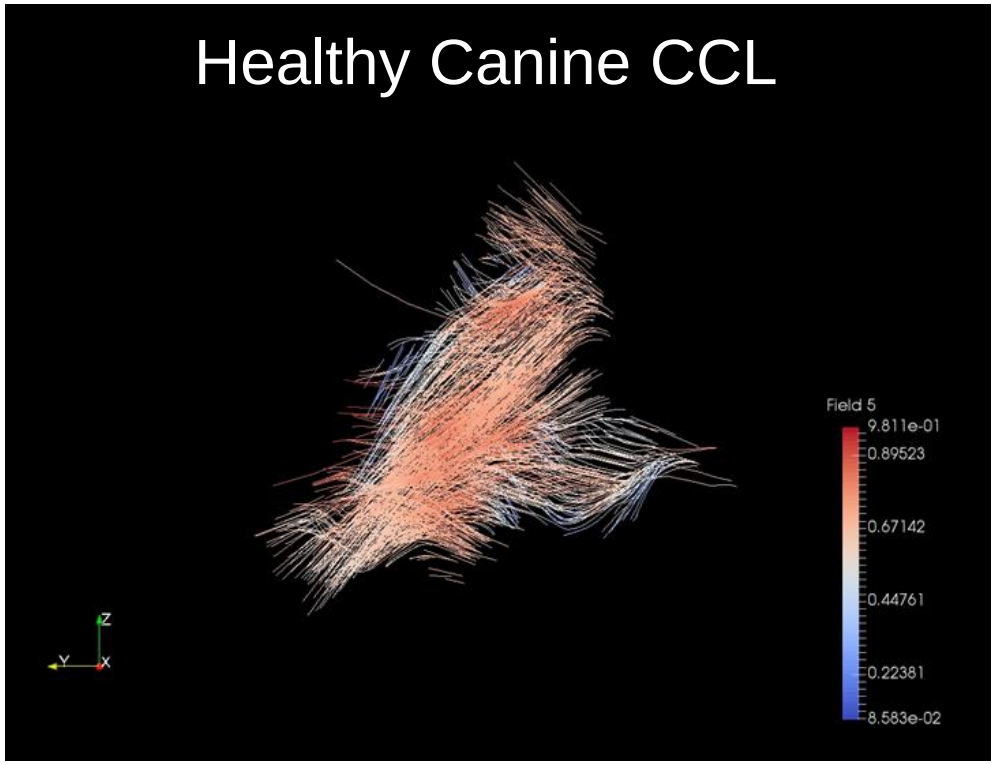


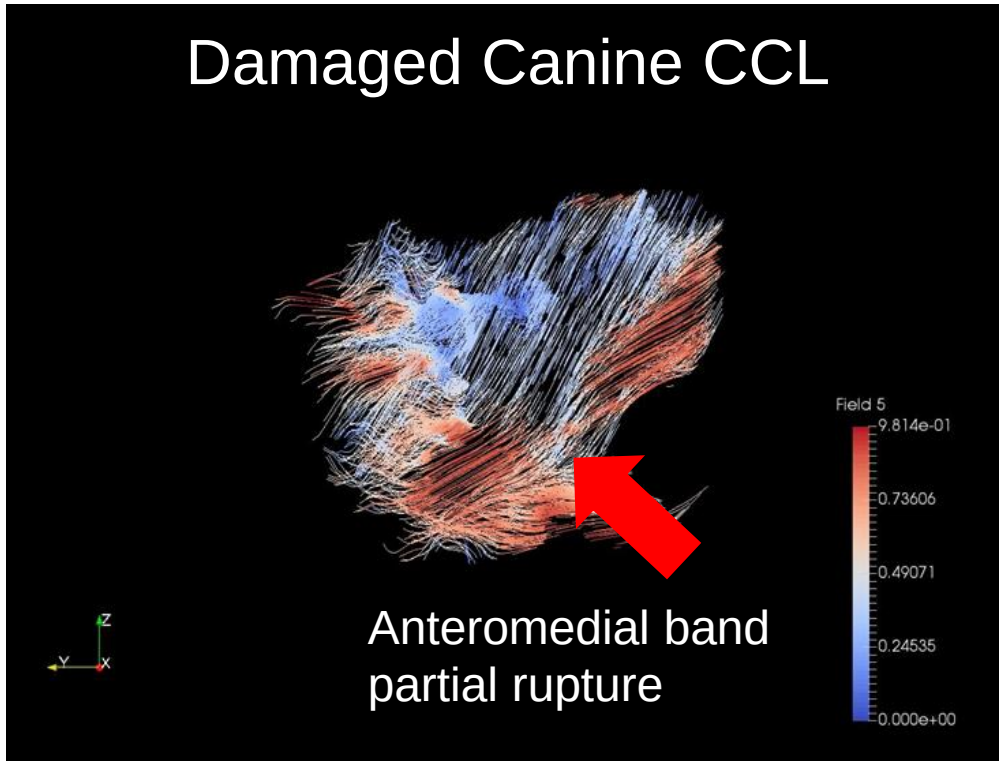


© Karyn Chappell 2018

Imperial College London

Results – Collagen fibers





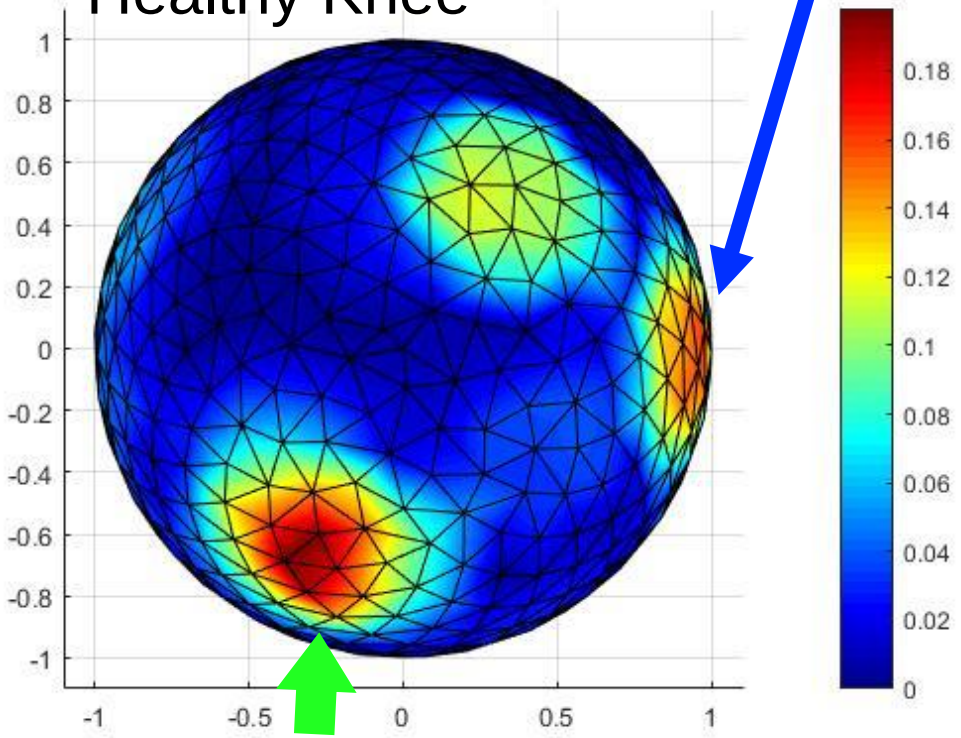
© Karyn Chappell 2018

Imperial College London

Results – Alignment Index

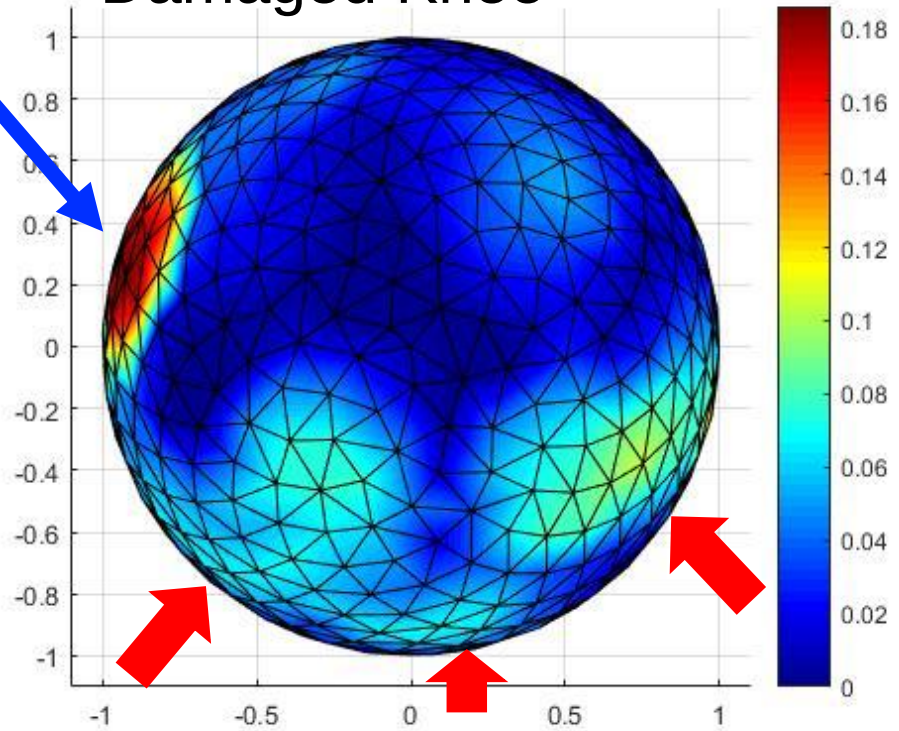
Posterolateral fiber bundle

Healthy Knee



Aligned fibers in the healthy anteromedial fiber bundle

Damaged Knee



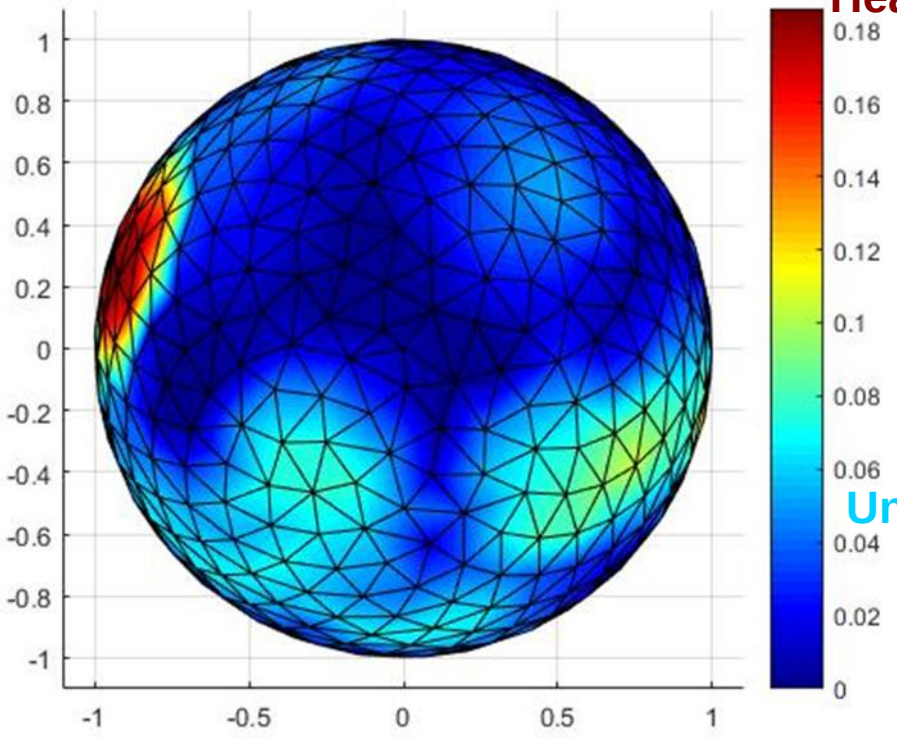
Disorganised fibers in the torn anteromedial fiber bundle

© Karyn Chappell 2018

Imperial College London

Discussion

- ECM degenerates causing ligament rupture
- Partial rupture clearly visible with magic angle imaging
- AI visualizes and quantifies changes in collagen fiber alignment within the same ligament



Healthy collagen = >0.18

Unhealthy collagen = 0.06

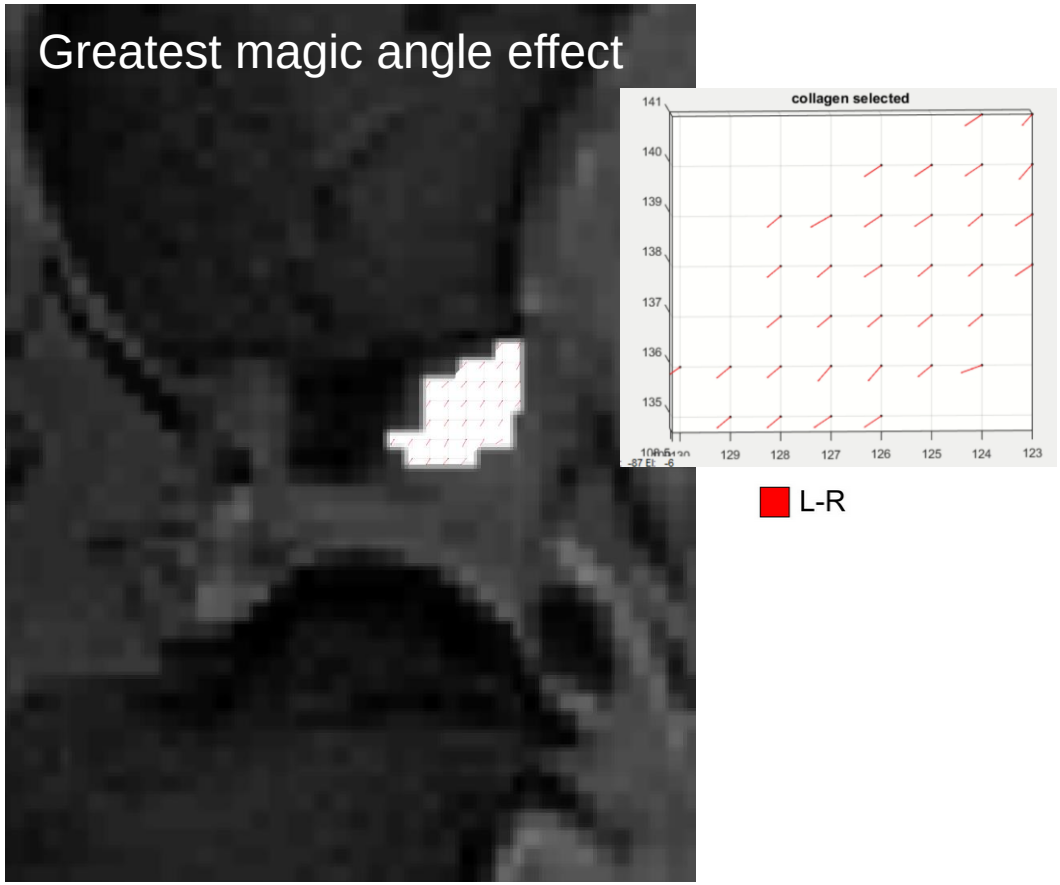
? ↓ dipolar anisotropy magic angle effect

© Karyn Chappell 2018

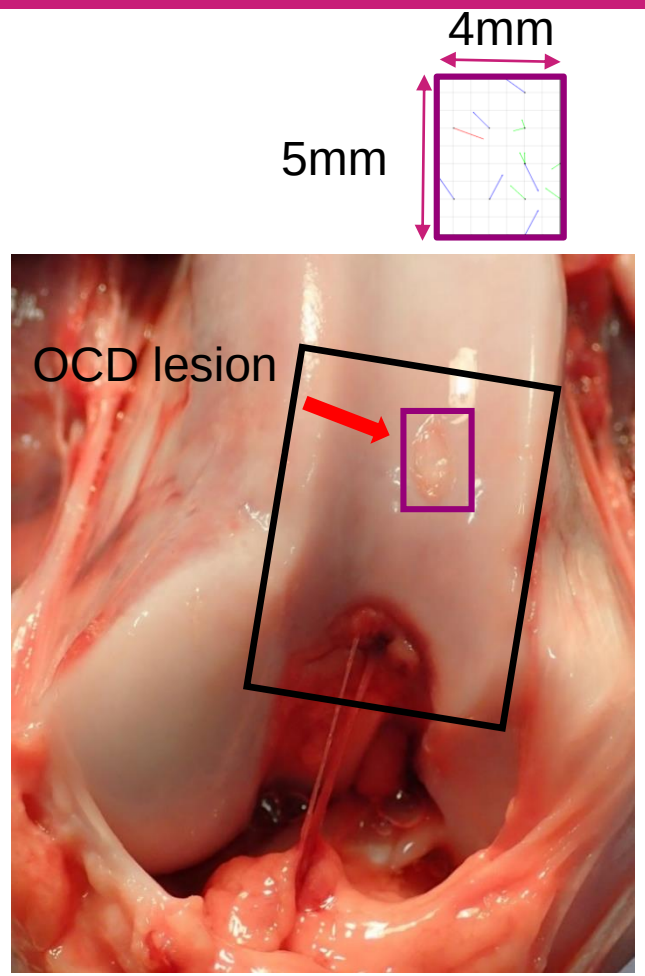
Imperial College London

Magic Angle reduced?

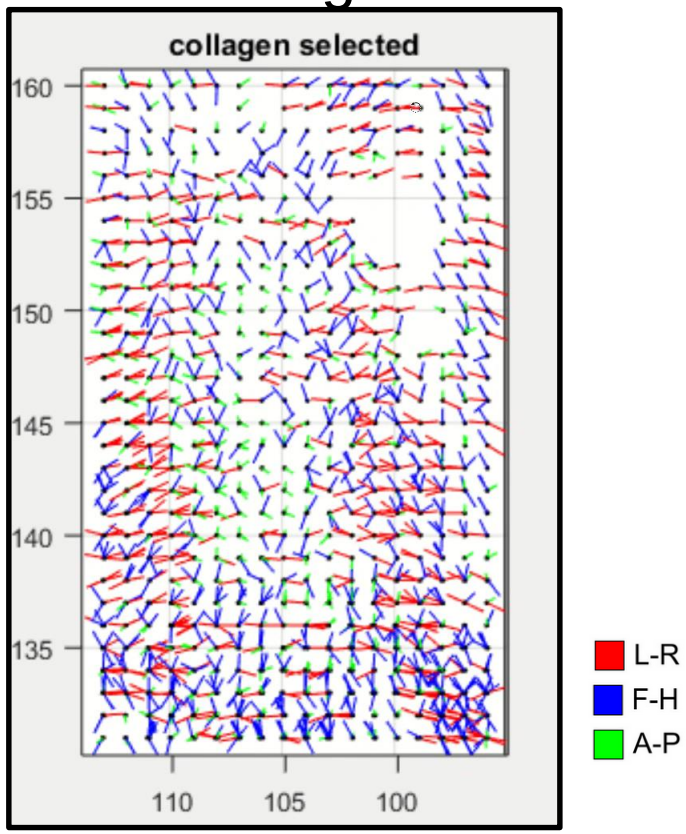
Ligament Origin



Greatest magic angle in ligament



Cartilage



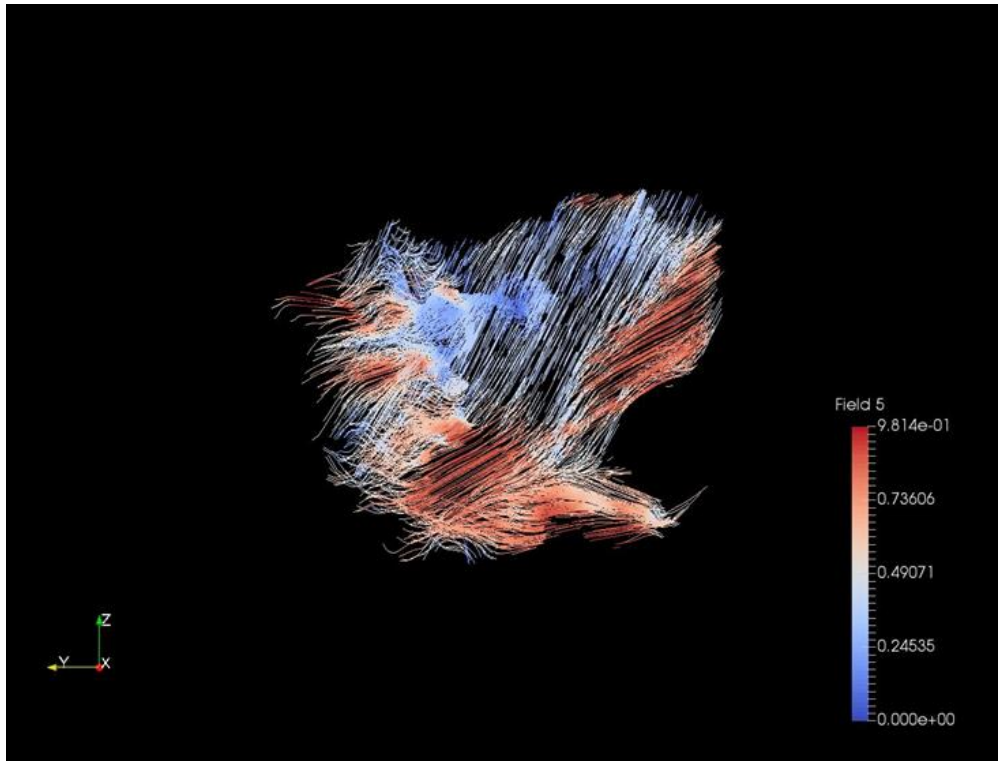
Reduced magic angle in lesion

© Karyn Chappell 2018

Imperial College London

Conclusion

- 1st visualization of a CCL partial tear with magic angle imaging
- Potential to become a non-invasive alternative to arthroscopy
- Could assess and monitor ligament damage and repair



© Karyn Chappell 2018

Imperial College London

Acknowledgements

Supervisors: Catherine Van Der Straeten, Donald McRobbie, Wladyslaw Gedroyc,

Imaging: Lesley Honeyfield, Uma Kumar, Charing Cross Hospital MRI Unit

RVC: Richard Meeson, Gordon Blunn, Richard Prior

Engineers: Magic Angle Scanner Project

- NIHR i4i Grant II-LA-1111-20005
- CoR Overseas Conference Grant

- Justin Cobb
- Alison McGregor
- Zoe Brooke

Abstract Number 0944
ISMRM 2018 Wed 16:27

Rotatable Main Field MRI Scanner for Angle Sensitive Imaging