Optimisation and visualisation of collagen fibre orientation using Magic Angle Directional Imaging (MADI)

The main aim of this thesis was to explore the potential of the magic angle effect as a new contrast mechanism. Until now, visualisation of the collagen fibres in tendons, ligaments, menisci and articular cartilage was not possible with MRI. The capabilities offered by a prototype MR scanner provided the opportunity to develop an in vivo technique. Several knee models were assessed to determine which produced the greatest magic angle effect; the goat was the optimal model. Different pulse sequences were optimised and tested to determine which was most effective. The minimum (seven) and optimal (nine) number of scan directions needed to image the collagen-rich structures of the knee were identified. A new technique was developed, Magic Angle Directional Imaging (MADI) which, for the first time, enables imaging of the key structures in the entire knee and evaluation of their underlying collagen fibres. A newly developed metric (Alignment Index) quantifies and visualises the collagen fibre orientation distribution identifying different tissue types, fibre groups and injury, showing potential as a biomarker. MADI was highly reproducible; the technique was able to identify changes to tendon microstructure after freezing and to visualise collagen fibrillogenesis. A blinded spontaneous injury model found MADI could distinguish a healthy ACL from an injured one in a canine model providing proof of concept. This work has clearly shown the efficacy of the MADI technique to assess collagenous intra-articular knee structures in two different species (goat and dog). This confirms the potential of the magic angle effect to image previously poorly defined structures in an entire joint. MADI demonstrates that the magic angle effect can be harnessed as in vivo contrast mechanism to visualise and characterise these tissues. The technique has numerous potential applications to develop our understanding of musculoskeletal health and improve patient pathways.

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