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A quantitative analysis of the effect of altered femoral bone structure with the onset of osteoarthritis in a preclinical rat model

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Osteoarthritis (OA) is a painful and slow-developing degenerative joint disease. It is seen in the changing structure of the joint tissues; e.g. cartilage and bone. Quantitative three-dimensional imaging methods allow rapid and comprehensive evaluation of bone in animal models. As such, a key to understanding the disease may be in discerning shape variations in the femoral condyles. In this study, we present shape deviations in the femoral condyles which characterise OA progression using micro-computed tomography (μCT) of rat knee joints.

Eight 3-month old male Wistar rats underwent medial meniscectomy/anterior cruciate ligament desmotomy on one knee joint (a mechanically-induced OA model), where the contralateral joint served as a control. Animals were sacrificed 6 weeks post-operatively and scanned using μCT (SCANCO Medical AG; 10 μm voxel size).

The μCT scans were processed; the femurs were segmented and all the samples were registered to the same orientation and scale. In the registered images the position of local minima in the lateral and medial femoral condyles and the local maxima in the condylar notch were identified in the coronal view (YZ plane) for all slices, see Figure 1. The height of the local maxima decreases abruptly, see Figure 2, which can be identified by a peak in the plot of the negative derivative, see figure 3. Relative to this peak, a region of 20 YZ slices were selected to find the average inclination of the medial condyle, ρ, and the average inclination of the straight line joining the local minima, p, see figure 4.

The results show that the average inclination of the medial condyle, ρ, was significantly different for operated and contralateral joints (74.3° ± 6.4° and 86.1° ± 2.8°, respectively; p < 0.02), due to altered bone structure and the presence of osteophytes; see figure 5a. Similarly, the average inclination of the straight line joining the local minima, p, was significantly different for operated and contralateral joints (7.7° ± 7.2° and 1.3° ± 1.2°, respectively; p < 0.02), indicating an increasing varus tilt in operated joints, see figure 5b.

The identification of an anatomical landmark, i.e, the local maxima in the intercondylar notch, allows for a robust analysis of altered femoral bone structure with the onset of osteoarthritis in a preclinical rat model. The average inclination of the medial condyle, ρ, and the average inclination of the straight line joining the local minima, p, in the same region show significant deviation between the contralateral and operated joints; where operated joints display an increased varus tilt and significant bone remodelling (and presence of osteophytes) on the medial condyle. These measurements are potential new metrics for clinical use to discriminate between the healthy and OA affected joints. It is expected that the OA-induced skew in the condyles would also reflect degradation in cartilage thickness. Future work will investigate cross-correlation of bone and cartilage metrics in order to build a statistical model of disease.

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