ZONAL DISTRIBUTION OF ARTICULAR CARTILAGE COMPRESSIVE STRAIN IN A MODEL OF EARLY EXPERIMENTAL OSTEOARTHRITIS

+*MATYAS, J; *Young, D; *Hulme, P; *Duncan, N
+*University of Calgary, Calgary, Alberta, CANADA. Dept. of Cell Biology & Anatomy, 3330 Hospital Drive NW, Calgary, AB, CANADA T2N 4N1, 403-229-7189, Fax: 403-270-3679, jmatyas@ucalgary.ca

Introduction: The zonal structure of normal articular cartilage is well described, though zonal differences in mechanical properties as a function of cartilage depth have recently been reported (1). As alteration of cartilage zonal architecture is an early hallmark feature of osteoarthritis (OA) (2), and cartilage softening (diminished compressive stiffness) is also characteristic of OA (3), we sought to determine if the distribution of strain within articular cartilage changes remarkably in early OA.

Materials and Methods: With the approval of the institutional animal care committee, four skeletally mature canines underwent unilateral surgical transection of the cranial cruciate ligament. Animals were euthanized 12 weeks after surgery, the distal femora were removed intact and placed into a special environmental chamber. Matched sites of the weight-bearing surfaces of the medial femoral condyle from unoperated (Ctl) and operated (OA) joints were then indented in four steps (approx. 5, 10, 15, and 20% strain) with a 3 mm diameter round, flat-ended indenter driven by a materials testing machine (MTS). Each step load was applied rapidly then allowed to reach equilibrium over 20 min with continuous recordings of load and displacement. After these tests, the cylindrical osteochondral sample that was located directly beneath the indenter was carefully removed from the joint, cut in half, and stained with the fluorescent nuclear dye Syto-13. The hemi-cylinder was then mounted face-down on a coverglass and visualized by confocal microscopy while a special instrument was used to successively compress the hemi-cylinder (after Guilak (4)). Low-magnification micrographs were used to measure successive changes in overall cartilage thickness and displacements of chondrocyte nuclei in the surface, middle, and deep zones.

Results: OA femoral cartilage was approximately half as stiff as site-matched cartilage on the contralateral control femoral condyle (Figure 1). At about 5% overall cartilage strain, the surface zone accounted for the majority of strain in CTL (65%), but reached nearly 90% in OA cartilage; the middle zone accounted for about 25% strain in CTL, but was only about 10% in OA cartilage; the deep zone accounted for about 5% strain in both CTL and OA cartilage. At 10% and 15% overall tissue strains, the surface zone strain in CTL continued to account for about 65% of the total strain; in contrast, surface zone strain in OA cartilage diminished to control values (about 65%) while mid zone strains increased to control levels (about 25%) (Figure 2).

Discussion: Although striking changes in the zonal architecture of articular cartilage occur in OA, the functional significance of these changes has remained unclear. The present study suggests that the early functional changes in OA cartilage occur primarily within the surface zone, where the proportion of total tissue strain is abnormally elevated (approximately 35%) during initial loading. These data further suggest that, if tissue strains are transmitted to the chondrocytes in OA cartilage, the likely consequence will be to dramatically alter chondrocyte metabolism and survival in the surface zone and to damage the extracellular matrix, possibly initiating or exacerbating cartilage fibrillation.


Acknowledgements: Canadian Institute for Health Research, The Arthritis Society, Natural Science and Engineering Research Council of Canada