INTERRELATIONSHIPS BETWEEN HUMAN ARTICULAR CARTILAGE THICKNESS, CHONDROCALCIFICATION AND THE SUBCHONDRAL PLATE

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INTRODUCTION: Human articular cartilage degeneration has been strongly associated with aging, the degree of osteoarthritis, as well as levels of biomechanical stress. Morphometric changes in the subchondral plate, chondrocyte density and levels of calcification have been implicated as causes of osteoarthritis, but these relationships remain controversial because of conflicting conclusions. For example, chondrocalcification has been described as an irritant, disrupting the articular matrix and advancing the process of osteoarthritis. Simultaneously, increased calcification has been thought to increase the mechanical stiffness of cartilage, which may delay or prevent osteoarthritis. This study aims to investigate the relationships between cartilage height, cartilage calcification, as well as subchondral bone thickness and density of human articular cartilage.

METHODS: One hundred six knee joints (49 female, 57 male, 50.3±17.4 years avg.) were harvested and analyzed for this study. Knee blocks were obtained from tissue banks and graded grossly (grades 1, normal, through 4, osteoarthritic) before separating the condyles for radiographic assessment of the four condylar regions (femur and tibia, medial and lateral). Radiographs were scanned and processed with image analysis software (ImageJ 1.34s, NIH). Cartilage height and area were measured manually. Calcification was identified on the radiographs as increased gray-scale intensity within the articular cartilage. The total area of these focal regions of interest were measured by thresholding or by manually painting over the area and quantifying the total area identified. From these values, a percentage of calcification could be measured. The radiographs were also used to measure the subchondral bone thickness and density. A density profile was created normal to the cartilage surface and extending through the trabecular bone. The thickness was determined as the distance from the surface of the calcified layer (highest density) to the region in which the trabecular bone was first observed (initial decrease in density). The density measurement was determined through calibration with a step wedge on all scans. Measures were taken in 5 regions for every condyle. Cell counts were performed manually on histologic preparations of the articular cartilage, stained with Safranin O. These measures were performed by cartilage zone (superficial, middle and deep) and averaged over 5 regions for every condyle.

All data were tabulated and assessed to verify relationships between age, gender, osteoarthritic grade, cartilage height, subchondral bone thickness and density, as well as chondrocyte density. Statistical differences were determined to exist with a p<0.05.

RESULTS: The average cartilage height was observed to decrease with age and was more significant in the tibial plateaus than in the femoral condyles. Cartilage thickness also tended to be greater in males than in females (p<0.05 for all condyles except medial tibiae). These values were assessed with non-osteoarthritic knee joints (grades 1 and 2) as seen in Figure 1. Thickness was also decreased with increasing grades of condylar fibrillation (Figure 2).

Neither the subchondral plate thickness or density showed a correlation with cartilage height. There were also no associations seen between these parameters and chondrocytic cell density at any zone level. Cell counts were observed to be independent of cartilage thickness and calcification levels.

No significant difference was seen in the calcification levels of cartilage between genders. There was a general negative correlation between cartilage height and calcification percentage. Though not statistically significant, higher calcification levels were observed in thinner cartilage. The subchondral bone density and thickness showed little to no influence on the calcium deposits in the matrix of the cartilage. There was a slight decrease in cartilage calcification observed in medial tibial and lateral femoral condyles with greater subchondral plate thickness.

DISCUSSION: Several interrelationships were assessed and described. Besides the expected results associated with aging and osteoarthritis, the lack of strong correlations between the morphology of the subchondral bone density and thickness and cartilage height infer that a greater skepticism should be applied to studies implicating these parameters as etiologic for osteoarthritis. There is a general consensus that greater subchondral thickness as well as increased cartilage calcification are associated with advanced OA and reduced cartilage heights. This was not seen in this study. This may be a result of the population sampling. Patients presenting clinically are generally at the end-stages of osteoarthritis and is the patient group most frequently studied. In our attempts to understand the relationships between the identified parameters, it was important to not bias the data on patients, but to include all stages of cartilage development, healthy or not.

The relative independence of cartilage height to morphologic changes, and calcium deposition gives some insight into the mechanisms that support the biomechanical equilibrium of the joint. Further studies into the biomechanical properties associated with changes in cartilage height as well as calcium distribution in the matrix and subchondral zones will better help to characterize the natural progression of articular cartilage fibrillation and degradation.

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