

Architecture of the trabecular bone between the metaphyseal and subchondral parts in the knee joint

Laura Müller(1), Alexandra Tits(1), Erwan Plougonven(2), Pierre Drion(3), Enrico Dall'Ara(4), Angélique Léonard (2), G. Harry van Lenthe(5), Davide Ruffoni(1)

(1) Mechanics of Biological and Bioinspired Materials Laboratory, University of Liege, Liege, Belgium

(2) Chemical Engineering Department, University of Liege, Liege, Belgium

(3) Experimental Surgery Unit, GIGA and Credec, University of Liege, Liege, Belgium

(4) Department of Oncology and Metabolism, University of Sheffield, United Kingdom

(5) Department of Mechanical Engineering, KU Leuven, Leuven, Belgium

Topic: biomechanics & biomaterials

Articular joints are complex structures that rely on biomechanical and biological integration of two strongly dissimilar tissues: the hard mineralized bone and the soft cartilage. Where bone and cartilage are joined together, both tissues present specific adaptation strategies to solve their dissimilarities. The bone beneath articular cartilage is composed of the subchondral region, a thin growth plate and then the metaphyseal region. Given the unique ability of bone to reorganize its structure according to the local mechanical environment, we investigate whether bone below articular cartilage in the knee displays specific microstructural features to facilitate force transmission. Specifically, we used X-Ray micro-computed tomography (micro-CT, 15 μm isotropic voxel size) to characterize the spatial evolution of bone microstructure when approaching the articular cartilage in adult male Sprague-Dawley rats. Our quantification of the overall bone morphology revealed that proximal trabecular bone in the metaphyseal region below the growth plate had a bone volume fraction (BV/TV) about 20% higher than in the subchondral region, mainly due to a decreased trabecular spacing (Fig. 1A), with only small changes in trabecular thickness. A central observation is the large difference in the degree of anisotropy (DA) between the two regions: the trabecular network beneath the growth plate was about 3.6 times more anisotropic than in the subchondral region. A spatially resolved analysis was then performed, using moving cubes of 750 μm side length, placed in the antero-medial position (Fig. 1B). Moving away from the growth plate, BV/TV decreased in a double-liner fashion: firstly quite fast (slope of 45.16%/mm) then more gradually (28.57%/mm). This drop was accompanied by an increase in the anisotropy when approaching the medullary cavity. Our results highlighted distinct microstructural features in locations right above and below the growth plate, probably reflecting fairly dissimilar loading conditions despite being very adjacent regions. Ongoing work focuses on characterizing microporosity at a higher resolution to quantify the shape and arrangements of osteocytes and chondrocytes lacunae in bone and mineralized articular cartilage, comparing healthy and aged bone.

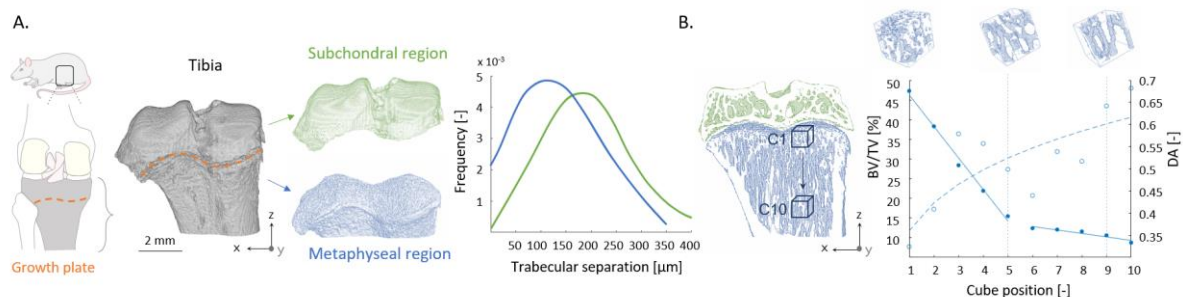


Fig.1: A. Sketch of the investigated bone regions and frequency distribution of trabecular separation in subchondral (green) and metaphyseal (blue) region. B. Spatially resolved analysis and evolution of bone volume fraction (BV/TV, full line and filled dots) and degree of anisotropy (dashed line and empty dots).