CHANGES IN SUBCHONDRAL BONE MICROSTRUCTURE AND SHAPE WITH AGE IN TIBIAL KNEE

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Introduction

Osteoarthritis (OA) is a degenerative joint disease, believed to be one of the leading causes of disability, with higher prevalence with aging [1]. The knee is a complex articular joint and one of the most commonly affected sites by OA. Subchondral bone, located just below the articular cartilage, is crucial to the functioning of the joint, helping to distribute forces and preventing stress concentrations. Despite the importance of subchondral bone in joint health, little is known about its microstructural, material and biomechanical changes with aging. This study aims to address this gap by characterizing the entire microstructure of subchondral bone in the tibial knee of adult and old rats, with a focus on both trabecular and cortical compartments. The ultimate goal of this study is to understand how changes in this region may contribute to the development of OA.

Methods

Proximal tibia specimens were harvested from adult and old (1 and 12 months old) Wistar rats (n=8), available as sample organ donation (approval: IACUC-22-2416) and scanned using X-ray micro-computed tomography (micro-CT, 10 µm voxel size, SkyScan1272). The subchondral trabecular compartment was separated from the cortical shell and trabecular bone morphology was quantified through bone volume fraction (BV/TV), trabecular thickness (Tb.Th), trabecular separation (Tb.Sp), and degree of anisotropy (DA), comparing bone medial and lateral regions. The thickness of the cortical layer (subchondral plate) was computed in two selected regions of the medial and lateral plateaus (Fig.1a). The top cortical surface (featuring mineralized cartilage) was described by a polynomial function and the local Gaussian curvature was calculated [2].

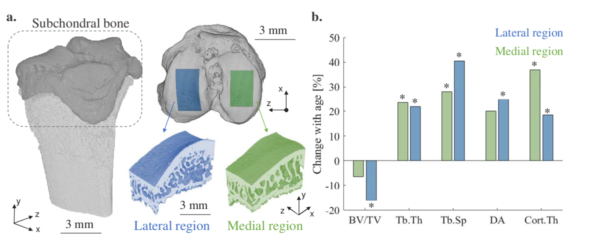

*Fig. 1: (a) Illustration of the extracted regions for cortical analysis. (b) Percentage changes of trabecular and cortical bone parameters with age in the medial and lateral regions. * denotes a significant change with age.*

Results

The global analysis of the subchondral trabecular bone revealed a higher DA in the medial region, which increased in both compartments with age, with higher DA in the lateral side. A decrease in BV/TV with age (up to 20%) was observed, mainly due to an increase in Tb.Sp. In contrast, an increase of up to 40% in cortical thickness was measured. These changes were present in both compartments (Fig. 1). Curvature was highly different between the two plateaus, with the lateral side characterized by a far less flat surface (Fig. 2). Aging seems not to affect local curvatures.

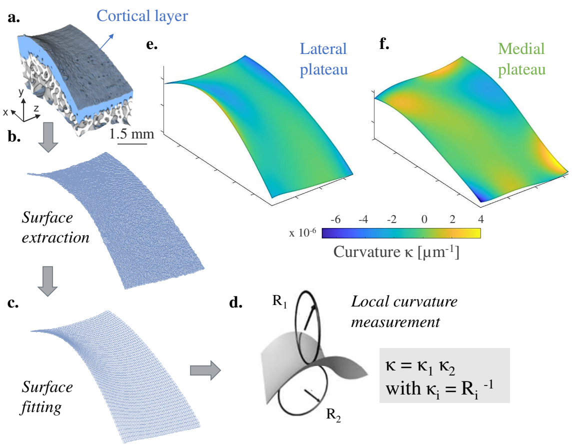

Fig. 2: (a-d) Methodology for curvature analysis and resulting two-dimensional map at the lateral (e) and medial (f) plateau. Scheme in (d) from [2].

Discussion

We highlighted different age-related changes in the medial and lateral subchondral trabecular bone microstructure and cortical layers. Trabecular bone loss was accompanied by an increase in the thickness of the subchondral plate. Building on the crucial role of curvature in biological systems [2], the shape specificities in the lateral and the medial plateaus, which are subjected to distinct loadings, suggest a potential adaptation to the local stress environment. Ongoing work focuses on possible correlations between the plateaus and the underlying trabecular architecture, as well as on higher resolutions micro-CT scans to characterize microporosity (cell lacunae and channels), comparing healthy and aged bones.

References

1. O'Neill et al., Clin Rheumatol, 312:326-32(2), 2018.
2. Schamberger et al., Adv Mater, 2206110, 2022.