Age-related changes of mechanics and structure in human trabecular bone

Christina Rönngren

The bones in our bodies are constantly rearranged throughout our lives, to maintain mechanical quality and strength of the bones. When we get older, the old bone is removed faster then new bone is formed. This results in a lower bone mass. The bone loss is mostly affecting the spongy, trabecular bone. Although lower bone mass may increase the risk for fragility fractures, the structure and shape of the bone seem to have a greater impact when estimating the risk of fracture. In this project I have investigated how the bone structure on the micro-scale is affected by age and how that is related to the bones ability to sustain load.

BONE

Bone is a remarkable material and tissue. It needs to be a light weight material, but still endure high stresses. This enables rapid movements without deforming too much or fracturing when exposed to heavy loads. The bone material itself consists of two main building bricks, a stiff mineral and a flexible collagen.

A whole bone has two different structures, one compact structure containing packed cylindrical shaped bone-units and one more spongy-like structure (Fig. 1). The compact part, also called cortical bone, acts as a shell to the bone and provides stiffness to the bone. Within the shell of compact bone a spongy bone structure is present, called trabecular bone, which is a mesh-like structure with rods and plates.

Around the age of 50 the amount of bone continuously gets lower as a result of faster removal then addition of bone with ageing. This leads to an increased risk of fragility fractures, most commonly in the hip and spine. A hip fracture can be a severe condition for an old person and these kinds of fractures often lead to hospitalization, or even worse, death. The amount of bone has a moderate effect on the resistance to fracture. More importantly, structure and shape of the bone are critical when assessing how easily the bone fractures. The trabecular bone volume is mostly decreasing in the beginning of the age-related bone loss. To understand how bone loss affects the trabecular bone, structural measurements and mechanical testing may be performed on bone samples, see Fig. 1. The results may contribute to a comprehensive understanding of the mechanics of the whole bone and explain the mechanisms behind bone damage and fractures.

CHARACTERIZING CHANGES IN THE TRABECULAR BONE

In this thesis project, structural and mechanical properties of trabecular bone plugs were investigated. The plugs were drilled out of the thigh bone, from the knob which is attached to the pelvis in the hip, see Fig. 1. The plugs were taken from donors of different age. Computed tomography with μm-precision was used to construct a 3D-image of the plug, using several X-ray projections of the samples from different angles were used. From the 3D-image, seen in Fig. 1, several structural parameters were calculated, e.g. the average thickness of the individual trabecular rods. I found that the trabecular rods becomes thinner with ageing. The mean thickness of an individual trabecular rod is around 0.2mm.

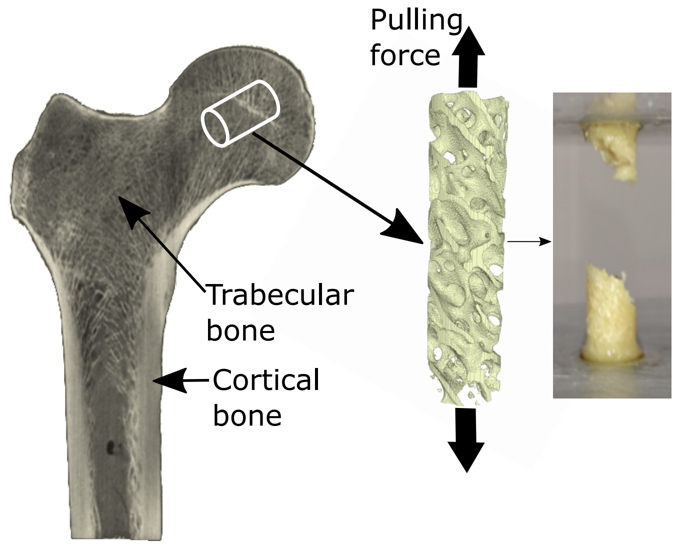

Fig. 1. Cross-section of a thigh bone near the hip. The bone plugs were drilled out from the knob and measured with computer tomography to access the plugs' internal structure. Then the plugs were mechanically tested by pulling them apart as the arrows indicate. The test resulted in a fracture of the bone plugs.

The mechanical data was obtained by pulling the sample plugs apart until they broke, as shown in Fig. 1, and at the same time record force and deformation. Several mechanical parameters were calculated and I found that the trabecular bone becomes more brittle with ageing. The energy required to fracture the trabecular bone and the ability to deform the bone is drastically impaired the older we get. Instead of resisting the permanent deformation, the bone breaks.

UNDERSTAND THE COMPLEXITY OF BONE

This thesis is a part of a larger research project investigating the damage and fracture mechanisms on the micro- and nano-scales. To further explain the bones complexity, it could be suitable to use other investigative techniques with higher precision and accuracy. By continuing the research on bone across many length scales with multiple methods, we may be able to fully understand the age-related bone loss and prevent fractures. This would save both money and lives.