Methods for quantitative analysis of bone degradation and remodeling from µCT images

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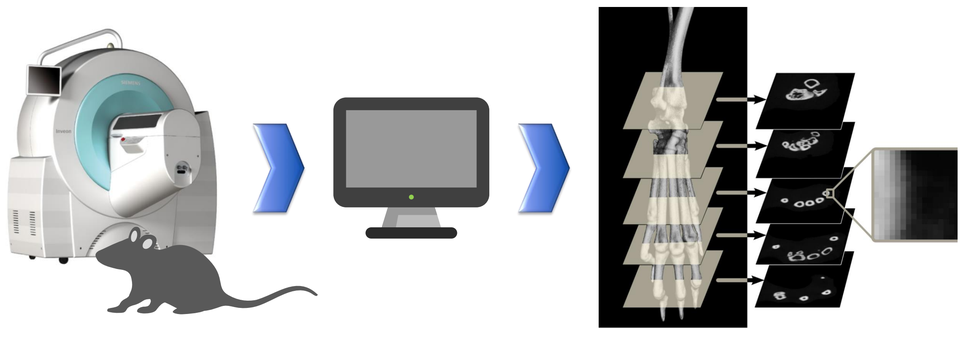
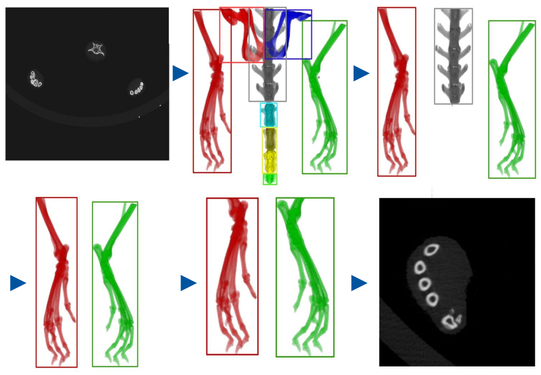
Introduction

Bone morphology and microarchitecture are important features in various fields of research and medicine. Since they change during development and growth, but also under pathological conditions, they can be utilized to assess disease progression or phenotypic abnormalities in new preclinical models of human diseases. The non-invasive imaging via modern high-resolution computed tomography (CT) allows *in vivo* bone studies, but at the same time produces huge datasets that have to be processed in an automated and objective manner. We therefore developed algorithms to quantify two different bone features, *i.e.* bone surface roughness [1] and the cortical thickness gradient [2]. Both were successfully applied in different research studies to quantitatively describe bone morphology and pathological bone changes.



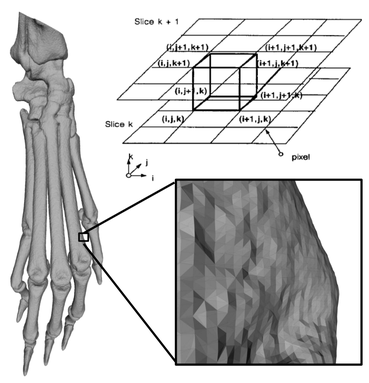
Bone surface roughness

Automated extraction of volumes of interest (VOIs)



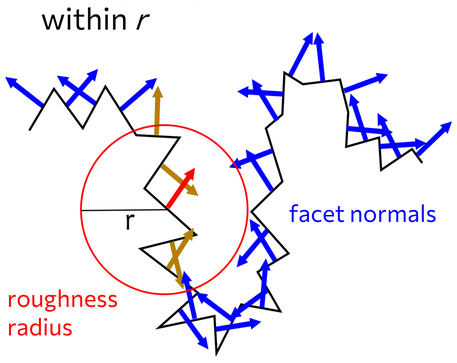
Surface reconstruction

- marching cubes algorithm [3]

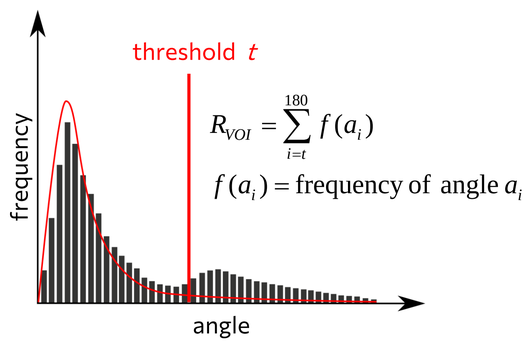


Roughness calculation for

1) local surface [4]
- average angle of facet normals within *r*

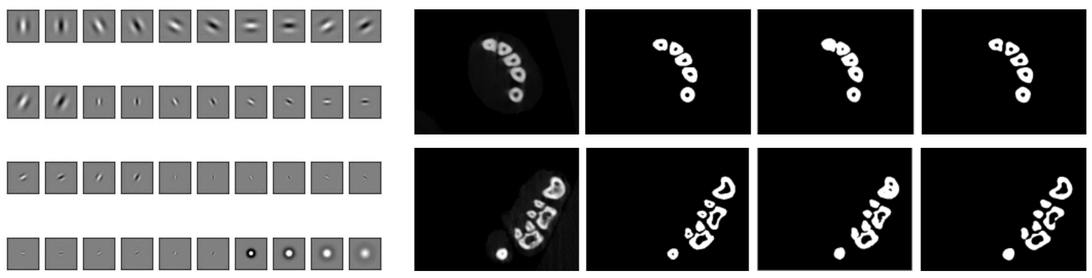


2) entire VOI
- integrated frequency of angles > *t*



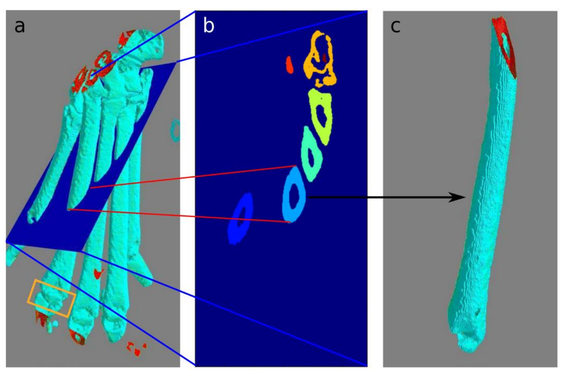
Cortical Bone Thickness

Texture-based segmentation of CT images



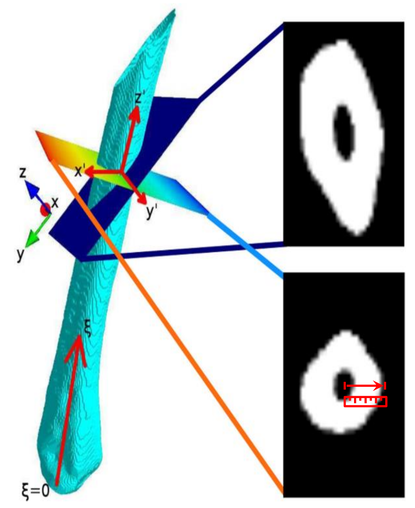
Isolation of metatarsal bones

- semi-automated extraction of three middle metatarsals



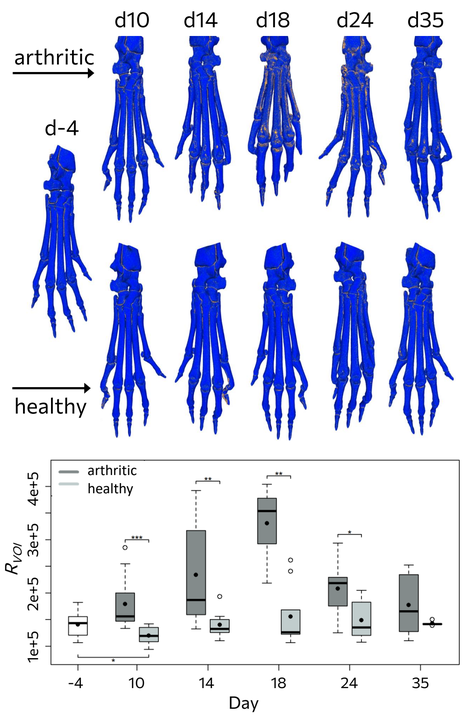
a – identification of metatarsophalangeal joints
b – tracking of individual bones along stack
c – isolation of metatarsals

Bone orthogonalization and tracking of cortical thickness

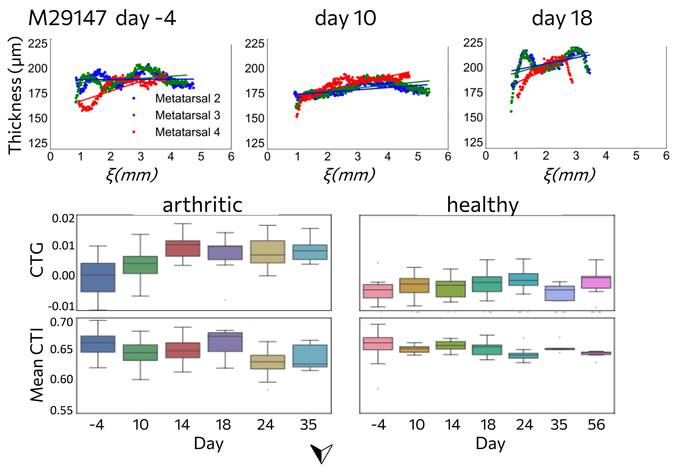


Applications of Bone Surface Roughness and Cortical Bone Thickness Analysis

Quantification of bone degradation in experimental rheumatoid arthritis [1, 2]

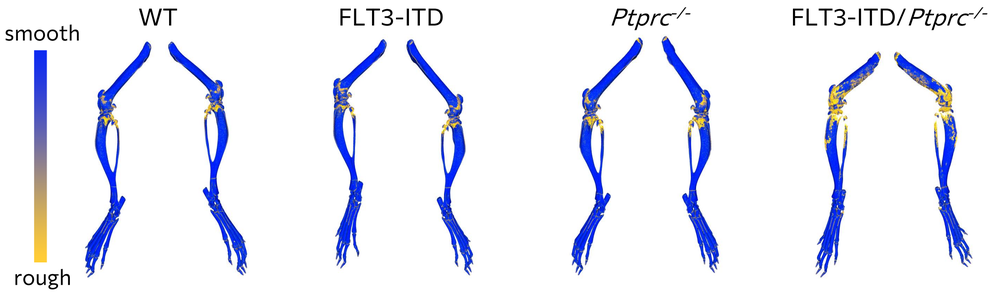


➢ roughness analysis reveals sites of bone degradation and dynamic arthritis progression



- cortical thickness gradient (CTG) captures loss of cortical substance near joints
- more sensitive than already established cortical thickness index (CTI)

Bone structural changes in FLT3-ITD positive mice of acute myeloid leukaemia model [5]



- visualization highlights regions of increased bone surface roughness
- roughness measure correlates with traditional bone measurements

Genotype	Femur length [µm]	Bone Density [HU]	Roughness [°]
WT	11.75	4363.3	31.4
FLT3-ITD	11.70	4016.9	33.3
Ptprc$^{-/-}$	11.25	4133.0	32.9
FLT3-ITD/ *Ptprc*$^{-/-}$	9.23	3601.2	38.8

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