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MICROSTRUCTURAL PROPERTIES OF ACETABULAR REGION OF HUMAN PELVIC BONE REVEALED USING MICRO-CT

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Summary: *The paper deals with microstructure investigation of trabecular bone in acetabular region. Trabecular bone microstructure is the main factor of the bone quality and mechanical propertites at macroscopic level. Data from high resolution micro Computed Tomography can be used to reconstruct the complex geometry of the trabecular bone inner structure and interface between bone and implant. The data are usable as for micro-FE modeling as well as for experimental loading tests evaluation.*

1. Introduction

Microstructural properties of trabecular bone at acetabular region have essential influence on hip join function. Living bone tissue is continuously in the process of growing, strengthening and resorption, a process called ”bone remodelling”. Initial trabecular bone adapts its internal structure by trabecular surface remodelling to accomplish its mechanical function as a load bearing structure (Currey, 2002; An, 2000). The stress state changes in acetabulum which can be caused for example by local overloading or osteoporosis. Osteoporosis is a disease of bone that leads to an increased risk of fracture because of bone mineral density (BMD) reducing. Osteoporosis is also very painful and could bring patient immobility. In this case the only way to recover the mobility of the patient is hip joint replacement, but after implantation is the stress state changes again. Using the high resolution micro Computed Tomography seems to be suitable way for inner microstructure investigation.

2. Microtomography measurment

The microtomography device at Institute of Experimental and Applied Physics (IEAP) was used to obtain the microtomography images of acetabular region. Because of X-rays the whole device is shielded by lead box. Manipulation with X-ray source, table with specimen and detector are provided by stepper motors with USB interface and controlled by Pixelman software plug-in. Hamamatsu microfocus X-rax source L8601-01 with wolfram anode was used. Further specification is in table 1.

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Table 1. MICROFOCUS X-RAY SOURCE L8601-01 specification

Parameter	Value	Unit
Target voltage	$20-90$	kV
Target current	$0-250$	μA
Max. output power	10	W
Focal spot size	5	μm
Beam angle	39	$^\circ$

In comparison with common medical snanners flat panel detector (FPD) with thin-film transistor (TFT) construction working area detection mode was applied in this scanning setup. Signal detected on each pixel on the detector is integrated to the memory and we get directly area scan (Dammer, 2005; Jakubek, 2007). Dimensions of detector are $120 \times 120\,\mathrm{mm}$ with maximal resolution $4\,\mathrm{Mpx}$.

Pelvic bone was fixed on rotating table in illiac area so the acetabular area was free for scanning. Scanning sequence consisted of 360 scans with 1° step. Acquisition was two times $1\,\mathrm{s}$ with voltage $40\,\mathrm{kV}$ and current $250\,\mu\mathrm{A}$.

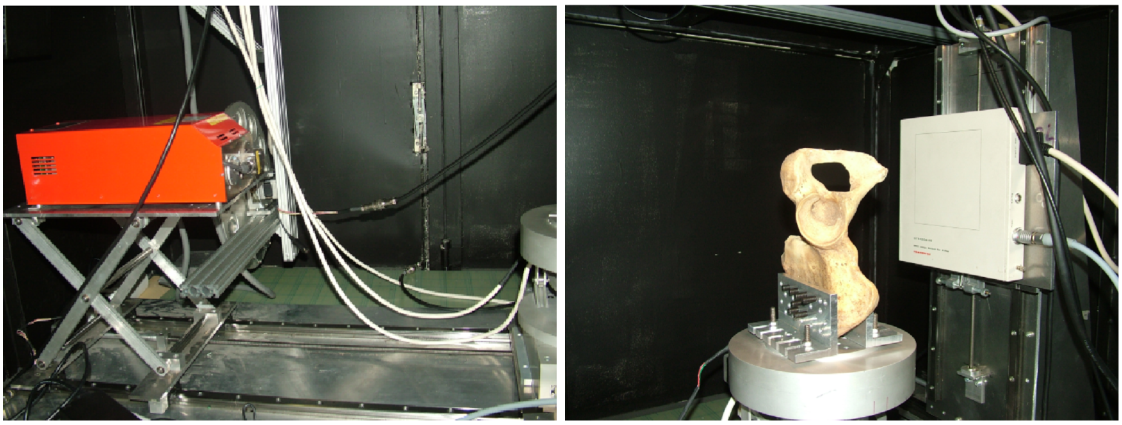

Figure 1: Measurment setup

Couple of calibration measurments have held for the noise reduction. Flat field correction (scanning without specimen) for inhomogeneity reduction of beam intensity, dark current correction (scanning with disconected source) to reduce detector defects and beam hadrening correction to get absorbing characteristic, were performed.

3. Reconstruction

Acetabulum was reconstructed from sequence of 2D matrixes. Every single element of the matrix represents output emission insensity I on detector. Relationship between input and output intensity is given by:

$$\frac{I_0}{I} = e^{\mu_T d} \tag{1}$$

where I_0 is the value of input emission emited by X-ray source, d is the thickness of the specimen and μ_T is linear coeficient of absorbation (Jakubek, 2008).

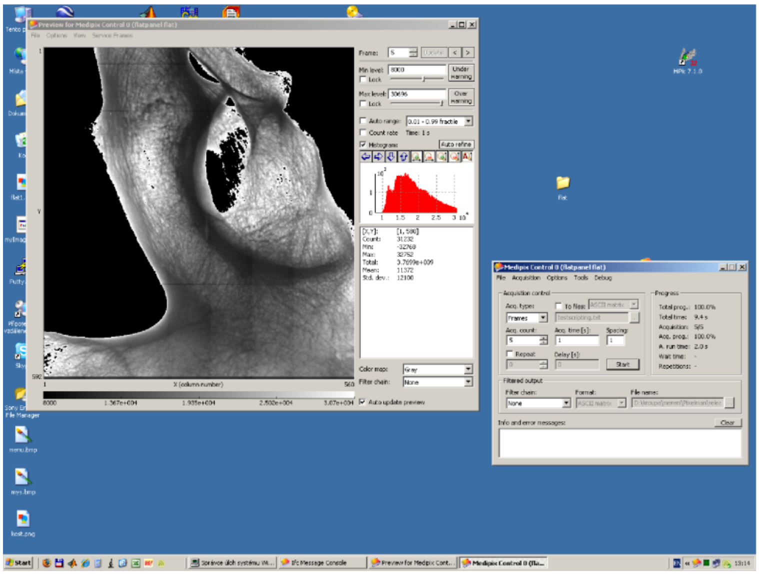

Figure 2: Scan preview in Pixelman

To make a correct reconstruction it is necessary to reduce the noise in the scans. Detector defect noise is reduced by subtraction of “dark current“ matrix from original scan, beam inhomogeneity is reduced dividing by ”flat field“ matrix (Jirousek, 2008). More noire was reduced by two step thresholding. Isolate element with peak intensity values (radom deficiency) was replaced by median value of adjacent elements.

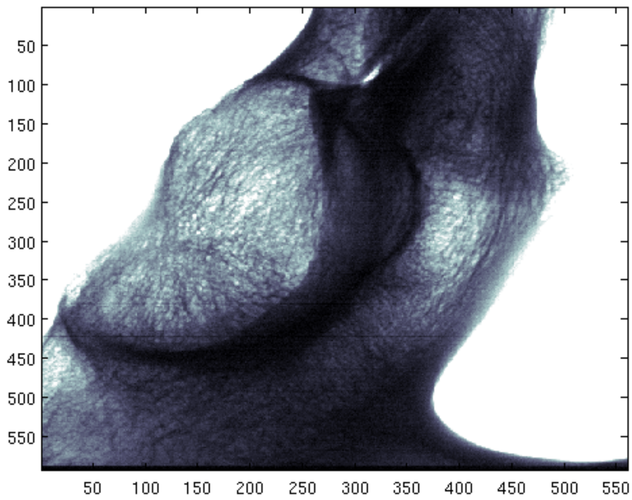

Figure 3: Filtered scan

Radon transformation, the integral transform consisting of the integral of a function over straight lines and the inverse Radon transform (Vlcek, 2007) is used for reconstruction. The result of the reconstruction is 3D matrix containing the object with visible inner microstructure.

4. Conclusions

Use of microfocus source and large high resolution flat panel detector allows reconstruction of full-scale microstructural models. These models are suitable for structural changes investigation in case of osteoporosis as well as for trabeculae microdamage and for total hip join replacement behavior. Migration, micromotions and consecutive loosening of the implant could be observed by this method.

5. Acknowledgment

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