3D Bone Architecture in Osteoporosis

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The bone mineralization process and its pathological alterations is one of the fields of interest for contemporary medicine. There are still open questions concerning the onset of its dynamics and the mechanism of being influenced by different physical or chemical factors. The aim of the project is to develop the method for precise assessment of the trabecular bone architecture allowing the investigation of the influence of different factors on the development of mineralization process. In particular, the influence of magnetotherapy on the experimental osteoporosis will be studied. The developed method will work on the basis of three-dimensional (3D) geometry and parameters describing the 3D trabecular bone architecture. The previously reported results suggest that the architectural parameters are more precise and reliable for the description of bone changes than density-related parameters [1,2].

At the current stage of the project we aimed on the choice of best bone architectural parameters allowing the estimation of subtle architecture changes. Two questions had to be answered: (1) are there parameters distinguishing between the normal and osteoporotic bones and (2) is it possible to recognize the difference between control group and bones treated with extremely low frequency magnetic field (ELFMF) [3].

The investigation is based on the rat bone model. Pregnant female rats were taken into consideration. One group was treated with ELFMF. Parameters typical for magnetotherapy in humans were utilized. The rats were also treated with their breed after the labour. The second group with their breeds were considered as a control. The young treated and control rats were killed in different age (10, 20 and 30 days). Their femoral bones were dissected and investigated. Moreover, one animal was ovarectomized in order to induce the experimental osteoporosis. The animal was killed 6 months after ovarectomy and their bones were dissected.

The bone samples were scanned with the microtomography with the use of synchrotron radiation. The beamline BW2 equipped with microtomographic scanning system was utilized. The energy of 24 or 18 keV was used depending on sample sizes. Achieved image resolution was about 10 μm for the biggest samples and about 6 μm for the smallest. Two young rat bones of the age of 20 days and 30 days as well as their control counterparts were investigated. Also the ovarectomized rat bone and its control counterpart were scanned. The proximal femoral head was taken into consideration. A set of parameters characterising the trabecular bone was calculated, e.g.: tissue volume (TV), bone volume (BV), trabecular thickness (TT), trabecular number (TN), trabecular separation (TS) and BV/TV. Also the trabecular thickness distribution (Fig. 1) and trabecular separation distribution were calculated. A reconstructed 3D image of the ovarectomized bone sample is shown in Fig. 2.

On the basis of calculated parameters it can be stated that the ELFMF treatment influences badly the bone architecture in the first stage of the mineralization process (20 d) but finally there is no big difference in measured parameters at further stages (30 d). The relative differences of chosen parameters calculated for the control and bone treated with ELFMF ((control - treated)/control) are as follows: BV/TV: -27%, TT: -10%, TN: -18%, TS: 37%. The same differences calculated for 30 d old bones are as follows: BV/TV: 3%, TT: -2%, TN: 5%, TS: 32%. The relative changes amplitude seems to be enough to investigate the influence of ELFMF on the bone architecture but the individual variability have to be investigated to draw the final conclusions.

In the case of ovarectomized animal compared to control sample TN is decreasing (-8%) while TT rises (13.5%). Surprisingly BV/TV rises (4%), but there is the same problem as in the case of

previous results. The individual variability is not known because of lack of data allowing statistical analysis.

In all cases the calculated parameters variability would be sufficient for drawing reasonable conclusions if it would be possible to compare it with the known individual variability of calculated parameters. In the present project stage additional samples should be investigated in order to allow the statistical analysis.

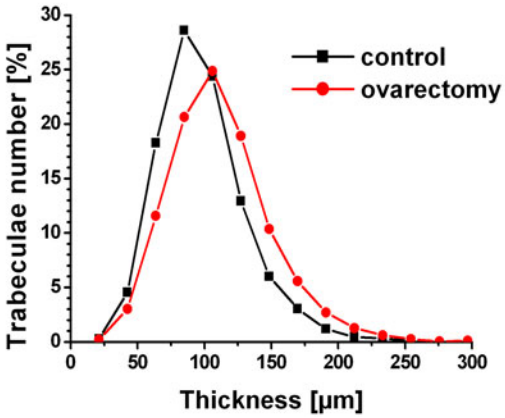

Figure 1: The distribution of trabecular thickness calculated for ovarectomized sample and control.

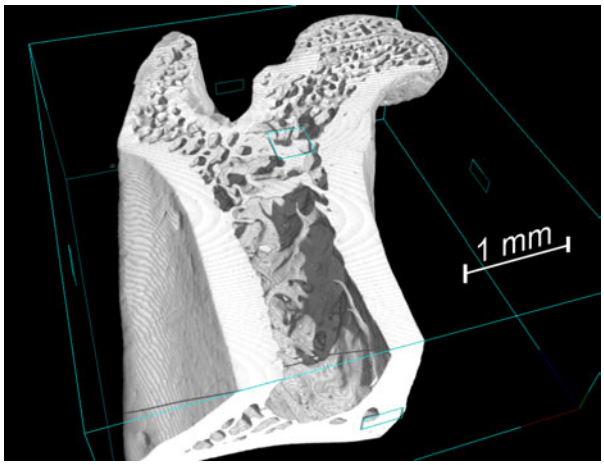

Figure 2: A sample of three-dimensional reconstruction of the ovarectomized bone sample.

References

[1] M. Stenstrom, B. Olander, D. Letho-Axtelius, J. Madsen, L, Nordsletten, G. Carlsson, J Biomech 33, 289 (2000)
[2] M. Audran, D. Chappard, E. Legrand, H. Libouban, M. Basle, Calcif Tissue Int, 69, 214 (2001)
[3] C. Sert, M. Deniz, M. Zahair Duz, F. Aksen, A. Kaya, J Bone Miner Metab, 20, 345 (2002)

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