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RELATIONS BETWEEN BMD DENSITY AND VOLUMETRIC AND FRACTAL INDICATORS OF HUMAN TRABECULAR BONE

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Abstract

BMD density, fractal dimension and volume tissue in volume of sample can be used to estimate the strength of trabecular bone. In the paper, presented is the comparison relations between the indicators for two groups of human trabecular bones – osteoporotic and coxarthrotic. Dependencies between the indicators were described with the determination coefficient R^2. Achieved values of the coefficient are contained in range 0,2÷0,56.

Keywords: *trabecular bone, BMD, fractal dimension*

1. Introduction

For the estimation of bone quality and risk of fracture, densitometric techniques are widely used, such as quantitative computed tomography (QCT) or dual energy x-ray absorptiometry (DEXA). The result of the measurement is the value of density of selected bone parts. The limitation of this methods is a lack of possibilities to explain individual differences in trabecular bone architecture [1-2]. Obtained density is a mean value which isn't allowed for local differences in subvolumes of trabecular bone. For example, one of the results of DEXA measurement is the value of BMD density.

Fractal dimension (Df) is also one of indicators used to describe a complex porous structure in medicine, e.g. trabecular bone architecture [3-5]. The dimension can be calculated for the structure of all samples of trabeculaes or subvolumes. The other indicator used to describe trabecular bones is the volume of tissue (V). The volume can be also calculated for all sample or subvolumes.

BDM, Df and V can be used to describe the strength of trabecular bone. The aim of this study is the estimation of relations between BMD density, fractal dimension and volume of tissue for trabecular bone.

2. Experimental methods

Material for the investigation were samples of human trabecular bone. Samples were collected from 21 osteoporotic (Ost) and 21 coxarthrotic (Cox) femoral heads gained in result of hip arthroplasty. Coxarthrosis is one of bone diseases. One of the results is hyperthrophy articular cartilage in volume and surface femoral head. Because authors didn't have possibilities to use as a reference group similar numbers of samples collected with bones without any bone diseases, they

assumed as reference group a set of coxarthrosis samples. Because coxarthrotic bones similarly as healthy bones are subject to fracutre very seldom, they assumed that mechanical strength of the bones is not less than that of bones without any bone diseaes [6].

The samples used for investigation have cylindrical shape with diameter of about 10 and height of 8,5mm. The manner of collecting samples is presented in Fig. 1.

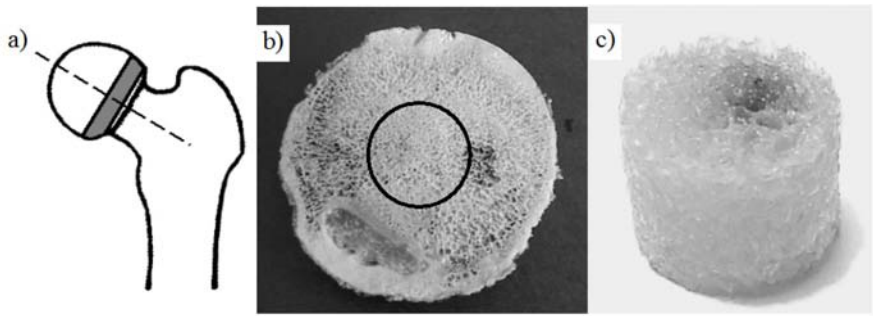

Fig. 1. Manner of collecting samples: cutting slice a), cutting sample b), sample c)

BMD density of samples was performed with scanner Lunar Expert, General Electric Company. Samples were also examined at microCT device (μCT80) with resolution of 36μm. In result of the investigation, sequential images slices perpendicular to the axis of the sample were obtained. On the basis of the images, geometrical models of samples were created. These were divided into subvolumes in shape of layer of height of about 36μm. The layers were created as following: images of two neighbouring slices were compared. When on the same coordinate in both image, colored pixels represented the bone, voxels of layer of bone between the images were created. The size of voxels was the same as of the pixels at images, i.e. 36μm.

The volume (V) of all layers for every sample was examined. On that basis, found were the mean (V_m), minimal (V_{min}) and maximal (V_{max}) volumes of layer for every sample.

For the same layers, the fractal dimension (Df) was calculated and then the mean (Df_m), minimal (Df_{min}), maximal (Df_{max}) value of this dimension for every sample was determined. For the purpose of defining the fractal dimension, the definition of 'box' dimension (Minikowski – Bouligand) was used.

Experimental results

In Tab. 1, presented are the values of detemination coefficient R^2 obtained for relations between BMD and mean, minimal and maximal volume of tissue for layers of sample. In Tab. 2, presented are the values of determination coefficient obtained for relations between BMD and mean, minimal and maximal fractal dimensions. In the tables, maximal values of R^2 are presented for the study of the description of power, logarithmic and numerical functions.

Tab. 1. Value of determination coefficient R^2 for the relationship of BMD with volume of tissue

Samples	Ref		V_m	V_{min}	V_{max}
		1	2	3	4
Ost	1	BMD	0,41	0,40	0,34
Cox	2	BMD	0,35	0,48	0,20

Tab. 2. Value of determination coefficient R^2 for the relationship of BMD with fractal dimension

Sample	Ref		Df_m	Df_{min}	Df_{max}
		1	3	4	5
Ost	1	BMD	0,42	0,37	0,34
Cox	2	BMD	0,44	0,56	0,23

Generally obtained values R^2 weren't to high and contained within the range (0,2÷0,56). In case of osteoporotic samples, better relations have been obtained for mean values V_m and Df_m. In case of coxarthrotic samples, better relations have been obtained for minimal values V_{min} and Df_{min}. Authors, on the basis of the analysis of topic literature, aren't able explain this fact. However, it indicates significant differences in the structure of both groups of samples.

The values R^2 pointed out that relations between BMD and V or Df aren't described with strong dependences. In result, for few samples of the same value of BMD we probably get different values of tissue volume and fractal dimension. It confirms the fact that the use of BMD can't find local differences in the structure of trabecular bone, thus finding places where risk of fracture is the greatest is impossible.

A further stage of the investigation will be mechanical uniaxial compression test of samples and finding description compression strength with the use of indicators. Obtained values R^2 point out that probably different exactitude of description of strength will be obtained using a different indicator.

Perhaps double combination of BMD and any indicator of trabecular architecture, e.g. fractal dimension or tissue volume, would probably get better results than the predicted strength of bone using only BMD density,V or Df .

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References

[1] Bauer, J. S., Kohlmann, S., Eckstein, F., Mueller, D., Lochmüller, E. M., Link, T. M., *Structural analysis of trabecular bone of the proximal femur using multislice computed tomography: a comparison with dual X-ray absorptiometry for predicting biomechanical strength in vitro*, Calcif Tissue Int., Vol. 78 (2006), pp. 78-89.

[2] Lochmüller, E. M., Bürklein, D., Kuhn, V., Glaser, C., Müller, R., Glüer, C. C., Eckstein, F., *Mechanical strength of the thoracolumbar spine in the elderly: prediction from in situ dual-energy X-ray absorptiometry, quantitative computed tomography (QCT), upper and lower limb peripheral QCT, and quantitative ultrasound*, Bone, Vol. 31 (2002), pp. 77-84.

[3] Feltrin, G. P., Macchi, V., Saccavini, C., Tosi, E., Dus, C., Fassina, A., Parenti, A., De Caro R., *Fractal analysis of lumbar vertebral cancellous bone architecture*, Clin Anat., Vol. 14 (2001), pp. 414-417.

[4] Benhamou, C. L., Poupon, S., ,Lespessailles, E., Loiseau, S., Jennane, R., Siroux, V., Ohley, W., Pothuaud, L., *Fractal analysis of radiographic trabecular bone texture and bone mineral density: two complementary parameters related to osteoporotic fractures*, J Bone Miner Res., Vol. 16 (2001), pp. 697-704.

[5] Majumdar, S., Link, T. M., Millard, J., Lin, J. C., Augat, P., Newitt, D., Lane, N., Genant, H. K., *In vivo assessment of trabecular bone structure using fractal analysis of distal radius radiographs*, Med Phys., Vol. 27 (2000), pp. 2594-2599.
[6] Ostrowska, A., Mazurkiewicz, A., Będziński, R., Ścigała, K., *The Investigations of Mechanical and Histomorphometric Properties of Human Femur Cancellous Bone*, Biomaterials Engineering, vol. 47-53 (2005), pp. 78-80.