TECHNICAL SCIENCES
Abbrev.: Techn. Sc., No 10, Y 2007

DOI 10.2478/v10022-007-0010-8

RELATIONS AMONG STRENGTH AND STRUCTURE OSTEOPOROTIC AND COXARTHROTIC TRABECULAR BONE

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Key words: trabecular bone, osteoporosis, coxarthrosis, structure, strength.

Abstract

In the paper presented results of measurement of selected coefficients structure and strength of samples of osteoporotic and coxarthrotic human trabecular bone. Analysis of relationships among coefficients in both groups of samples were executed. Aim the work was description of dependence among coefficients, and qualification them of relationship with compression strength of samples of bone.

RELACJE MIĘDZY WYTRZYMAŁOŚCIĄ A STRUKTURĄ OSTEOPOROTYCZNEJ I KOKSARTRYCZNEJ KOŚCI BELECZKOWEJ

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Słowa kluczowe: kość beleczkowa, osteoporoza, koksartroza, struktura, wytrzymałość.

Streszczenie

W pracy przedstawiono wyniki pomiarów wybranych wskaźników opisujących strukturę oraz wytrzymałość na ściskanie ludzkiej osteoporotycznej i koksartrycznej kości beleczkowej. Przeprowadzono analizę wzajemnych związków między wskaźnikami struktury oraz wytrzymałością kości w obu badanych grupach kości. Celem pracy było określenie wzajemnych związków między badanymi wskaźnikami struktury oraz określenie ich związków z wytrzymałością kości beleczkowej.

Introduction

Examining construction of bone on structure level, are able to differentiate following tissues: cortical bone called also compact bone, trabecular bone and articular cartiliage. Cortical bone is external part of all bone,

trabecular bone fills interior of long bone and interior of short bone. Articular cartiliage is external layer of bone in places of contact with other bones – joints. Quality of trabecular bone determines strength of all bones. Loss trabeculaes and disturbances them structures, eg. during osteoporosis, leads to diminish strength of bones. Therefore important problem is estimation of coefficients of structure of trabecular bone, which can be base to indirect estimation strength of bone.

Aim the work

Aim the work is qualification of dependences among selected coefficients structure nad strength samples collected with osteoporotic and coxarthrotic human trabecular bone. Executed also description founded dependences mathematical equations.

Sample of trabecular bone

Trabecular bone is porous tissue, which has anizotropy construction and mechanical properties. In dependences from age, and also of kind of disease structure of bone can be composition plates or trabeculaes. From bone material ie. 42 femoral heads (21 osteoporotic and 21 coxarthrotic) gained in result of hip arthroplasty, in first stage were cut out slice from base of head about thickness 8.5 mm, perpendicularly to the axis of neck of bone. Next, from central region of slice were cut out sample in shape of cylinder, about diameter 10 and heights 8.5 mm. Manner of collect and shape of samples presented in figure 1 a÷c.

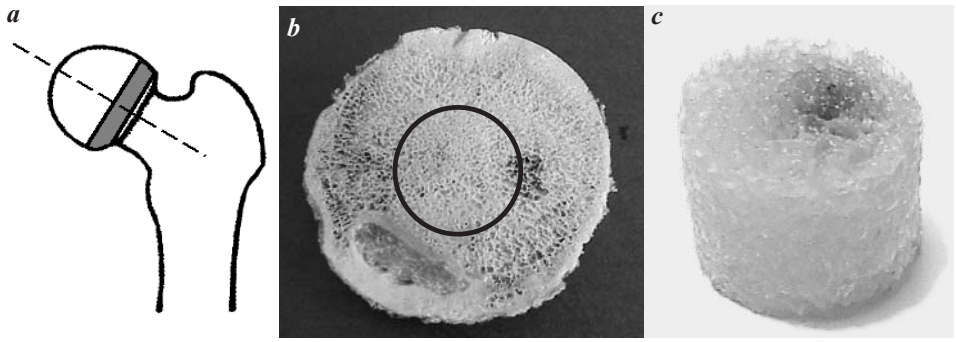

Fig. 1. The schema collect a,b), and shape of samples c)

Coefficients of structure of trabecular bone

To the description of structure of trabecular bone accepted selected coefficients among proposed by Parfitt (Parfitt 1987). The coefficients are universally usaged to estimations of construction of trabecular bone. To investigation accepted following coefficients:

– **Tb.N**, 1/mm – trabecular number – average number continuous trabeculaes on unit area or volume of sample,
– **Tb.Th**, mm – trabecular thickness –average thickness trabecula in sample,
– **Tb.Sp**, mm – trabecular separation – average distance among trabecula in sample (average dimension of pores in sample),
– **TV**, mm^3 – trabecular volume – volume of sample (volume tissue and pores),
– **BV**, mm^3 – bone volume – volume tissue in sample,
– **BS**, mm^2 – bone surface – area tissue in sample,
– **BS/BV**, 1/mm – quotient: bone surface and bone volume,
– **BV/TV**, – quotient: bone volume and trabecular volume,
– **US**, MPa – compression strength.

Methods of the investigations

Measurement of morphological parameters executed at microtomographic system μCT80 at Technological University in Eidhoven - Netherlands. In figure 2 presented typical image of layer of sample of bone received from ěCT80. The device is able to imagining layers of sample distant from oneself about 36 μm. On the base of analysis obtained images and calculations executed at microtographic system obtained values all coefficients with exeption for compression strength. The values of compression strength obtained from mechanical test.

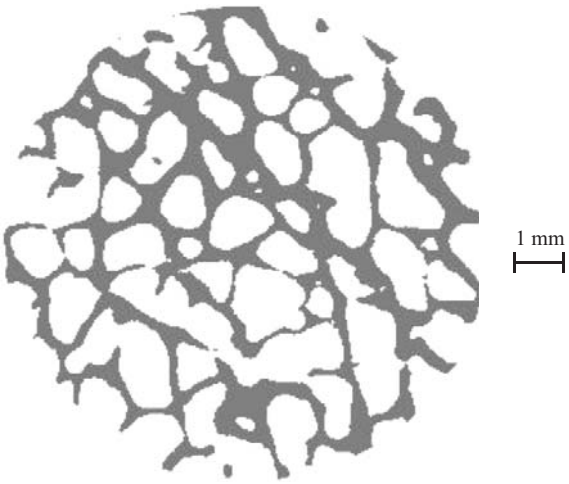

Fig. 2. Typical image of layer of sample obtained from ěCT80 system

Results

In figures 3÷6 presented values of parameters Tb.N, Tb.Th, Tb.Sp and compression strength in function BV/TV. In figures 7÷10 are these same coefficients in function BS/BV. Quotient BV/TV describes ratio content volume of tissue in volume of sample. It is reverse of porosities of sample – porosity is defined as relation of volume of pores to volume of sample. Quotient BS/BV describes ratio extending of structure. If compared two structures about the same tissue volume and different tissue surface can ascertain, that structure about greater surface is structure about smaller thicknesses, but about more extending of architecture. In all figures drew lines of regression, together with equations of regression and values of coefficients of determination.

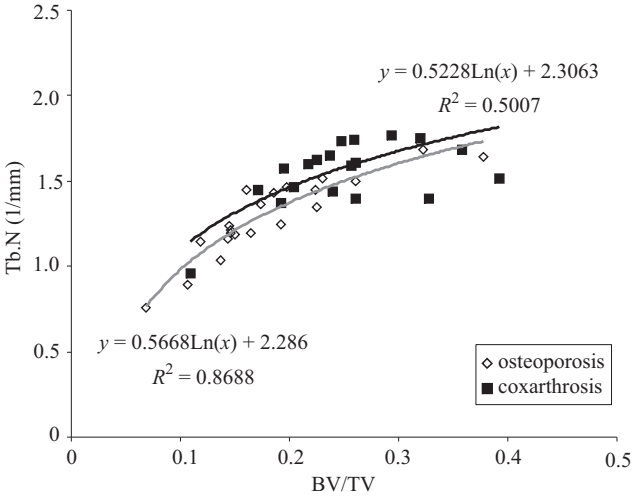

Fig. 3. Graph of values of Tb.N in function BV/TV

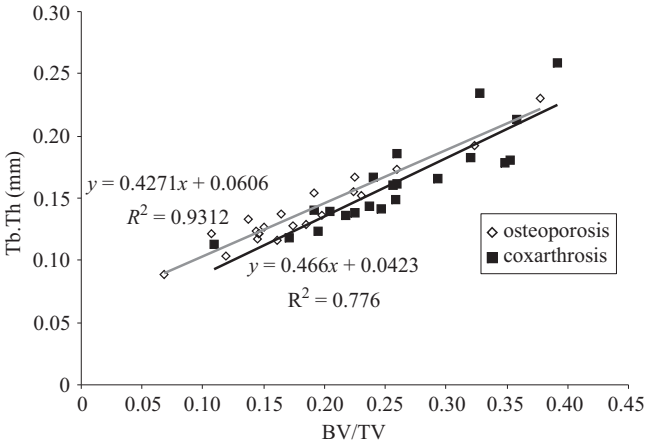

Fig. 4. Graph of values of Tb.Th in function BV/TV

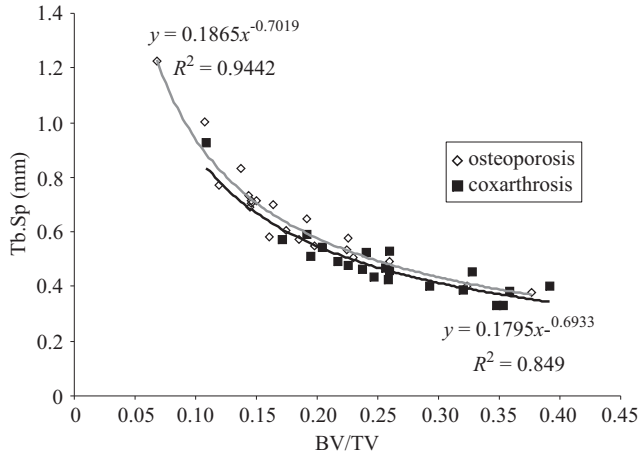

Fig. 5. Graph of values of Tb.Sp in function BV/TV

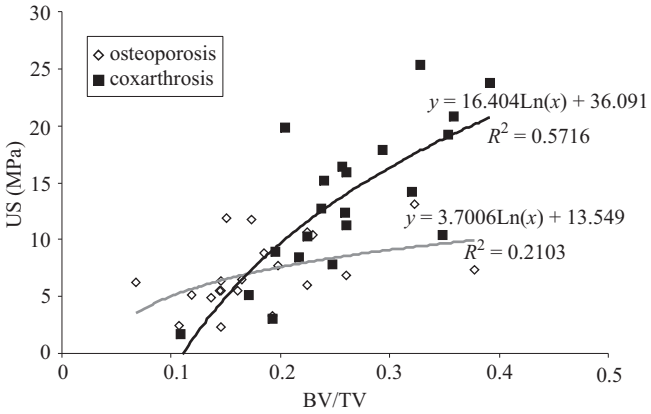

Fig. 6. Graph of compression strength US in function BV/TV

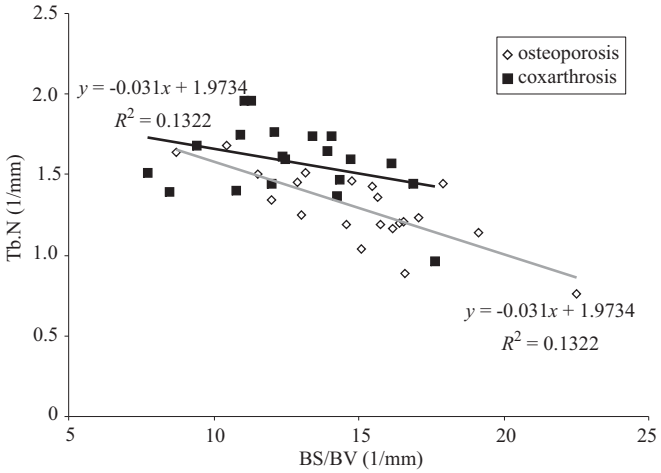

Fig. 7. Graph of values of Tb.N in function BS/BV

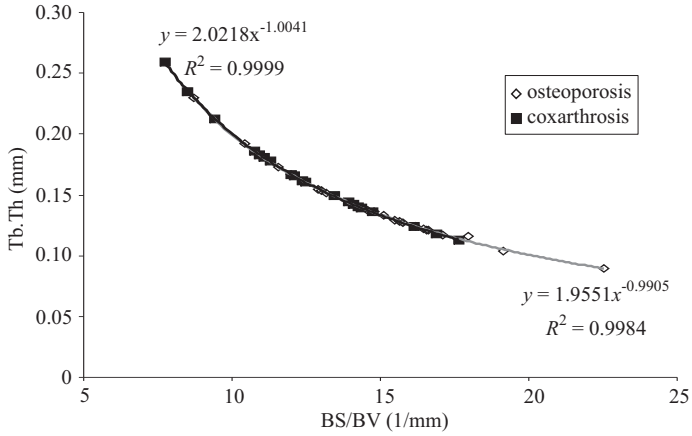

Fig. 8. Graph of values of Tb.Th in function BS/BV

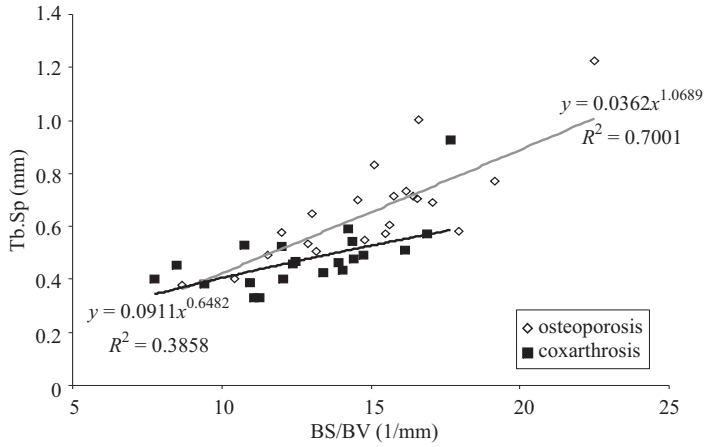

Fig. 9. Graph of values of Tb.Sp in function BS/BV

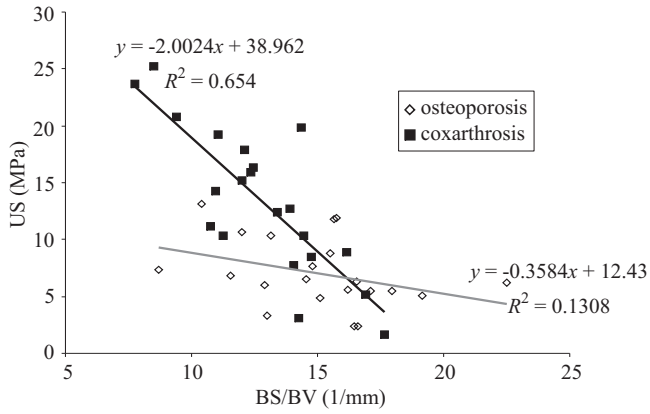

Fig. 10. Graph of compression strength US in function BS/BV

Discussion

Analysing figures 3÷4 are visible distinct relationships among number continuous trabeculaes and average thickness of trabecula for osteoporotic samples. Coefficient of determination achieved value 0.93. For coxarthrotic samples the value are lower, however do not come down below 0.5. In both cases for greater "amount bone in bone" number of trabeculaes is greater – describing equation is logarithmic – and at values BV/TV below 0.2÷0.25 dynamics this grow to diminish. Relationship among thickness of trabecula and "amount bone in bone" was linear in examined material. The results of investigations pointed, that osteoporotic bone has less number continuous trabeculaes at greater average thickness of trabeculae than coxarthotic bone. Simultaneously increase walues of BV/TV marks diminish of distance among trabeculaes, and dynamics this grow to diminishing. Description this relationship about high values of coefficient of determination R^2=0.84 for coxarthrotic samples, R^2=0.94 for osteoporotic samples – is possible to description power function about power less than one – at small differences among osteoporotic and coxarthrotic bone.

Increasing "amount bone in bone" for coxarthrotic bone means increase of strength – drawing 6. For osteoporotic bone about less number continuous trabeculaes and greater distance among trabeculaes in all range of changes BV/TV – is not relationship between strength and BV/TV, at weakly tendency of height of strength at increase BV/TV, and visible difference of between both groups of samples. This ascertainment leading to conclusion about lack of relationship between Tb.N, Tb.Th, Tb.Sp and compression strength of bones.

Considering regular structure can ascertain, that conversion structure from structure about large thicknesses of trabeculaes to structure about greater number and smaller thicknesses of trabeculaes lead to increasing BS/BV, what confirmed results presented in figure 8, for both groups of samples. Osteoporotic damages of structure lead to damages greater numbers of trabeculaes than more the stucture is crumbled – figure 7, in effect lead to increasing distance among trabeculaes – figure 9. In case coxarthrotic bone this relationship don't appeared.

In case coxarthrotic samples increasing values BS/BV lead to decrease of strength – figure 10, described linear equation about coefficient of determination R^2=0.65. For osteoporotic samples don't exist the relationship – coefficient of determination about value R^2=0.13 points on irregularities of damages of structure.

Conclusions

Value of BV/TV gives informations about degree fulfilments of structure called "amount bone in bone" what often is pointed in descriptions and diagnosis of osteoporosis. For examined samples the coefficient has value from above 0.05 to near 0.4. At increasing the value in very similar manner for both examined group of samples increasing linearly Tb.N and Tb.Th and decreasing Tb.Sp. However values above-mentioned of coefficients are similar at these same values BV/TV, strength both kinds of bones can be different. It can be result this, that about strength of samples decides not only values of BV/TV, but also structure and properties trabecular bone in idividual persons. In spite collected of samples from the same place of femoral heads (Mazurkiewicz 2003), difficulty directly to take into account direction trabeculaes structure as individual feature of peoples, which is result for example their life activities.

Value BS/BV gives informations about degree of extending (crumbling) structure of bone. With increasing of crumbling should growing Tb.N diminish Tb.Th and Tb.Sp. Results of investigations not exactly confirm this ascertainment. Decrease Tb.Th is observed, don't observed increase Tb.N and Tb.Sp. It can be result this, that Tb.N is number continuous trabeculaes - having supported two ends. Only such trabeculaes can carrying the loads. In the investigations examined samples of bone collected from people with osteoporosis and coxarthrosis, what causes, that structure of samples is irregular as consequence of the diseases. Even in case crumbling structures number propperly trabeculaes in the sample isn't to large, what causes that distances among them also are large. It is visible on example of osteoprotic samples where, increase Tb.Sp and decrease Tb.N is more distinct, than in coxarthrotic samples. Influence of changes BS/BV on strength isn't easy to interpretation, but is visible, that is more significant for coxarthrotic than osteoporotic samples.

In further analysises, should be use not single coefficients but them double or triple combinations, what should lead to improvement obtained results.

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Accepted for print 10.05.2007