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RELATIONSHIP BETWEEN FATIGUE LIFE AND STRUCTURAL INDICES OF HUMAN TRABECULAR BONE

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Abstract

Trabecular bone is one of components of human bone. It is a porous structure which strength has principal influence on strength whole bone. In the study has been presented results investigation relationship between fatigue life (loading with stepwise increasing amplitude) and structural indices of human trabecular bone. Dependencies were described by determination coefficient R^2. Obtained values the coefficient were contained in range 0,50÷0,69.

Keywords: *trabecular bone, fatigue life, structure trabecular bone*

1. Introduction

Trabecular bone is one of components of human bone. It is a porous structure which strength has principal influence on strength whole bone. A typical loading for bones, eg. during gait is the cyclic loading variable in time, and thus behaviors under such loading are fatigue behaviors [1-2]. Thus, besides bone tests exposed to static compression, bending or torsion, research is carried out under cyclic variable loadings. It investigation covers both the cortical bone parts [3] and the trabecular bone parts [4-5].

The aim of the work is estimation relationship between fatigue life under cyclic loadings with stepwise increasing amplitude and structural indices of human trabecular bone.

2. Experimental methods

Material to the investigation were 61 samples of human trabecular bone. Samples were collected from osteoporotic and coxarthrotic femoral heads gained in result of hip arthroplasty. The samples used to investigation have cylindrical shape about diameter 10 and height 8,5 mm – Fig.1 [6].

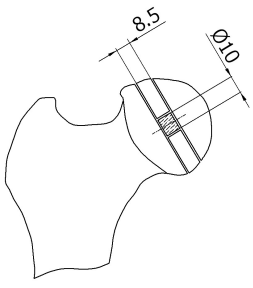

Fig. 1. Test sample obtained from the femoral head

The age of the patients ranged from 46 to 88 with an average of 73 years. The samples were obtained from 40 women and 21 men and were stored in 10% formalin solution at the room temperature. Samples were examined at microCT device (μCT80) with resolution 36μm (parameters: 70kV, 114μA, 500 projections/180°, 300ms integration time). In result the investigation were obtained values 11 structural indicators of samples e.g. trabecular number Tb.N, trabecular thickness Tb.Th as well as bone volume fraction BV/TV.

Fatigue tests were carried out under compression with stepwise increasing loadings using the testing machine INSTRON 8874. The frequency of sinusoidal loading was 1 Hz, the minimum loading for all the loading layers was 5-7N. The maximum loading started from 20N with a gain every 10N at successive steps. Each level of load maintained 500 cycles, realized under constant-amplitude loadings.

Fatigue life was determined by estimation the median of the values of deformation increment and then considering the value of the first loop for which the deformation gain exceeded the value of the median by 10% (to be the fatigue life).

3. Results

Fatigue tests with stepwise increasing loading demonstrated the fatigue life of the trabecular bone samples between $3{,}75 \cdot 10^3$ cycles and $5{,}02 \cdot 10^4$ cycles (time of test between 1,04 h and 13,95 h). In Fig. 2 presented values of fatigue life versus maximal compression stress achieved in test.

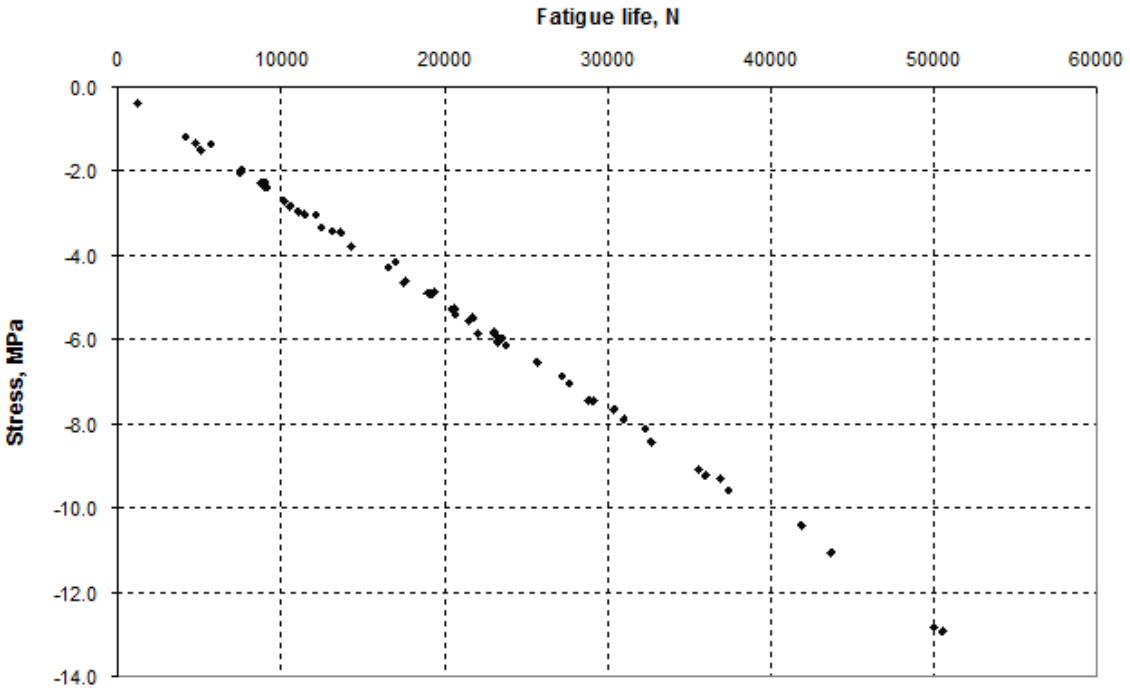

Fig. 2. Fatigue life versus maximal compression stress

In Tab. 1 presented values of selected indices structure of tabecular bone obtained from microCT investigation. The table includes minimal, maximal and mean values as well as standard deviation SD and relative standard deviation RSD.

Tab. 1. Values of selected indices structure of trabecular bone obtained from microCT investigation

Indicator	min	max	mean	SD	RSD
BV/TV,-	0.0759	0.4595	0.2049	0.0747	36 %
Tb.Th, mm	0.1053	0.2677	0.1714	0.0354	21 %
Tb.N, 1/mm	0.5109	1.5435	1.1329	0.222	20 %
BS/BV, 1/mm	5.2056	18.995	11.997	2.7467	23 %

In Fig. 3-6 presented relationship between fatigue life and BV/TV, Tb.Th, Tb.N and BS/BV respectively. Obtained values coefficient of determination R^2 for this relationship were in range 0,5÷0,69.R^2

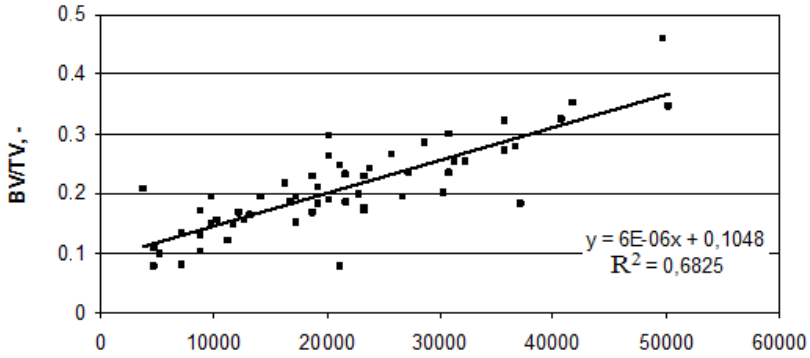

Fig. 3. Relationship between fatigue life N and bone volume ratio BV/TV

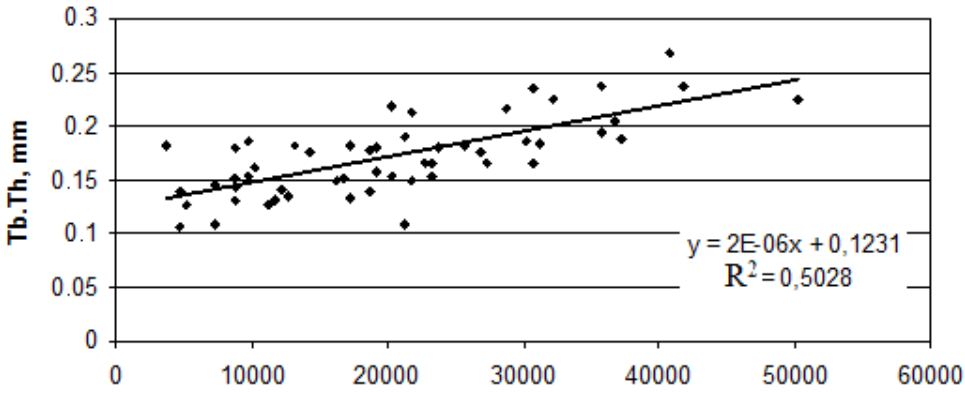

Fig. 4. Relationship between fatigue life N and trabecular thickness Tb.Th

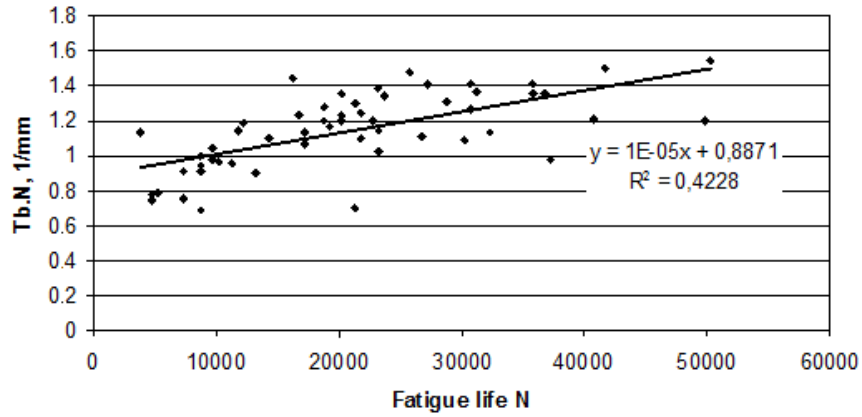

Fig. 5. Relationship between fatigue life N and trabecular number Tb.N

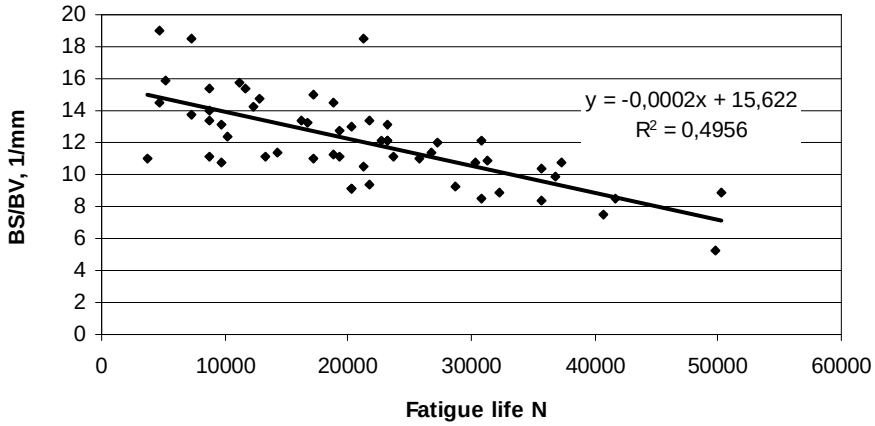

Fig. 6. Relationship between fatigue life N and BS/BV

4. Conclusions

From microCT investigation obtained wide range of values structure indices and significant values SD or RSD. It point out significant differences in structure samples of trabecular bone.

Obtained values R^2 for relationship structure indices and fatigue life contained in range (0,5÷0,69). Values R^2 is the highest for BV/TV. To tell about existence strong relationship between BV/TV and fatigue life. For the other investigated indices values R^2 are similar – about 0,5.

In spite of differences in structure trabecular bone obtained values of coefficient of determination for relationship between structure indices and fatigue life point out existence relationship between structure of trabecular bone an its fatigue life.

Acknowledgements

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