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INFLUENCE OF THE TRABECULAR BONE STRUCTURE INDICATORS ON ITS STATIC AND FATIGUE STRENGTHS

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1. Introduction

Trabecular bone fills in the ends of long bones, the inside of small bones and irregular-shaped bones. It is porous, and its structure is dependent on gender, age, bone diseases history and other factors [1, 2].

In particular cases, differences in the number of trabeculae, their shape and thickness occur, which is strictly related with the bones strength [1, 3-5].

In this paper it was evaluated how the individual trabecular bone structure indicators influence its static and fatigue strength.

2. Material and Method

The tests were performed on samples collected from femoral heads. The bones were collected as a result of implanting femoral joint of persons suffering from arthrosis.

The samples were collected in the following mode. Firstly, a plaster of depth 10 mm was cut out from the head, perpendicular to the neck axis. Then, samples of 10 mm diameter were cut out from the plaster. Then, the face surfaces were ground until 8,5 mm sample height was achieved. Finally, the samples were 10 mm in diameter and 8,5 mm in height. They were stored in a 10% formalin solution, at room temperature.

The samples structure was examined using SkyScan 1172 microtomograph. The scanning resolution was 25 μm. Based on the examination results, parameters of the structure, including trabeculae number, trabeculae thickness, ratio of tissue volume in the sample to the sample volume were calculated.

Based on this, the samples suitability for the test was also evaluated. In advanced cases of arthrosis, pathological changes at the joint surface of the head, and near the trabecular bone occur. The microtomographic examination allowed to evaluate the occurrence of this type of changes in the sample. Those samples in which such changes were identified were eliminated from further tests. 30 samples were used in the tests, divided at random into two groups. One of them was used for testing static strength (GS group), and the other for fatigue tests (GF group).

The samples were subjected to tests on a Instron E3000 strength testing machine.

Was subjected to initial load of force 3N. Then, 5 cycles of load up to value 0,65% of the sample height were performed. Cycle time 30 s, with a 5 s pause between the cycles. Then, the test was conducted at fixed deformation speed until obtaining the maximum force value. Static strength was evaluated as quotient of maximum force and sample surface area.

Fatigue test was performed at gradually increasing amplitude. The initial load was 5N. Maximum load started from 20N and incremented by 10N at each subsequent level. The volume of each level was 500 cycles. At each level, the minimum and maximum load was constant. Fatigue life was evaluated as follows: determined the median values of deformation increment of sample. Assumed that fatigue life is defined as: number of the first loop for which value the deformation gain exceeded the value of the median by 10%.

3. Results

Shapiro- Wilk test (p=0.05 value) was used for evaluating the distribution of the obtained values of structure and values of static and fatigue strengths

The test results show that the all the values are normal or log-normal distribution.

Table 1 presents the results of measurement of the structure indicators. Table 2 presents the value of static and fatigue strength, calculated for both of the tested groups. The values of correlation coefficients obtained between the structure indicators and the strength were presented in table 3.

	Tb.N, 1/mm	Tb.Th, mm	BV/TV, -
GS group	1.47 (SD ±0.24)	0.167 (SD ±0.032)	0.252 (SD ±0,063)
GF group	1.39 (SD ±0.22)	0.148 (SD ±0.038)	0.233(SD ±0,052)

Tab. 1.. Values of trabecular bone structure indicators.

US, MPa	NS, cycles
12.12 (SD ±5.71)	26 163 (SD±12 182)

Tab. 2. Values of static strength and fatigue life.

	Tb.N	Tb.Th	BV/TV
US, MPa	0.59	0.64	0.69
Ns, cycles	0.51	0.61	0.62

Tab. 3. Values of the coefficients of correlation between the structure indicators and strength.

4. Discussion

The correlation between the structure indicators values and static strength R=0.59÷0.69.

The correlations with fatigue strength are in range R=0.51÷0.62.

Based on the above it may be concluded that the structure indicators are useful for evaluating static and fatigue strength of trabecular bone.

A certain limitation to the usability of the test results is that the bones were collected from persons suffering from arthrosis, and that several samples might have originated from the same bone. This introduces certain difficulties in evaluating the results. For instance, the impact of the sickness and treatment on changes to the chemical content of the trabecular bone tissue is unknown. These factors could have effected in varying strength between the trabecular bones collected from persons with arthrosis and from healthy persons, at comparable trabecular bone structure in the sample.

Another limitation was the sample size used in the tests. In order to obtain a more credible static evaluation of the results, a larger number of samples would be required. The use of several samples collected from the same bone could influence the test results due to the individual features of persons from which the heads were collected.

Also, the samples were not divided according to age or gender. A comparable number of persons of the same gender and age were qualified to both groups. In the view of the sample size, a different approach to splitting the groups seemed unjustified.

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