THE NUMERICAL MODELING OF OSTEOPOROTIC CHANGES IN SELECTED BIOMECHANICAL STRUCTURES

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Osteoporosis is metabolic disease of bone which causes progressive decrease of the osseous pulp and the changes of bone structure. Such weak bone is more susceptible on fractures. The early diagnosis of osteoporosis enlarges chance of the treatment. It is a big problem because disease progresses without symptoms – first symptoms appear when the loss of osseous pulp is big (about 30%) and it is the large risk of fractures. The treatment of osteoporosis usually depends on treatment of results - fractures and consists in providing analgesic and stabilization of places of fractures. It would be better to prevent that disease because lack of movement is causes of weakness of bones. Knowledge of physical properties of bone tissue is helpful in diagnosing of the diseases of the bone system (especially that properties change during progress of disease) [4].

From mechanical point of view the fracture of bone occurs in two cases:

- the correct structure of bone but the loads are so big that cause the stresses larger than stress limit,
- the disorders of bone structure caused decrease of strength properties of bone when normal activity of organism can result stresses larger than stress limit.

The paper concerns the second situation, which take place e.g. in osteoporosis. The most common preventive examinations are:

- densitometry of bone – method of representing of the bone density by using dual energy X-ray absorptiometry (DXA) ,
- computed tomography – method depending on mapping cross-section of bone; it makes possible localizing the places where is the considerable loss of osseous pulp.

These are standard examinations which gives enough information and to enable to make a correct decision in routine situations. However when data will be use to building of quantitative model of bone tissue these methods can be insufficient. Then it is necessary to perform Quantitative Computed Tomography [5].

To present the problem of the osteoporosis the strength analysis of the human hip joint were performed (health joint and the joint with osteoporotic changes). Numerical simulations give important information about behaviour of object on condition that numerical model is similar to analyzed structure (geometry, material properties and boundary conditions). During create geometry of the model date from coordinate measuring machine is used (it was concentrated on the pelvis bone). There is important the delimitation of material properties which are changed during osteoporosis. During examination the bone system as well as density phantom are X-rayed. The phantom is composed of regions representing specimens of bone density. The X-ray photographs are analyzed by use specialist software (the dependence between quantity of the absorbed radiation and the radiological density is used). The output density is standardized in Hounsfield scale (HU). Then the HU density is converted to the density of bone tissue. The next step is delimitation of material properties of bone tissue, especially elastic modulus (on the basis of experimental research the dependences between bone density and material properties were developed) [1, 2].

Because Computed Tomography gives cross-section for different places so material properties was delimitated in the same places of bone (on the base of linear regression for measuring points the calibration curve is created, it enable to calculate the properties for every voxel of photographs) - the more exact data from CT, the better representation of bone structure. This is important because bone is non-homogenous, especially pelvic bone, with regard to complex geometry and functions in organism, is characterized by changeability of material properties [5].

Delimitated properties were given to model. Next the boundary conditions were assumed.

The fixed was realized by use elements type bar type beam (during analysis the number and the stiffness of elements were changed). The boundary conditions were given both in the points and in the areas [3].

Strength calculations were performed in system MSC Patran/Nastran. The structure on the base of distributions of equivalent stresses, strains and displacements was analyzed. Obtained results can be helpful to estimated effort of pelvis and femoral bone and planning surgical interventions during treatment of injuries caused by osteoporosis.

The exemplary photographs with Quantitative Computed Tomography were presented in Fig.1. Examinations were performed in sagittal plate. Density phantom and the pelvic bone were X-rayed.

a) b) c)

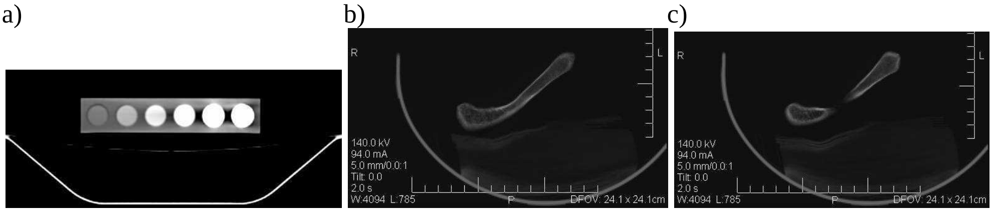

Fig.1. The images from computed tomography: a) density phantom, b) and c) pelvic bone

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