Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 49
ISSUE 2
December
2011

Computer aided diagnostic of risky state in human pelvic bone

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Received 18.10.2011; published in revised form 01.12.2011

Analysis and modelling

ABSTRACT

Purpose: of this paper is to raise the issue of recognition of dangerous states in human pelvic bone. These states can lead to damages of bone.
Design/methodology/approach: consist of using the images from quantitative computed tomography (QCT). On the base of obtained data the numerical model of pelvic bone was created. Very important stage it was determination the values of material parameters. In the paper two methods were described. The first method directly basis on the data from radiology. In regard to difficulties with tomography data the second method was applied – the numerical simulations. The computer program was developed to obtain distribution of material parameters in numerical model of pelvic bone on the base of decreasing of bone mass.
Findings: of the paper is that when decreasing of bone mass occurs in whole bone the stresses grow up continuously at the time. When decreasing of bone mass appears in individual region only the stresses decrease at the beginning and next increase while the bone mass still decrease. It could be one of the reason of lack of the symptoms in primary stage of osteoporosis.
Research limitations/implications: are connected with accessibility of data from QCT. During QCT the bone system as well as density phantom are X-rayed simultaneously. On the base of standard density coming from the phantom the calibration curve is drown.
Practical implications: it is the proposed procedure which facilitate the detection of risky state in pelvic bone.
Originality/value: of researches consist in complex approach to problem of osteoporosis in human pelvic bone and applying the numerical simulations to create the numerical model of pelvic bone with osteoporotical changes.
Keywords: Risky state; Pelvic bone; Material parameters; Numerical simulation; Osteoporosis

Reference to this paper should be given in the following way:
A. John, P. Wysota, Computer aided diagnostic of risky state in human pelvic bone, Journal of Achievements in Materials and Manufacturing Engineering 49/2 (2011) 313-322.

1. Introduction

Human bone system is subject to frequent damages and diseases (e. g.). In generally one of them like fractures or sprains are the results of external conditions e.g. incorrect loading, others are connected with internal structure of bones – one of them is osteoporosis. This is a systemic disease of skeleton which causes progressive decreasing of bone mass and changes in bone structure. In the course of time these changes are so serious that bones become weaker and weaker and can undergo accidental fractures [1, 3]. In Fig. 1 the internal structure of bone is presented. We can notice that in the second case (Fig. 1b) the cells of bone tissue are thinner – this is a consequence of osteoporosis.

From the 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 produce stresses larger than stress limit [2].

a) b)

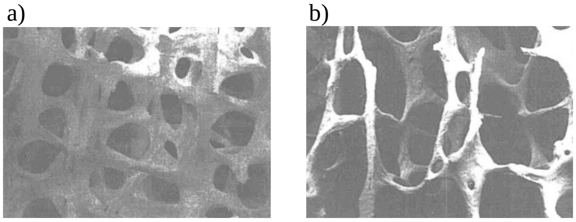


Fig. 1. Microstructure of bone tissue: a) correct, b) with osteoporotical changes [14]

The attention is concentrated on the second situation (when only the physiology loading of organism can cause accidental fracture of bone) because it takes place in osteoporosis.

Very important factor is diagnosis of osteoporosis. This is a serious problem because this disease progress without symptoms. First signs appear when the loss of bone mass is big (about 30%) and the risk of fracture is high. Comparison of radiological images of knee and hip joint for healthy state and state with osteoporosis is shown in Fig. 2 and Fig. 3 [12].

a) b)

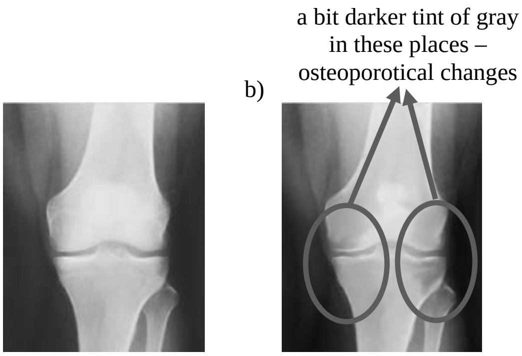


Fig. 2. The knee joint: a) correct, b) with osteoporotical changes [12]

Usually, patients come to doctors when they have difficulties during move and pains in spine and/or in hip joint. Unfortunately, until then osteoporosis is recognized and treatment is begun. The treatment of osteoporosis usually consists of providing analgesic and stabilization of places of fractures. It would be better to prevent this disease because lack of movement causes of weakness of bones. The 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).

To diagnose the osteoporosis the following preventive examinations are realized:

a) Radiology Absorptiometry (RA),
b) Roentgen Absorptiometry:
  - Single X-ray Absorptiometry (SXA),
  - Dual-energy X-ray absorptiometry (DXA),
c) Quantitative Ultrasonography (QUS),
d) Quantitative Computed Tomography (QCT).

a) b)

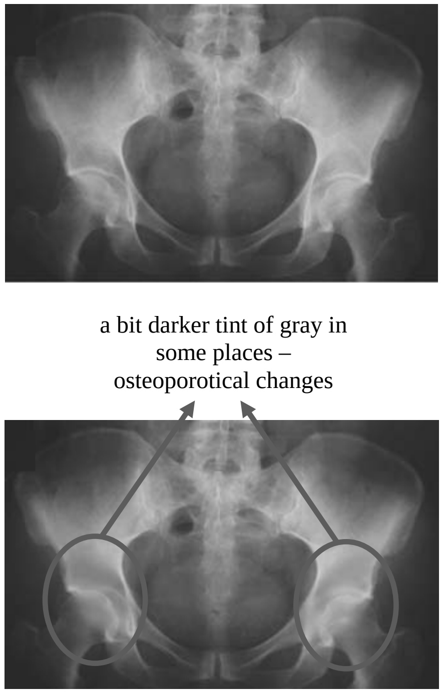


Fig. 3. The hip joint: a) correct, b) with osteoporotical changes [12]

These methods work on the base of Lambert-Beer's law which describes phenomenon of weakness of the radiation during crossing through the objects. In the course of examination the part of radiation is absorbed or distracted. The intensity of radiation depends on thickness as well as the content of minerals in the bone. In result of iterative reading of the images for individual pixels, after transformation, the measurement density of whole object is obtained. In estimation of the progress of osteoporosis the largest meaning have DXA and QCT.

DXA is a method which use the measure at the same time the high- and low-energy radiation beam. Absorption of radiation in bone tissues of both beams is the same, however it is different in living tissues. Knowing absorption of both beams it is possible to calculate quantity of absorbed radiation. The next step is to determine the bone mass per surface unit (in g/cm^2). There is not taking into consideration the third dimension in that method. It is disadvantage of this method because it may cause of incorrect results in case of two structures at the same density but different thickness (then the density of object at larger thickness will be larger). The others inconvenience is the lack of possibilities of differentiation the kind of bone at the densitometry images [6, 7].

These both methods are densitometry examinations in which risky of osteoporosis estimate on the basis of distributions of density of bone tissue. In literature there are many papers consider both of these methods in aid of diagnosis osteoporosis. J.E. Adams in [1] described in details QCT. Authoress go into genesis of these method, its development, clinical applying, in particular in diagnosis of osteoporosis. On the base of the papers: J. E. Adams [1], K. Engelke et al. [2] and S. Nayak, M.S. Roberts, S.L. Greenspan [11] we can say that when we compare both of these methods: DXA and QCT, more precise data of bone density is from QCT (from DXA we obtain “surface density” – in g/cm^2, from QCT “volume density” – in g/cm^3). Besides, in DXA it is more difficult to differentiate the kind of bone at the densitometry images. Second reason is the fact that data from QCT is more useful to create numerical model. In our case better solution is to use Quantitative Computed Tomography – that’s why we applied this method. More details about this method were put into chapter 2.

2. Quantitative Computed Tomography

2.1. General information

In this method the tomograms from CT is used to analyse the mineral density of bone. Through using the composition of projection images from different directions one can to get cross-sectional and solid images in all researched structures (Fig. 4). Tomographs come from individual voxels [5, 6]. Each voxel is characterized by coordinates x, y, z and colour in grey scale. On the base of an experimental research the formulas between amount of radiation and bone density it is possible to determine a value of density for each voxels. During QCT the bone system as well as density phantom are X-rayed simultaneously. The phantom is composed of regions representing specimens of bone density (in Hounsfield Units). By dint of applied procedure one may to estimate bone density (in g/cm^3) in all analysed object, exact to one voxel. So this method makes possible not only distinction of bone structures, but even observe the differences of thickness in the same tissue [3, 6].

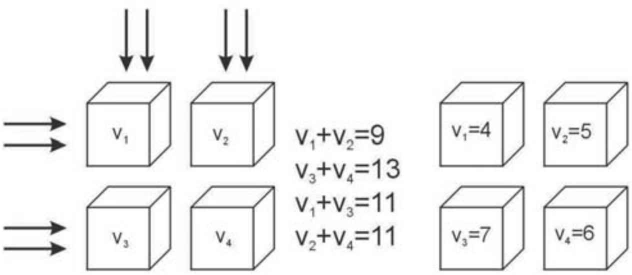


Fig. 4. Reconstruction of images in computed tomography [13]

Quantitative Computed Tomography is differ than standard tomography. Here the density phantom is X-rayed together with patients. The phantom is composed of regions representing specimens of bone density in Hounsfield Units. The density phantom is presented in Fig. 5.

Our phantom is composed of six specimens. On the base of these standard density the calibration curve is drown. Formula of this curve enables to determinate the density for every voxel of researched bone. The exemplary calibration curves were presented in Fig. 6.

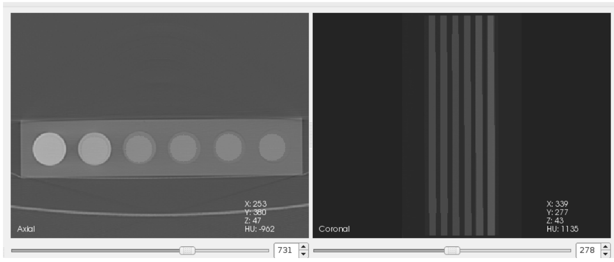


Fig. 5. The density phantom in different views

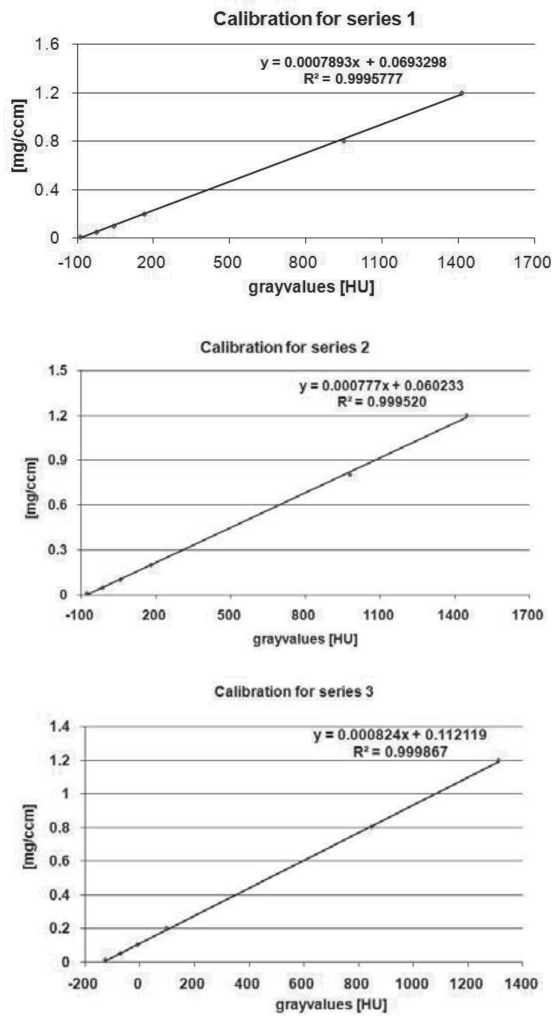


Fig. 6. The calibration curves for different series

2.2. Conversion of data from QCT

After radiological examination one can obtain images of researched structure. The next step is to converse these data to receive information about analysed bones [10].

The general course of transforming data is following [7]:

a) The tomography examinations are performing. In a result the images (sections in different places) of analysed object are received,
b) The tomography images are analysing by use specialist software (the dependence between quantity of the absorbed radiation and the radiological density in bone tissue is used). The exemplary tomograms of pelvic bone were presented in Fig. 7;

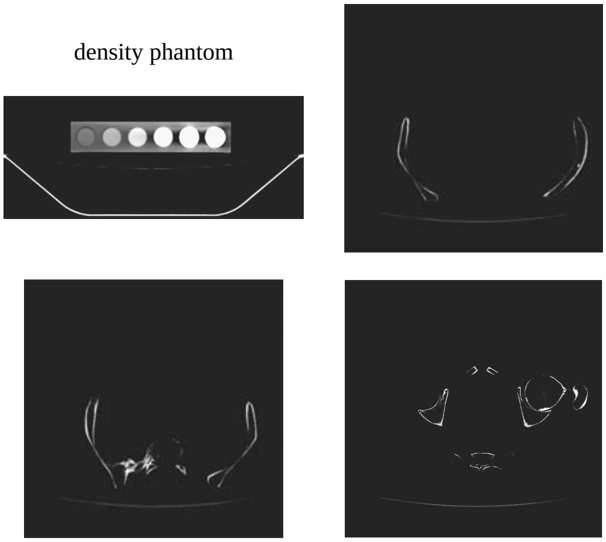


Fig. 7. Exemplary images of human pelvic bone from QCT

c) The obtained density is standardizing to Hounsfield scale – HU [9, 13]:

$$1HU = K\frac{\mu_p - \mu_u}{\mu_u} \quad (1)$$

where:
K – amplification factor of images,
μ_p – absorption factor,
μ_u – absorption factor of reference object;

d) On the base of HU the density of bone tissue is determining [9, 13]:

$$\rho = 1.122 \cdot HU + 47 \quad (2)$$

where:
ρ – density of bone tissue, kg/m^3;

e) The material properties of bone tissue are determining, especially elastic modulus – on the basis of experimental research the dependences between bone density and material properties were developed [9, 13]:

$$E = 1.92\rho - 170 \quad (3)$$

where:
E – elastic modulus of bone tissue, GPa.

2.3. Quality of images from QCT

Very important problem it is quality of images from the radiology examinations. On the base of obtained information, it is deducted about patient's state, disease's progress and it is possible to plan the treatment and check the correctness of therapy. In the case of QCT, when dates are often converted, the quality of tomograms has special meaning. There are a few important features of images, which decide about useful in medical diagnostic: contrast, sharpness, resolution, noise-to-signal ratio, artifacts and distortion of signals.

Occurrence of hums and disturbances it is one of the characteristic features of signals. In dependence on method there is different kind of hums. Increase of hums level lead to reduce the visibility and the decrease of contrast. In a consequence photographs give little information and are less useful. Hums are observed on the every stage of transformation data and it would be the best if minimization of disturbances started from the very beginning of creation of images and lasted during whole registration process of the data. Hums and disturbances can influence on incorrect interpretation of photographs. Influence of hums can be limited by using the low-pass filters and locally enlarging the contrast. Unfortunately, during reducing the disturbances it can lead to loss of the part of information which will influence on level of medical content.

The artifacts are others problems during conversion of photographs from radiology. These are unwanted feature of images appearing in medical modalities. The artifacts do not reflect the properties of researches structures but are the result of accidental factors [8]. In Fig. 8 the comparison between normal image and image with artifact is presented.

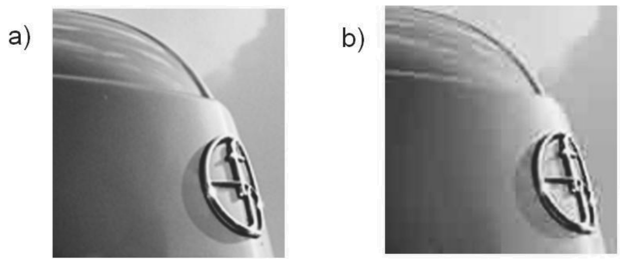


Fig. 8. The differences between: a) correct images and b) images with artifacts [12]

Sometimes it does not influence significantly on perception of diagnostic information, however in some cases it can limit accuracy of interpretation or even mislead (the artifacts pretend features of living structures). Many different factors can cause formation of artifacts e.g.: methods of data processing, algorithms of creation of images, movements of patients or shift of X-ray lamp. During QCT examinations frequent artifacts are appearing defects on boundaries of areas with different density – in images are local the decrease of sharpness and contrast, the rise of shadows or the exaggerations. In a consequence it can cause to incorrect estimation of material properties.

3. Numerical model of human pelvic bone

During modelling of biological structures the difficulties connected with representation of geometry and subordinating of material properties to numerical model occur.

Bones have complicated and non-regular structure. Additional difficulty is mapping of internal structure of bone (there are problems with delimitating of thickness of each layers). Traditional building of geometry in some cases is very hard, time-consuming and created models are over simplified. For these reasons during creations of biomechanical structure one use radiological images – on the base data from radiology (e.g. computed tomography) the information about structure of bone is received.

However, the problems with representation of geometry of pelvic bone are solved, the problem of determination the material properties still lead to difficulties.

3.1. Geometry of model

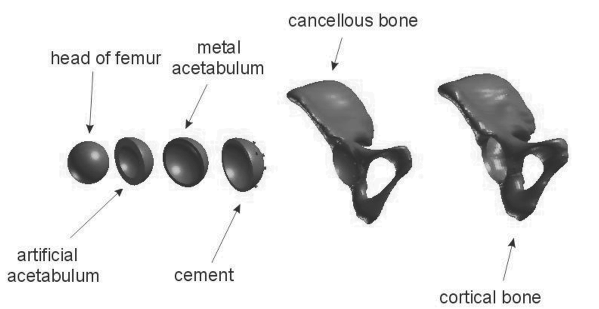
After performing tomography examination, the next step it is to convert obtained images and calculate effort state of bone. Data from QCT was used to create the numerical model of human pelvic bone. First, the geometry of the model should be prepared. The geometry from tomography or from measuring coordinate machine can be applied.

The model consists of three main parts:

- pelvic bone (compact and trabecular tissue),
- endoprosthesis of hip joint (cement layer and artificial acetabulum),
- femur head (metal or ceramic).

The components and whole model of human pelvic bone are presented in Fig. 9.

a)



b)

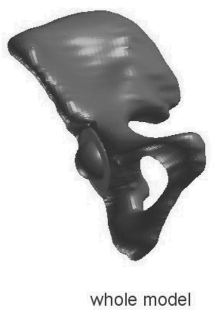


Fig. 9. Numerical model of pelvic bone: a) components, b) whole model

3.2. Material parameters

Data from tomography

Biomechanical structures usually belong to non-homogenous and anisotropy material. Reference point there are the material parameters determinate in experimental researches but in organism conditions they may have different values. Another problem is to estimate material properties during pathological changes. Recognition of these changes and local non-homogenous is a large challenge for medical doctors, biomechanics and manufacturers of diagnosis devices. For the purpose of assignation material parameters obtained from QCT to numerical model the in-house procedure was used. On the base of QCT images (with resolution 512x512) the matrixes were created.

For every CT images the matrix of values of elastic modulus is determined. When we combine all matrixes for one set of CT images in one big matrix we will receive values of elastic modulus in one file. In the next step the values of Young modulus from this matrix are subordinating to numerical model. Demonstrative process of converting images from tomography is presented in Fig. 10.

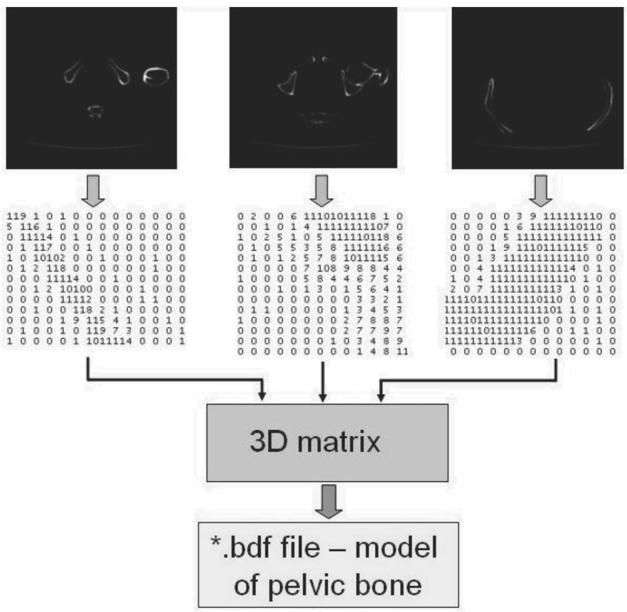


Fig. 10. The procedure to convert images from QCT to create numerical model

Additionally the text files with coordinates of nodes of researched model are created: x.txt, y.txt, z.txt.

Algorithm of the program consists of following steps:

a. Creation of 3D table: [u, v, w] on the base of file combined.txt: in numerical model coordinate *u* represents coordinate x, *v* represents z and *w* represents y.
b. Modification of input file to MSC.Nastran: the values of elastic modulus (obtained on the base of tomography) are inserted to numerical model. In this way we come into FEM model in which in every finite element the individual material parameters were subordinated.

The exemplary image from QCT and equivalent cross-section in numerical model are presented in Fig. 11.

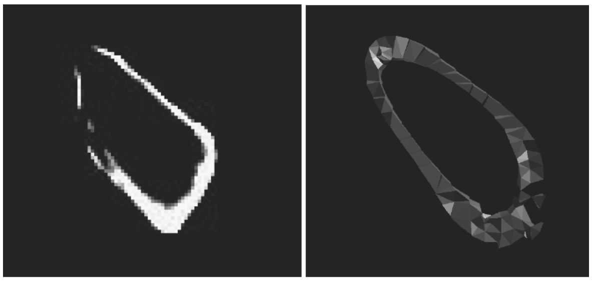


Fig. 11. Tomography image and cross-section in the numerical model

Exemplary part of matrix with values of Young modulus is shown in Fig. 12.

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119 1 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 1 0 0 1 0 2 0 0 6 11101011118 1 0 0 1 0
5 116 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 1 0 1 4 11111111107 0 0 0 0
0 11114 0 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 1 0 2 5 1 0 5 111110118 6 0 1 0
0 1 117 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 5 5 3 5 8 1111116 6 6 0 0
1 0 10102 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 2 5 7 8 1011115 6 7 1 0
0 1 2 118 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 7 108 9 8 8 4 4 6 8 0
0 0 0 11114 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 5 8 4 4 6 7 5 2 2 111
0 0 1 2 10100 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 3 0 1 5 6 4 1 1 104
0 0 0 0 11112 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 3 2 1 1 108
0 0 1 0 0 118 2 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 1 3 4 5 3 2 119
0 0 0 0 1 9 115 4 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 2 7 8 8 7 5 119
0 1 0 0 1 0 119 7 3 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 7 7 9 7 10116
1 0 0 0 0 1 1011114 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 3 4 8 9 11113
0 0 0 1 0 0 3 11115 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 4 8 1111111
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0 1 0 0 1 0 0 8 11119 5 4 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 4 7 119 11110
0 0 1 0 0 0 0 1 111110118 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 3 6 7 111111110
0 0 0 0 0 0 1 0 9 111111101 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 6 8 111111110
0 0 0 0 1 0 0 0 0 111111115 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 5 1111111110
0 0 0 0 0 0 0 0 0 101111119 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 3 101111118 0
0 0 0 0 0 0 0 0 0 0 1111117 2 1 0 1 1 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 2 111111115 0
0 0 0 0 0 0 0 0 0 0 111011107 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 3 111111101 0
0 0 0 0 0 0 0 0 0 0 6 111111116 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 9 111111110 0
0 0 0 0 0 0 0 0 1 0 0 11111011113 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 1 6 11111110110 0
0 0 0 0 0 0 0 0 0 1 0 6 111111114 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 5 111111111111 0
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0 0 0 0 0 0 0 0 0 1 0 0 0 4 11111111111106 4 7 9 5 5 3 1 0 4 111111111110 1 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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Fig. 12. Fragment of table with values of elastic modulus obtained from tomography, GPa

Numerical simulations

With regard to difficulties and limited access to images from tomography the numerical models were created also in different way. Second approach consist of division oh whole model into the subregions – groups. Cortical bone was divided into five sub-regions. In each subregions elastic modulus is in the some range of value. In Fig. 13 the subregions of cortical bone are shown:

- Pubic symphysis and joint of pelvic and sacral bone (15000-15600 MPa) – 1,
- surroundings of acetabulum (13000-13500 MPa) – 2,
- upper part of ilium ala (12000-12600 MPa) – 3,
- central part of ilium ala (13500-14000 MPa) – 4,
- ischium and pubis (14000-14500 MPa) – 5.

Cancellous bone was divided into following parts – Fig. 14:

- External layer of bone:
  - Surroundings of acetabulum (2300-2600 MPa) – 6,
  - Upper and lower part of bone (2000-2300 MPa) – 7,
- Internal layer of bone:
  - Surroundings of acetabulum (250-300 MPa) – 8,
  - Upper and lower part of bone (200-250 MPa) – 9.

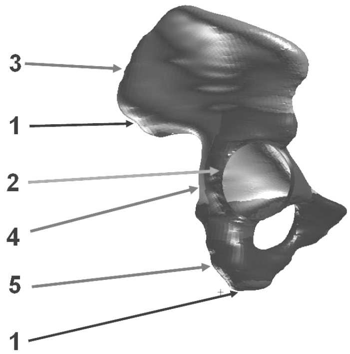

Fig. 13. The subregions of cortical bone

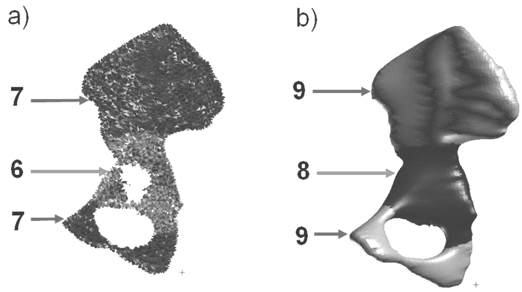

Fig. 14. The subregions of cancellous bone: a) external layer, b) internal layer

In each of these groups the values of elastic modulus in individual finite element were determined on the base of decreasing of bone mass and the range of changeability of Young modulus (Fig. 15).

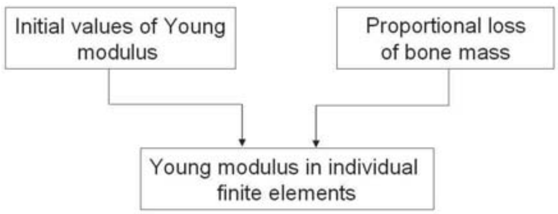

Fig. 15. Determination of elastic modulus in individual finite element

During calculations following relationships were used:

- for cortical bone – conception of Weinans [7, 9]:

$$E = 4.249 \cdot \rho^3 \tag{4}$$

- for cancellous bone – conception of Mow and Hayes [7, 9]:

$$E = 2.195 \cdot \rho^3 \tag{5}$$

where:
E – elastic modulus, GPa,
ρ – radiological density of bone tissue, kg/m^3.

It is possible to change these formulas to the another ones and compute the distribution of material properties according to the new relationships.

3.3. Boundary conditions

In the model the following boundary conditions are accepted:

- fixing (head of femur) – 1,
- roller support (pubic symphysis and connection of pelvic and sacral bone) – 2,
- nodal forces represent acting of muscle actions – 3,
- loading of upper part of body equal 500N (connection of pelvic and sacral bone) – 4.

Boundary conditions of model are presented in Fig. 16.

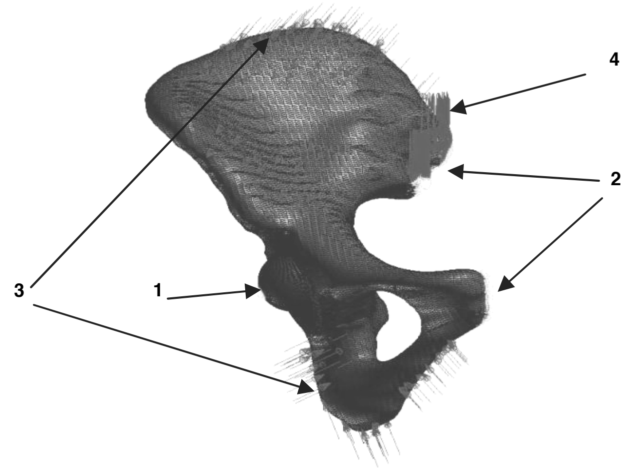

Fig. 16. Meshing and boundary conditions of the model

The values of loading stem from anatomy and physiology of hip joint [4].

4. Results from calculations

Calculations were performed on the base of linear static according to the Huber-Von Mises criterion.

In chapter 4.1. the results were presented for numerical model in which material parameters were obtained from tomography, in chapter 4.2. for model in which the material parameters were get on the base of numerical simulations.

4.1. Data from QCT

In Figs. 17, 18 and 19 the distributions of reduced stresses, strains and displacements are presented.

4.2. Numerical simulations of osteoporotical changes

The exemplary distributions of stresses, strains and displacements are presented in Figs. 20, 21 and 22.

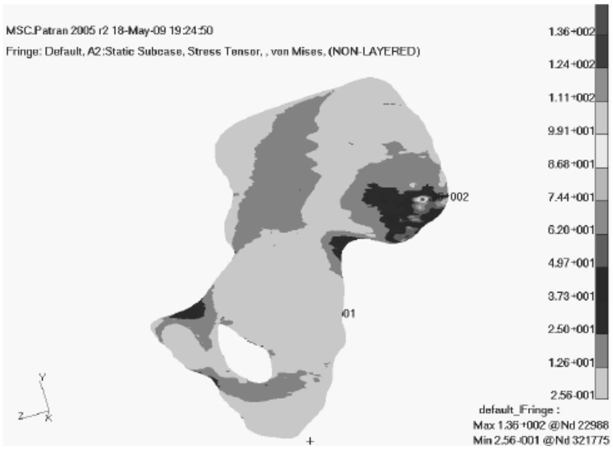

Fig. 17. The distributions of reduced stresses, MPa

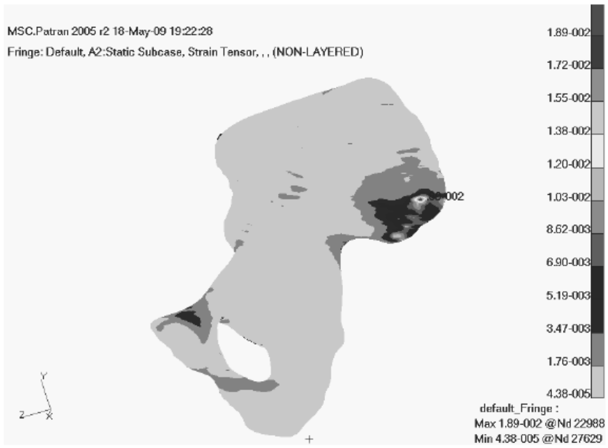

Fig. 18. The distributions of reduced strains

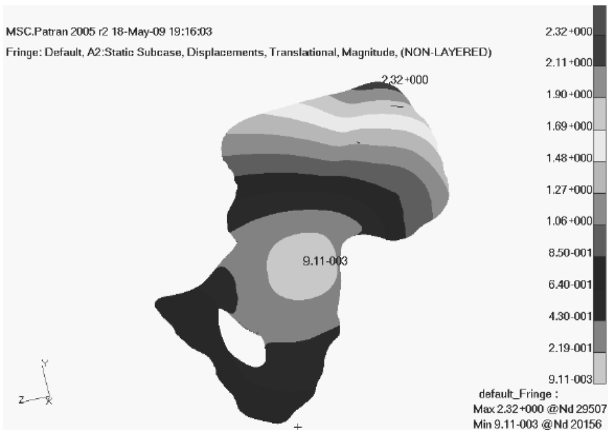

Fig. 19. The distributions of displacements, mm

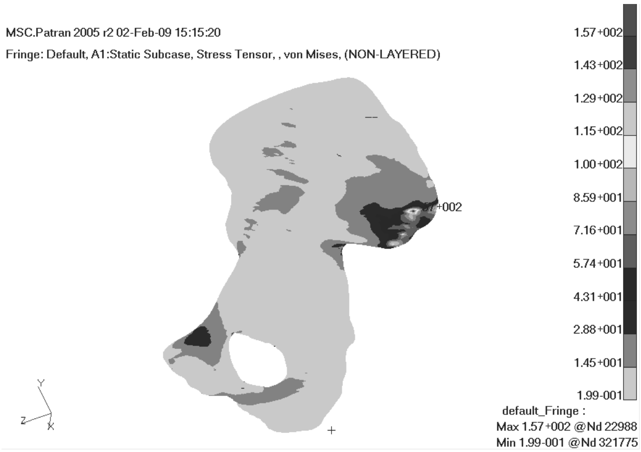

Fig. 20. The distributions of reduced stresses, MPa

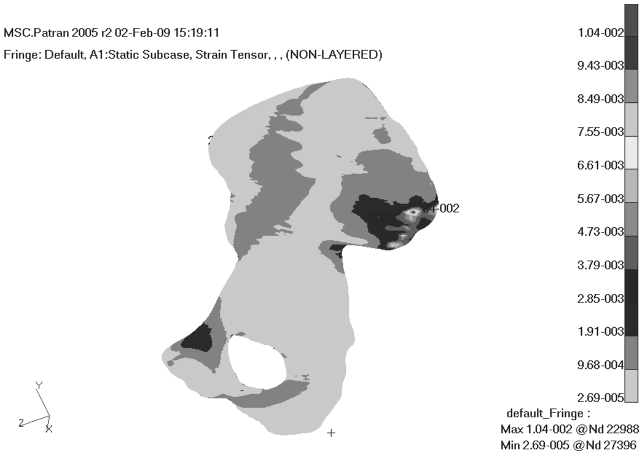

Fig. 21. The distributions of reduced strains

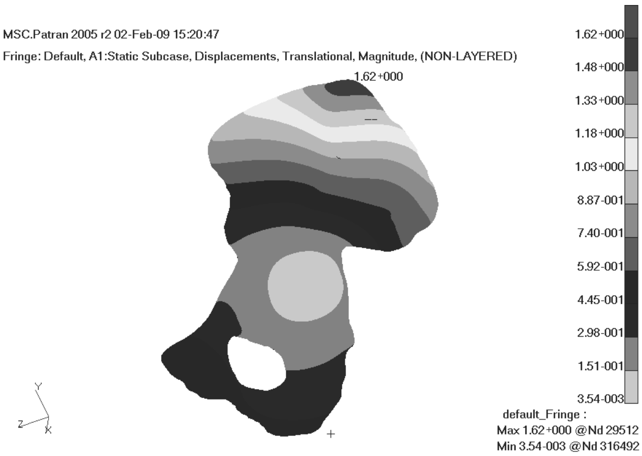

Fig. 22. The distributions of displacements, mm

Some results of numerical simulations are put into Table 1 and Table 2.

Table 1.
The displacements and stresses for loss of bone mass in upper part of ilium ala

loss of bone mass, %	u_{max}, mm	σ_{max}, MPa
0	1.38	157
10	1.51	149
20	1.68	140
30	1.89	144
40	2.16	154
50	2.49	164

Table 2.
The quantities for loss of mass in pubic symphysis and joint of pelvic and sacral bone

loss of bone mass, %	u_{max}, mm	σ_{max}, MPa	ε_{max}
0	1.38	157	$8.00 \cdot 10^{-3}$
10	1.49	148	$1.14 \cdot 10^{-2}$
20	1.62	137	$1.50 \cdot 10^{-2}$
30	1.79	130	$2.00 \cdot 10^{-2}$
40	1.98	144	$2.70 \cdot 10^{-2}$
50	2.22	162	$3.67 \cdot 10^{-2}$

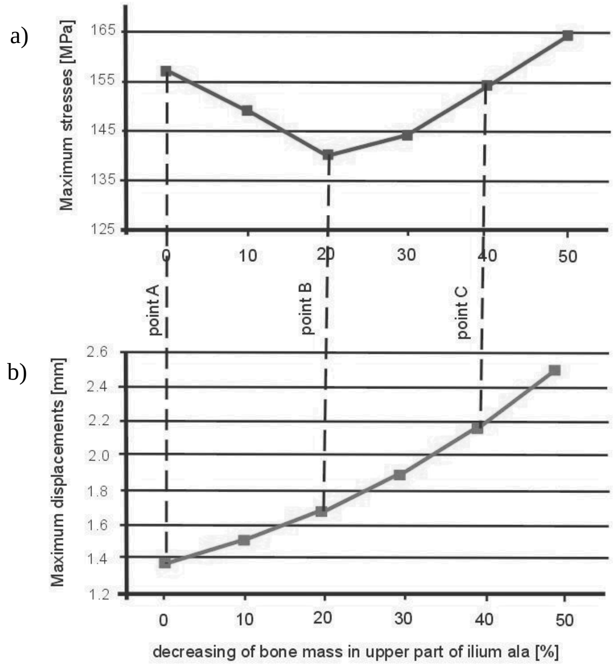

Fig. 23. The relationships between loss of bone mass and: a) stresses, b) displacements

In Fig. 23 the exemplary graph shows relationships between decreasing of bone mass and stresses and displacements. To infer about dangerous state in bone system one should take into attention all of quantities characterizing effort state, e.g. for point A, B and C information only about stresses is not unambiguous (it is not enough information about loss of bone mass) however when we also consider displacements we can determinate how loss of bone mass is in each points.

5. Aid of diagnosis the risky state in pelvic bone

5.1. Data base

After QCT examinations the tomograms of researches structure are obtained. At first, it is necessary to determine the radiological density. To transformation of that quantity one should rescale it to HU. The next step it is delimitation the density of bone tissue (on the base of density in HU). By using relationship between density of bone tissue and material properties it is possible to calculate material properties of bone tissue in each voxel. From the other hand, on the base of QCT data it is possible to create the geometry of numerical model. When the model is prepared the material properties are inserted and the strength calculation (according to FEM) is performed. On the ground of obtained results (distributions of stresses, strains and displacements) one can get information about effort in researched bone.

When the large amount of QCT examinations will be realized (the set of data will be converted and strength calculations will be performed) it will be possible to create the data base. This base will can aid detection of osteoporotical changes in human pelvic bone. This data base one can compare to table – matrix which consists of CT photos: column symbolize images for individual patients, row vector places where images were done. The base one have to divide on two main parts: QCT images and numerical simulations. General structure of data base is shown in Fig. 24.

5.2. Procedure to aid of diagnosis the risky state in human pelvic bone

After building the numerical model the next step of work is to develop procedure to aid of recognizing osteoporotical changes in pelvic bone.

The general principle is as follow: after radiology examination it takes place searching to find the most similar images (searching CT photo from data base). When these images are found the whole model with strength parameters is assigned. Next the results (from strength calculations) are analysed. As a consequence, particular images from QCT are subordinated effort of bone. In case of need it is possible to return to searching of base and analysing the larger number of data. The simplified block diagram of the program is presented in Fig. 25.

In the program are available two searching procedures: on the base tomography images and decreasing of bone mass.

In procedure of searching on the basis of QCT, first one should read image which will be analysed, next he should read the images from data base. When sorting is ready, one should insert number of image, which is the most similar, to the textbox of the program – the information about dangerous state will appear in the window of the program. This procedure is presented in Fig. 26.

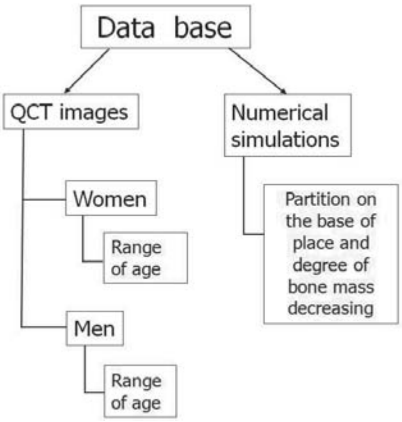

Fig. 24. Schematic structure of the data base

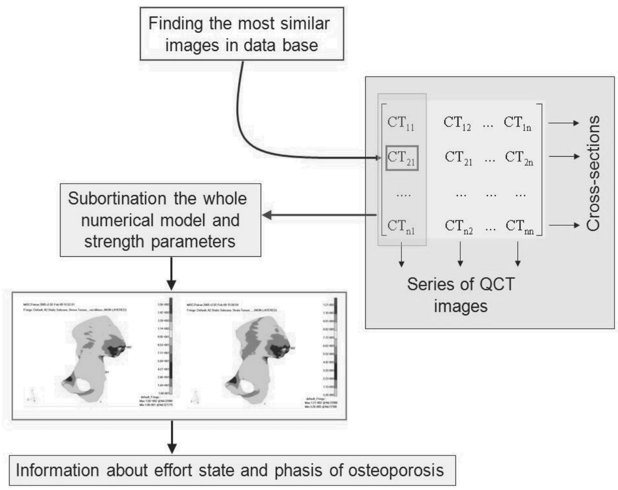

Fig. 25. The block schema of the program

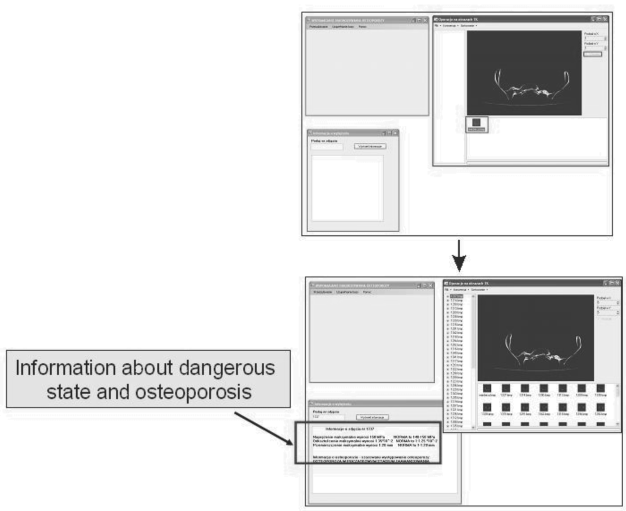

Fig. 26. The algorithm of the searching on the base QCT images

In procedure of searching on the basis of loss of bone mass one should indicate the proportional decreasing of bone mass (from the combo box) in each subregions of cortical bone in numerical model of pelvic bone. When all lists are ready in the window of the program the information about dangerous state and potential dangerous of osteoporosis will appear. This procedure was presented in Fig. 27.

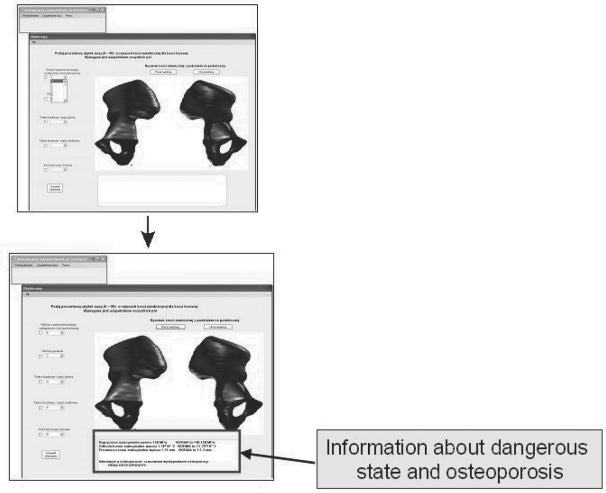

Fig. 27. The algorithm of the searching on the base loss of bone mass

6. Conclusions

- Applied procedure facilitates interpretation of data from QCT and it enables better visualisation of osteoporotical changes.
- Presented procedure delivers additional information about effort state of analysed bone.
- Information from QCT can be helpful for researching progress of osteoporosis in individual clinical cases (because easier one can find the differences between earlier and later images).
- Subordinating individual images from QCT to effort state provides information about bone system.
- Creation of numerical model on the base of radiological data (especially material properties) increasing its conformance to real conditions.
- Quality of obtained results depends on amount of information gathered in the data base.
- Presented procedure enables noticing changes in bones more precisely than standard methods (this is important when the difficulties with clear diagnosis appear).
- The structure of data base enables easy and quick extension.

7. Future plans

- Extension of data base. The structure of data base enables its easy extension. The more data collected in the base it means the higher possibilities in aid of diagnosis.
- Widening this procedure to another elements of bone system. Here, the example of pelvic bone was presented, but one can also apply this procedure to another bone and joint e.g. for the spine or metatarsus bone. To perform this one can dispose the data necessary to prepare the numerical models and create proper data base.

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