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Computer systems for determination of pressure distribution in the hip joint articular surface: validation and results

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Background. *In this work, we describe the computer systems Viprecox and Active Contours that are used in the process of realistic estimation of some biomechanical parameters of the hip joint, including the maximal value of the stress in the hip joint* p_{max}*. The computer system Active Contours uses standard anteroposterior radiographs of the whole pelvis and both hips for its calculations and Viprecox in its kernel uses a relatively simple three-dimensional mathematical model of stress distribution in the hip-joint articular surface which has been extensively described elsewhere (e.g. Iglič 1996).*

Material and methods. *Both state-of-the-art computer systems were tested by analysing the calculated values of* p_{max} *for 81 patients (37 males and 44 females).*

Conclusions. *In this way we prove that the described computer systems can be used for the determination of the contact stress distribution from standard AP radiographs.*

Key words: hip joint; biomechanics; computer systems; weight bearing

Introduction

Higher and unevenly distributed contact stress in the hip-joint is a risk factor for the development of arthrosis.[1,2,3] There are several biomechanical parameters that describe the distribution and the peak value of the stress in the hip joint, such as the gradient of the stress at different positions of the articular surface or the maximal value of the pressure on the articular surface of the hip joint $p_{\max}$. The realistic measurement or the estimation of these parameters would be helpful in exploring the incidence of degenerative joint diseases.

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In this work, we describe the computer systems *Viprecox* and *Active Contours* that are used in the process of a realistic estimation of some biomechanical parameters of the hip joint including the value of the parameter $p_{\max}$. Our additional purpose is to test these *state-of-the-art* computer systems by analysing the calculated values of $p_{\max}$ for 81 patients (37 males and 44 females).

Materials and methods

The computer system Active Contours uses standard antero-posterior radiographs of the whole pelvis and the both hips for its calculations (Figure1) and *Viprecox* in its kernel uses a relatively simple three-dimensional mathematical model of stress distribution in the hip-joint articular surface, which has been extensively described elsewhere.[4]

The system *Viprecox* was developed as a 100% pure Java application, which enables the compatibility with any platform that uses the Java Virtual Machine. In the process of design and application development the object-oriented paradigm was used. The use of the object-oriented programming technique will allow the system easy maintenance and upgrades, but it will also allow a conversion to other platforms.

The system *Active Contours* uses digitised profiles of standard antero-posterior radiographs of the pelvis and the both hips in order to extract the important data about the geometry of the both hips and the pelvis (Figure 1). These data are then transformed by using a non-homogeneous tailoring procedure[5] in order to prepare the input data for the three-dimensional mathematical model of stress distribution in the hip-joint articular surface.[4] For this purpose a reference model of the hip-joint musculature is used.[6]

As a result of the non-homogeneous tailoring procedure certain muscles' origin and insertion points are estimated. The reference muscles' origin points[6] on the pelvis and the reference insertion points on the femur were not corrected in the antero-posterior direction because of the lack of data. All other coordinates are corrected as follows:

Figure 1. The system *Active Contours*: detection of points that lie on the contour of the endoprosthesis head.

The reference origin points on the pelvis for all muscles were corrected in the medio-lateral direction by using the ratio C/C_{ref}, where C is the distance between the sagital plane passing through the femoral head centre and the most lateral point on the pelvis. The system *Viprecox* automatically measures this point. C_{ref} is the corresponding distance in the model of Dostal and Andrews[6] $C_{ref}=(B_{ref}-L_{ref})/2$. The insertion points on the femur are divided into three groups: 1. m. gluteus medius and m. gluteus minimus, 2. the lateral point of m. piriformis and 3. the inferior points of m. tensor fasciae latae and m. rectus femoris. The system *Viprecox* automatically measures the Cartesian coordinates of the insertion points of the gluteus muscles in the frontal plane from the digitised antero-posterior radiographs. The insertion point of m. piriformis lies laterally and was therefore corrected only its medio-lateral coordinate by using the ratio between the already corrected medio-lateral coordinates of the gluteus muscles and the corresponding reference values. The distance L between the two centres of rotation of both hips was taken as automatically measured by the system *Viprecox*.

After such non-homogeneous tailoring procedure the prepared data are presented to the mathematical model of the hip-joint.[4] In this way the maximal pressure on the hip joint articular surface p_{max} is calculated.

Results and conclusions

Figure 2 shows the calculated hip joint contact stress for a patient with implanted hip endoprosthesis (for the other healthy side). In order to establish the clinical relevance of the

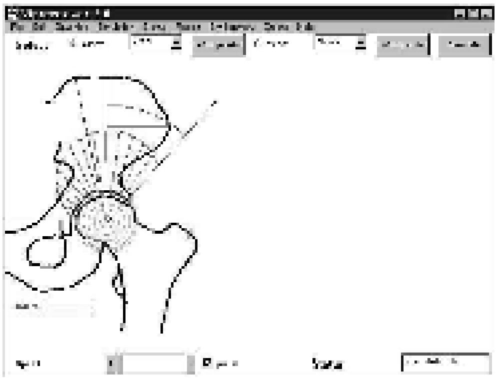

Figure 2. An example of distribution of the stress on the hip joint articular surface graphically presented by the system *Viprecox*.

parameter p_{max} the computer system should be applied to various populations of patients where the correlation between the clinical status and the hip stress may be studied. Recently, these systems have been used in order to determine the peak contact stress in the articular surface of the hip joint from standard AP radiographs for 37 male and 44 female healthy hips of patients subject to trauma of the other hip (Figure 2). It was shown that the peak contact stress is considerably higher (cca 20%) ($p<0.00005$) in the female population (1.99 MPa) than in the male population (1.63 MPa). These results are in favour of the hypothesis that the increased hip joint contact stress in the female population could contribute to the greater incidence of arthrosis in the female population relative to the male population.

To conclude, the described computer systems *Active Contours* and *Viprecox* can be used for the determination of the contact stress distribution from standard AP radiographs. The systems can be applied in the clinical practice to predict an optimal stress distribution in different operative interventions in the hip and to analyse the short and long term outcome of the treatment of various conditions of the hip.

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