MODELLING BONE – IMPLANT DYNAMICS

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Abstract

The aim of this paper is to consider dynamics of a system composed of bone and implant, with different quality of their attachment, using theoretical and experimental modal analysis. The studies are focused on development of a diagnostic tool based on the vibration technique.

Artificial bone replacements used for implants have become widely applied elements of treatments in orthopedic surgery for recent years. Destructive diseases or accidents call for prosthesis, which in many fields have achieved a certain degree of perfection, yielding pain-free functionality and longevity. However, gradual loosening of the implant-bone attachment integrity due to wear, bone regress (related to ageing or diseases) and micro-mechanical damage lead eventually to the failure of the replacement and thus to painful consequences: a repetition of the implanting surgery takes place under unfavourable conditions. On the other hand total costs of the healing are multiplied.

The existing methods of quality monitoring of implants are based either on the X-ray imaging or ultrasonic inspection (among them: standard radiography, contrast radiography and scyntigraphy). They are therefore impaired by shielding effects when complicated shapes of the prosthesis are needed. All methods above mentioned reveal not sufficient sensitivity and specificity when needed. Moreover, too frequent X-ray irradiation may lead to other serious injures.

Fig. 1. Mesh of substitute – simplified model.

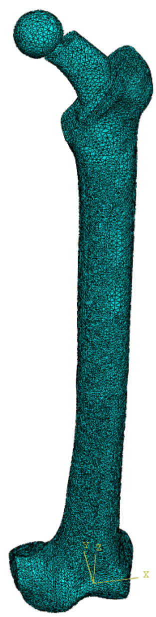

Fig. 2. Mesh of anatomical model.

An alternative method of diagnosis is considered, based on the monitoring the integrity of the implant and bone by checking the changes of its vibrational characteristics. Unlike the ultrasonic inspection, which works on the principle of pulse dispersion and reflection for waves of certain frequency chosen for the tested tissue, the proposed method would rely on monitoring of the shifts of the frequency spectrum caused by the changes in the mechanical properties due to the deteriorating state of the system. A feasibility study for this relatively new method begins with the modelling of attachment integrity. This constitutes a starting point for both FE simulations using numerical modal analysis and experimental study based on vibrational techniques.

In the numerical part of the research two general types of models, taking into account geometry, are considered: substitute - simplified models which are grounded on beam model and anatomical models, fig. 1, based on real geometry of femur bone and implant. In this part of study called theoretical modal analysis Abaqus numerical environment is used to perform computations.

In the experimental study substitute-simplified systems are investigated using modal analysis which model the attachment. The set of dynamic parameters of the system is identified by measuring vibrations. The experimental tests are accomplished by introducing either impulse or harmonic excitation.

Analysis of numerical and experimental data which include: shifts in frequency spectrum, changes in eigenmode shapes, fluctuations of amplitude revealed significant changes in frame of proposed model of bone-implant integrity deterioration. It creates a starting point for determination of quantitative assessment of bone-implant integrity.

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