Finite element analysis of fixation of intertrochanteric fractures of the femur using different designs

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1. Introduction

In the last decades the number of fractures of the trochanteric and subtrochanteric region of the femur has increased significantly and continues to grow. In the elderly intertrochanteric fracture occurs as a result of a fall or injury in the area of the greater trochanter. Osteosynthesis at the present time can significantly reduce pain, to provide the support ability of the limb and to restore movement in the joint. Obviously, each type of fixation should be used reasonably [1]. The efficiency of the "bone-implant" biomechanical system is defined by the condition of the stress-strain state and mechanical behaviour of each element of the system under the action of functional loads. If in certain areas of the bone or implant the functional load causes stress which exceeds some value (for example tensile strength, fatigue limit, etc.), then a destruction or plastic deformation of one or more components occurs, which leads to partial or complete loss of functionality of the whole system [2]. Finite element method (FEM) has been used for computer simulation of the behavior of "bone-implant" system.

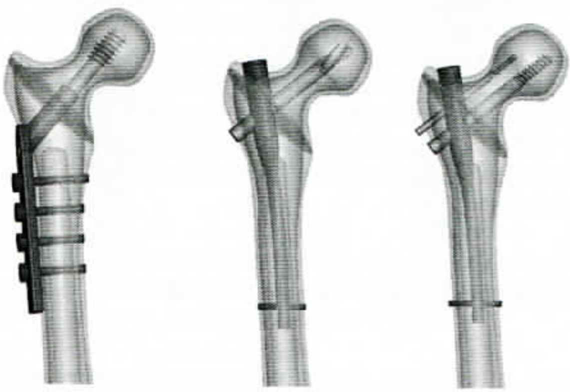

Fig. 1. Fixation of intertrochanteric fractures using plates and intramedullary nails.

2. Materials and methods

In order to improve treatment outcomes and quality of life of patients, the biomechanical oriented analysis for the choice of optimal implant in case of osteosynthesis of intertrochanteric fractures of the femur using the finite element modeling of stress-strain state systems "bone – implant" is carried out. Using images of computer tomography (CT) the proximal part of the femur, and intertrochanteric fracture have been generated. The load acted on the femoral head, in the case of a standing human weight 70 kg, was taken equal F = 458 H. For the numerical calculations was chosen isotropic model of the material for all bodies, with the relevant physical and mechanical parameters. Stainless steel (316L), having a modulus E = 210 GPA and Poisson ratio ν = 0.3, has been selected as the material for the physical properties of the implant component. The following parameters are fixed during our

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study of the cortical layer of the femur (see reference [3]): elastic modulus E = 17 GPa, Poisson's ratio $\nu = 0.3$, tensile strength $\sigma_b = 120$ MPa; spongy layer: E = 1.5 GPa, $\nu = 0.3$, $\sigma_b = 6$ MPa.

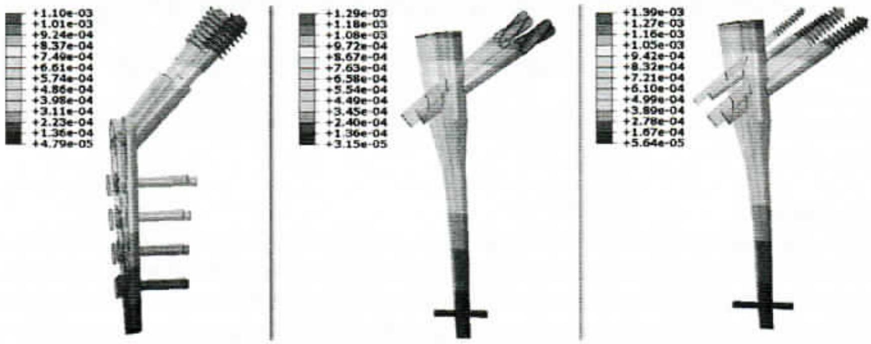

Fig. 2. Deformation (scale 10:1) implants in the frontal plane in the case of application of different variants of fixing.

3. Results

The following biomechanical characteristics of the system have been studied: distribution of stresses and displacements in the femur and fixation constructs and also defined safety factor of implants and bone. In general, the results of the calculations showed that in the case of selecting these parameters of the system "bone – implant", maximum stresses in the elements of the assembly does not exceed the yield strength of the material, and all elements of the system are in a state of elastic deformation. This means that stresses in the metal of the implant under the action of functional loads are less dangerous. The dangerous stress value in this case is assumed to be greater than the fatigue strength of steel 316L which is used to manufacture the implants. The value of fatigue strength of 316L is equal to the magnitude of about 200 MPa. Thus, employment of these structures provides a sufficient safety margin. Despite the higher stiffness of the elements of the plate compared with intramedullary nails, the displacement of the components differs slightly (Fig. 2). This means that fixation of bone fragments is carried out satisfactorily.

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