The iMPact of stabilization configuration on bone union possibility for fractures of the distal femur

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Abstract

Nowadays intramedullary nailing is a gold standard for the surgical treatment of femoral shaft fractures. The aim of present study was to determine which of the variants of intramedullary fixation of femoral shaft fracture provides most stable conditions for the bone union. In our study, we developed five variants of intramedullary fixation. The numerical simulation using the finite element method was conducted in the Ansys 17.2 environment. In our calculations we showed that using one-plane distal stabilization combined with the use of a reconstructive screw is the most secure type of stabilization.

Keywords: finite element method, femur bone, hip fractures

1. Introduction

Nowadays intramedullary nailing is a gold standard for the surgical treatment of femoral shaft fractures. Placement of the implant in a correct position in 3-dimensions, combined with its shape, is critical and allows uniform load transfer which reduces the risk of stress-shielding. The aim of present study was to determine which of the variants of intramedullary fixation of femoral shaft fracture provides most stable conditions for the bone union.

2. Materials and methods

The numerical simulation using the finite element method was conducted in the Ansys 17.2 environment. A bone model was developed on the basis of CT scans of a healthy 45-year-old man. Data set was converted into a geometrical model with the help of the Ansys Design Modeler package and some opensource packages (i.e. Meshlab). Secondly, a 2 mm wide fracture gap was generated in the model of the bone – type 33A2 according to the AO classification. The model was divided into cortical and trabecular bone tissue and materials were assumed isotropic. The thickness of the cortical layer was dependent on the location in the bone.

A model of the anatomical nail was developed based on CT data and parameters available in the manufacturer's catalog with the help of the SolidWorks 2014 package.

Both models were meshed using different types of elements – the bone was discretized using 20-node brick elements due to the need for tissue division, the nail and locking elements were discretized using 10-node tetrahedron elements due to its complicated shape with numerous holes.

In our study, we developed five variants of intramedullary fixation (Figure 1A). In the first variant, we used a static method using two locking screws in the frontal plane – one in the lesser trochanter and the second in the distal part of the bone using an oval, static hole. In the second variant, a compression method was used with four locking elements – two screws in the proximal part and two in the distal end of the bone. The third variant was almost the same as the second, except that the last screw at the distal end has been introduced in the sagittal plane. In the fourth variant, we used reconstruction method, however, instead of usually applied two reconstruction screws, we used only one of them. The fixation of the nail in the distal part was carried out in the same way as in the second variant. In the last variant, the nail in the proximal part was fixed such as in the fourth variant but the distal part was carried out in the same way as in the third variant. The screws crossed over the two cortical layers have different lengths depending on the zone of the bone.

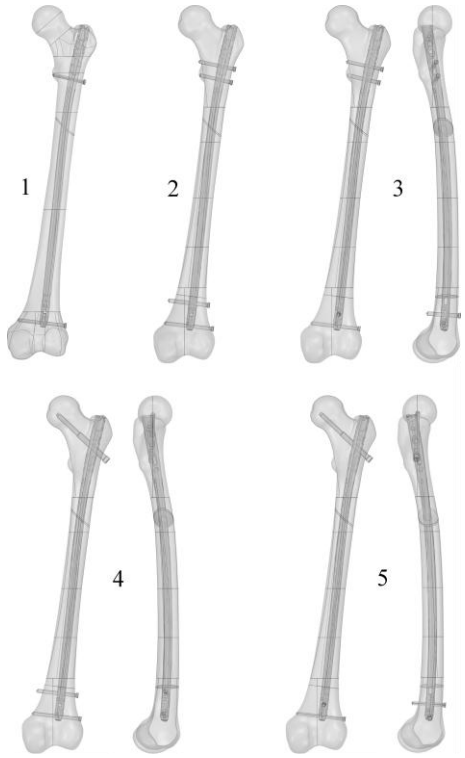

Figure 1: Analysed variants of intramedullary fixation

The calculations were made using the resources of the Wrocław Centre for Networking and Supercomputing (http://www.wcss.pl), calculation grant No. 397.

The boundary conditions were adjusted to those the femur bone undergoes during one-legged standing with 50% of nominal forces. The model was loaded with forces proposed by Będziński [1] – Fig. 2A. Next, the bone model was attached according to the Fig. 2B.

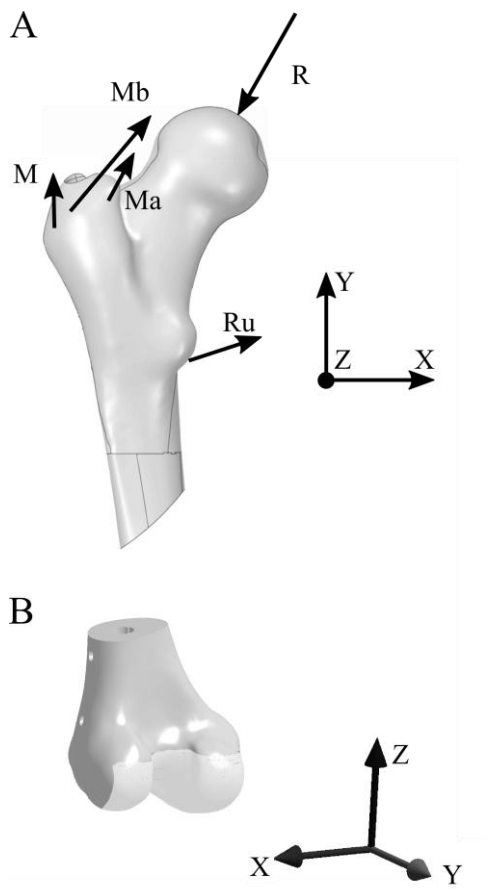

Figure 2: The boundary conditions: loading forces (A), fixed support (B)

The material properties of the implant, locking elements, and bone tissues (Table 1) were adopted on the basis of the data presented in the literature [3].

Table 1: Material properties of the model

Material	Material properties	
	E [MPa]	ν [–]
CoMPact bone	16700	0.3
Cancellous bone	155	0.3
Fracture gap tissue	2	0.4
Ti6Al7Nb	105000	0.36

3. Results

The obtained results show that application of one-plane distal stabilization leads to stress reduction irrespective of the type of proximal stabilization. In fact, this method of stabilization is the most commonly used in Polish clinical practice The use of two-plane distal stabilization leads to a deterioration of the stress conditions in the fracture gap. At the fracture site, the stresses obtained for implants are in the range of 250-333 MPa – Fig. 3, which is below the critical parameters of the implant's material. It must therefore be considered that in the modeled system, for the selected load, the patient's tissue will be more likely to be destroyed. The stresses obtained in the bone tissue for 2nd and 3rd variant would be considered as potentially hazardous and could lead to degradation of bone material, which in turn would lead to loss of stability of the fracture. Destabilization of the system always requires surgical intervention, which in turn raises the risk of failure of treatment [2]. From the mechanical point of view variant 4th and 5th seem to be the most secure for the patient - the probability of implant damage is reduced with proximal stabilization with a reconstructive screw.

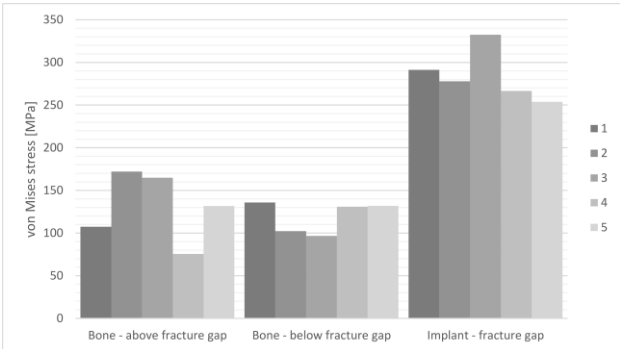

Figure 3: Maximum stress obtained for every variant of fixation in three region of the model

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