1. Introduction

The study describes a computational approach for predicting the mechanical response of different configurations of the Ilizarov external fixation system. The Ilizarov type fixators are now being used to an increasing extent to stabilize bone fractures and for limb lengthening [5,6] and its functions are investigated using numerical [e.g. 3,7] and experimental [e.g. 1,2] techniques. The device is a specialized form of external fixator, modular in construction. Stiff rings are fixed to the bone via wires (called pins or Kirschner wires). The rings are connected to each other with adjustable rods. The circular construction and tensioned wires of the Ilizarov apparatus provide better structural support than the traditional monolateral stabilizers. This allows early weightbearing. The stabilization enables a degree of movement between the connected bone parts, and, under some conditions, this is considered as beneficial to the healing process. The stiffness characteristics of the device are, therefore, crucial to bone healing [3,5,7].

Computational parametric modelling used in the work can provide some information about the influence of different configurations of the fixator and its parameters on the mechanical behaviour of the device without the need for a laborious and time-consuming experimental testing.

2. Methods

In this study a few FE parametric models of the Ilizarov external system and its components were built to characterize the behaviour of each individual part and the whole device. Finite element method is the well known powerful tool, often used in biomechanics [3,7]. Parametric approach permits a finite element model to be defined as a function of variables (parameters) instead of the more conventional numerical data. Dimensions are expressed as named variables or expressions involving other dimensions. The currently defined values are automatically reflected in the entire model. FE models created in this way may be also used for numerical optimization of the structure.

![Computational model of the Ilizarov device](image.png)

**Fig.1.** Computational model of the Ilizarov device: the scheme of the load transmission, FE geometrical model and the part of it with the element mesh
The FE set of equations is in the considered models nonlinear: \((K_0 + K_u + K_d) \mathbf{d}q = \mathbf{dF}\), where \(K_0\) is stiffness matrix, \(K_u\) – large displacements matrix, \(K_d\) – stress stiffness matrix, \(\mathbf{dq}\) – increment of nodal displacements, \(\mathbf{dF}\) – the increment of the nodal forces and takes into account such reasons of nonlinerities as prestress effects, large deformation and elasto-plastic properties of the materials.

3. Results

The obtained results reveal the impact of different parameters of the device on the stiffness of the stabilization (relative movement of the bone fragments), the stresses within the stabilizer components and within the bone. The factors investigated here were e.g.: the dimensions of the rings and Kirschner wires, pretension forces in the wires, mechanical properties of the material used for the structure components.

![Figure 2. The maximum stress in the wires and the relative axial movement of the bone parts as functions of the preload force in the wires. Stabilizer under the axial force \(P_c=300\)N](image)

4. Discussion

The analyses performed using the parametric models of the fixator system provide the information helpful for the design of the stabilizer parts and for adjusting the configuration for the patient, taking into account the available components and the treatment case. Particularly the strength and the flexibility of the device is estimated as dependent on the potential loads of the bone and other parameters. The conclusions may be helpful for custom design of the stabilizer configuration.

References


