Biomechanical analysis of bone healing at one and double-plates fixation of femoral bone fractures

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1. Introduction

Along with the development of technology, mainly motorization and active lifestyle of a contemporary person, we can observe a substantial increase of a variety of injuries of organs responsible for locomotion. In the light of medical knowledge, in the cases of healing bone fractures it is essential to reduce the fracture and maintain it in such a position as to restore the functions of the injured body part until synostosis occurs. The most beneficial method is to obtain a stable fixation of the fractured bone, which enables the patient to undergo therapeutic rehabilitation as soon as possible. In the majority of clinical cases, difficulties are observed in long bone stabilisation with the use of widely applied osteosynthesis methods. Excessive obesity, ankylosis, infected non-union of fragments with bone defect, mental diseases and the need to avoid the bone fractions rotation constitute an example complex of factors making it impossible to apply an ordinary plate, an intermarrow rod, or an external stabiliser in order to obtain stable fixation.

The main direction of the research carried out in the work were the unsolved issues of the biomechanics of the bone–Polfix type plate stabiliser system functioning in a multi-plane system. The work includes an analysis of the influence of different plate fixation parameters on the state of the fixation’s tensions and displacements with the use of a parametric numerical model as well as experiments on a physical model with the aim to establish the actual biomechanical characteristics.

In order to facilitate physicians in the process of diagnosing, highly advanced computer systems are becoming more and more popular. CAE (Computer Aided Engineering) programmes are often used, allowing to analyse the model’s operating with the load force imposed on it. An example of such a programme is ANSYS using the Finite Element Method (FEM). Some of the advantages of this type of research are its low costs and the possibility of carrying out the research practically in all conditions. For a more complete description it is of course indispensable to carry out also the experiments aiming at verification but the latter are easier to conduct in the presence of the first assessment resulting from the use of the numerical model.

2. Materials and methods

On the basis of a literature analysis as well as clinical data, a parametrical numerical model of a two-plane plate femoral bone fixation was created. The model takes into consideration the following parameters: the bone diameter, the cortex layer thickness, the closer and farther fraction lengths, the interfragmental crack, the plates inclination angle, the lengths of the fixing plates, the distance between the plates and the bone, the angle of mounting of the first plate, and also the number, lengths, and diameter of the screws, as well as the distances between the latter.

The experiments were also carried out using ESPI (Electronical Spankl Photo Interferometry). This method uses the phenomena of reflection and diffusion of laser light on a rough surface of the tested object. ESPI method bases on registration of spot images electronically acquired which enables for automatic processing of data about the state of dislocation of the tested surface.

3. Results

The results obtained on the basis of the numerical simulations performed with the use of the FEM illustrate the tension and deformation fields distribution patterns. The obtained results confirm clinical data on loosening of the outermost screws of the plate stabilisers. The highest tension values were observed at the screw – first bone cortex layer boundary, i.e. the layer closest to the fixing plate. The above is confirmed by clinical reports informing on the observed loosening of the screws at these points.

Analysis of test results using ESPI shows that application of double plates stabilization in comparison to single-plate stabilization, causes substantial decrease of lateral distortion of bone fragments in the area of the fracture gap, with a negligible change of axis distortion parameters. This can favourably affect the state of loads in a newly formed bone tissue in the fracture crack. Change of bone screw’s length, fixing stabilizers in the area of the fracture causes insignificant changes of distortion state. It is important thought to take under consideration that, models of bone fractures are characterized by a greater stiffness in realation to the actual bone tissue. Examples of displacement test results using ESPI are presented in figure 1.
From the point of view of biomechanics, bone fractions fixed with the use of a two-plane plate fixation constitute quite a complex, dimensional construction. The selection of the appropriate parameters in fixations of this type directly influences the stabiliser’s rigidity, thus influencing the conditions of the callus formation and shape, the durability of the bone grown together, and in the final effect – the success of the whole operation.

4. Discussion

On the basis of the results obtained it can be concluded that applying two-plane plate stabilisers makes it possible to control fixation parameters to a large extent. At the same time, it has to be emphasised that even a small change of the stabilising system geometry might lead to a significant change in the conditions of the process of fractured bone union. It is thus necessary to investigate the details of biomechanics of such a fixation, and then develop instruments facilitating selection of an optimal configuration of plates and fixing screws. In terms of a two-plane fixation, the centre of rotation is located in the fracture crack. In this area the approach of bone fragments takes place. This effect is not of danger to the healing process, because there are no tangent forces present, which can destroy (as an effect of shearing) the bone tissue. The scheme of distortion vector distribution on the surface of the model shows that system’s centre of rotation is located in the fracture crack and in this area the approach of fracture fragments from the opposite side of the plate takes place, and distancing movement on the plate side. This type of distortion in the fracture crack stimulates formation of new bone tissue. From the obtained test results we can notice that application of two-plane fixation causes distortion of fragment’s centre of rotation to the fracture crack, at the same time allowing for better healing conditions. This is in accordance with literature data and also is confirmed by clinical tests. Results of these tests show a significantly better and faster synostosis achieved through two-plane fixation.

References


