Biomechanical investigation of contact interactions on articular surfaces of elbow joint

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Key words: *distal humerus fracture, range of motion, contact stress area, stress-strain state, finite-element mesh*

1. Introduction

Fractures of the distal humerus metaepiphysis arise in the case of a fall onto the hand with a straightened elbow joint, in combination with the abduction of the forearm. This fracture can arise simultaneously as a result of a direct blow to the elbow joint, in the area of the medial epicondyle, and broken coronoid process of the ulna. Treatment of intra-articular fractures of the distal humerus is a difficult problem. Great trouble arises in patients older than 60 years in the event of prolonged immobilization (more than 14 days). This causes the deterioration of motion of the elbow joint and reduce possibilities for the restoration of movements in the minimum required physiological range [1]. In this sense, a question arises, at which minimum displacement of the fragments, the components of the articular surface can be obtained the desired range motion of the elbow joint during rehabilitation. In order to find an answer to this question, it is necessary to study the contact interaction between the articular surfaces in the case of modeling intra-articular fracture of the distal humerus metaepiphysis [2, 3].

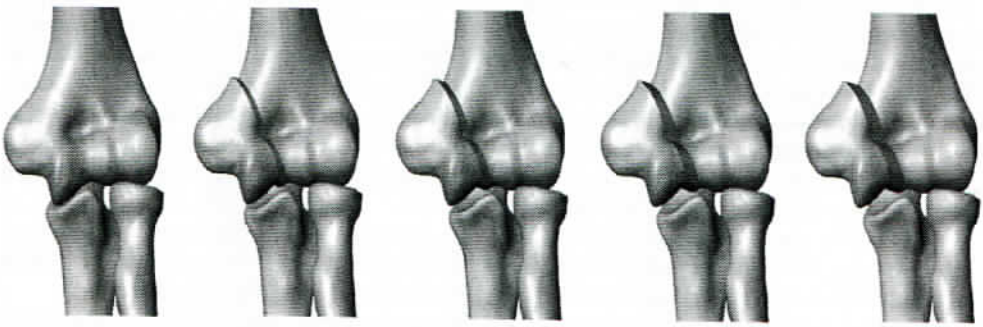

Fig. 1. Geometrical model of the elbow joint with fracture of the distal humerus without displacement, with displacement of 2-5mm.

2. Materials and methods

We are aimed to determine the dependency between the contact stresses and the contact areas and the possible range of motion in the elbow joint. Finite element method (FEM) was used to solve this problem. Employing images of the computer tomography (CT), the geometrical model of the elbow joint (Fig. 1), satisfying requirements for the study of stress-strain state, have been constructed. Five different types of the elbow joint have been illustrated: a fracture without displacement; fracture of the distal humerus with different values of displacement of the articular surface of the humerus block, which was equal to 2-5 mm. The carried out computation included analysis of the system at angle of flexion in the elbow joint taken from interval of 0 to 120 degree.

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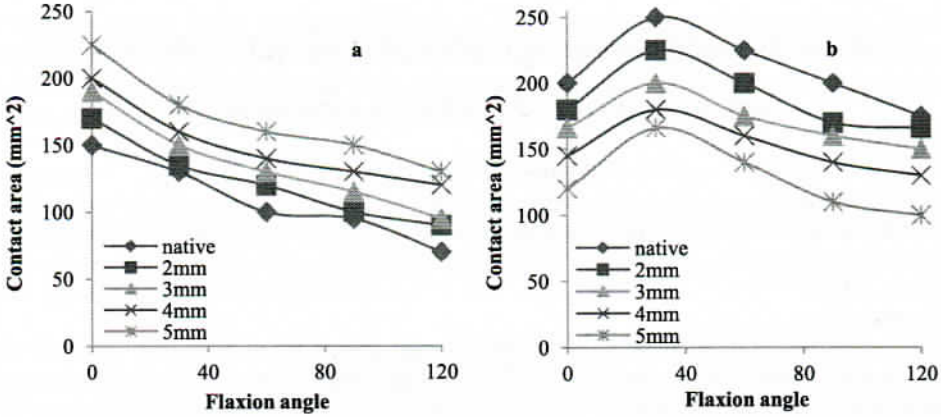

Fig. 2. The dependence of the contact area of the radial head bone (a), the articular surface of the ulna (b) with the articular surface of the humerus and the flexion angle and magnitude of displacement of fragments in the case of fracture.

3. Results

The results showed that in the case of the fracture of the block of the humerus with displacement from 2 to 5 mm, the contact area of the radial head bone with head of capitellum of humerus varies by about 50%, depending on the angle of flexion. Namely, increase of the flexion angle implies decrease of the contact area (see Fig. 2a). When considering the contact area between the block of the humerus and coronoid process of the ulna, it has been determined that the increase in the displacement of bone fragments yields decrease contact area and increase of the flexion angle as well as decrease of the magnitude of the contact area (see Fig. 2b). The carried out investigations allow to formulate the following conclusion: decreasing the contact area of the articular surface of the ulna and humerus in the case of increasing the displacement of fragments and the angle of flexion at the elbow joint, as well as increase contact stresses on the articular surfaces leads to limitation of flexion of the elbow joint. It also occurs as a result of a breach of congruence of the articular surfaces, and the increased pain caused by increased pressure on the articular surfaces.

Our results showed that the fragment offset of 2-3 mm, in the case of fracture of distal humerus metaepiphysis does not significantly reduce the angle of flexion at the elbow joint, regardless of the increase of the contact stresses up to 20-30 % compared to normal physiological stresses.

This fact may be useful in the treatment and subsequent rehabilitation. Thus, displacement of intra-articular fragments on 2-3 mm can be considered as the maximum allowable offset, which will not significantly bound the motion in the elbow joint.

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