Biomechanical Analysis of Nail and Plate Osteosynthesis for the Humerus Fracture

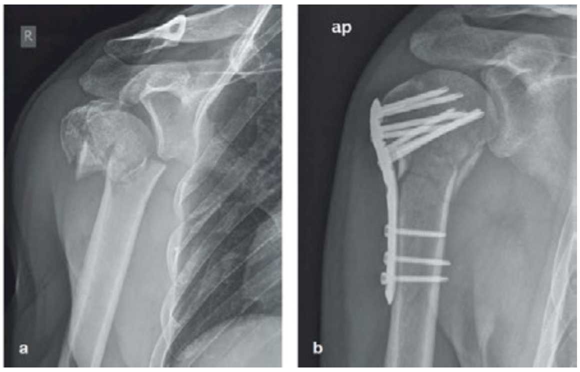

Fig. 1 : X-Ray of three fragment facture of the proximal humerus (a) and humerus with implanted bone plate (b)

Fakultät für angewandte Naturwissenschaften und Mechatronik
HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN MÜNCHEN

Osteosynthesis is a surgical procedure that stabilizes and joins the ends of fractured bones with mechanical devices such as metal plates, pins, rods, wires or screws. Osteosynthesis aims to bring the fractured bone ends together and immobilize the location of the fracture while healing takes place.

But the in vivo stresses of implants (e.g., at the proximal humerus) are almost unknown although these are really important in choosing the right implant. Due to the application of measured in vivo loads, it was possible to simulate realistic activities and to measure the displacements of the interacting stabilizing bodies.

SCIENTIFIC PROBLEM

Fractures of the proximal humerus are one of the most common type of fractures. In particular, elderly people are affected due to loss of bone density, i.e. osteoporosis. Biological, anatomical and biomechanical aspects influence the clinical functional results of the operative therapy.

For the operative therapy, different osteosynthesis techniques are known. In the last few years, more so-called angular locking implants were used. Locking means a fixed, rigid connection that does not allow any movement between implant and locking screws.

In general, the use of locking osteosynthesis implants results in an increase in the connectivity between the bone and the prosthesis as well as higher stability within the osteoporotic bone. Combined with angular stability, an increased number of metal bone screw cutouts of the head of the humerus bone were observed.

Depending on grade, type of fracture, and quality of the bone, the impact of the implants on osteosynthesis at the proximal humerus differs.

The goal of this study was to compare the biomechanics of an angular locking nail osteosynthesis and an angular locking plate osteosynthesis in terms of the risk of a bone screw cutout at the head of the proximal humerus.

"...a detailed multi-body model of an experimental test set-up including the fractured human humerus was developed using SIMPACK."

Due to the application of measured in vivo loads, it was possible to simulate realistic activities and to measure the displacements of the stabilizing interacting bodies.

MBS MODEL

For the numerical simulation, a detailed multi-body model of an experimental test set-up including the fractured human humerus was developed using SIMPACK.

Based on CT data, the humerus is modeled as a rigid body describing the exact 3D geometries of three fractured bone parts.

An intramedullary nail system, Fig. 2, as well as a bone plate, Fig. 3, were modeled as flexible bodies. Both CAD models were created by 3D scans of implants that are well known on the market. Also, the bone screws were modeled as flexible bodies. All implants were modeled by using the material properties of medical grade titanium alloy Ti6Al4V.

Based on the results of experimental 3-point bending tests, verification of the flexible models of the intramedullary nail system and the anatomical bone plate were carried out. In the MBS simulation, the models showed comparable bending properties as measured in the experimental setup.

Good alignment of the intramedullary nail system, and corresponding anatomical bone plate at the bone is one of the main influencing factors of the clinical functional results of operative therapy. Therefore, a realistic optimum positioning of the implants was carried out in the model.

To ensure a good comparison of the simulation results, both osteosynthesis models were digitally implanted in the same fractured bone model. In this biomechanical study, a three segmental fracture according to the so-called Neer classification was simulated. This situation is one of the most frequently treated fracture types. Due to the bad bone quality, three segmental fractures often include a comminution zone, which cannot transmit load. Therefore, this situation describes a worst-case scenario for the implants and their fixation in the bone segments.

The fixation of the screws within the bone segments was realized using spring-damper elements. The stiffness of the spring elements can be varied to simulate different bone density.

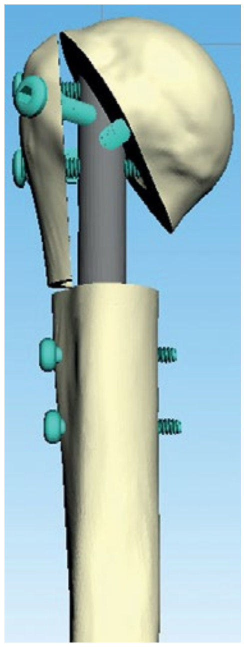

Fig. 2 : Humerus with implanted intramedullary nail system

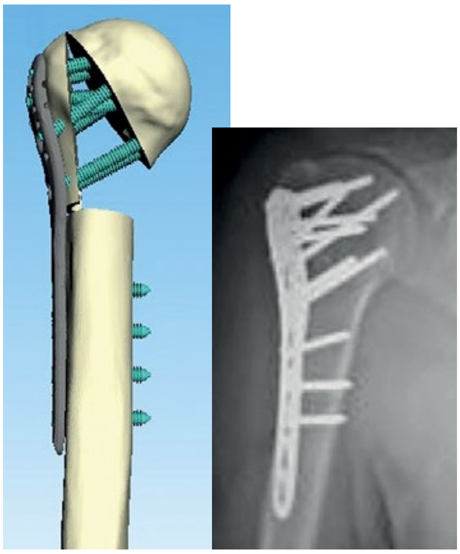

Fig. 3 : Model and x-ray of humerus with implanted bone plate

To apply realistic loads resulting from daily activities, in vivo data published in the Orthoload database (www.orthoload.com) were used for the simulation. The forces are measured in three directions using an instrumented shoulder implant. Fig. 4 shows the position and the orientation of the specified coordinate system. Two activities were simulated:

In the first load case, the in vivo measurements in the hip joint for a patient walking with a pair of crutches were used. This activity showed maximum resulting forces of approx. 60 % body weight.

In the second load case, a 10 kg mass (here, a crate of water) was lifted in a standing position. In this case, maximum resulting forces of approx. 95 % body weight were measured.

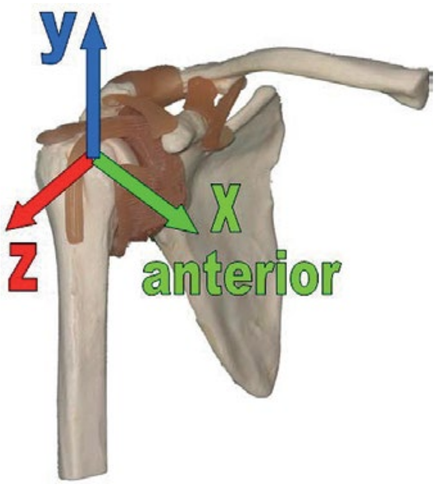

Fig. 4 : Coordinate system used in the orthoload measurements

RESULTS AND DISCUSSION

First, it must be mentioned that this study only considers the mechanical aspects, not the operational or medical point of view.

From a biomechanical perspective, the bone plate showed higher deformations than the intramedullary nail in both simulated load cases, Fig. 5 and 6.

The absolute deformation of the bone plate in the patient walking with a pair of crutches was twice as high as the deformation of the nail.

During lifting of the 10 kg mass, deformation in the bone plate was eight times higher than deformation of the nail.

Also, it was shown that the location of the maximum deformations is different for both osteosynthesis implants.

In the bone plate, the deformation is only in the proximal part; in the intramedullary nail, a small deformation was also observed in the distal part.

The deformation of the different screws strongly depends on their position in the implant and especially on the direction of the applied forces.

Therefore, in the next study, the loading situation in the screws will be analyzed in more detail. Different variations will be carried out, e.g., use of varying number and arrangement of screws with the plate.

In particular the ratio of screws to cutouts of the humerus bone head has to be analyzed.

"Using flexible components within SIMPACK opens further possibilities in biomechanical simulations."

CONCLUSION

Using flexible components within SIMPACK opens further possibilities in biomechanical simulations. With the developed and validated model, it is possible to analyze clinical problems with osteosynthesis systems in more detail.

REFERENCES:

[1] Fig. 1: Behandlung der proximalen Humerusfraktur des Erwachsenen Dtsch Arztebl Int 2013; 110(35-36): 591-7; DOI: 10.3238/arztebl.2013.0591

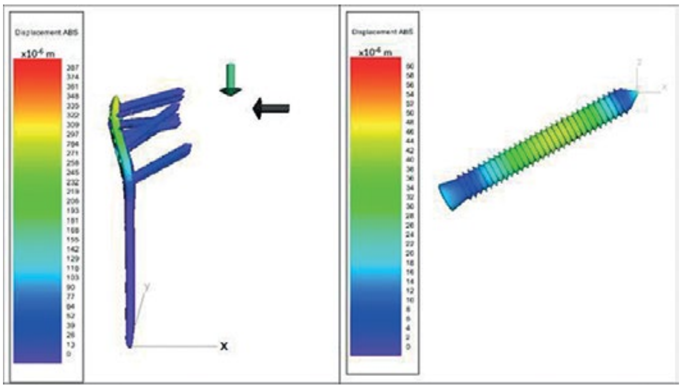

Fig. 5: Deformation of the bone plate and the screws during walking with crutches

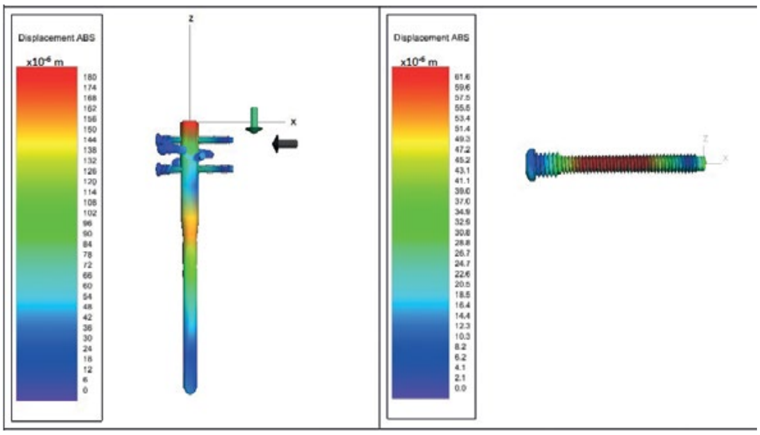

Fig. 6: Deformation of the intramedullary nail system and the screws during walking with crutches