FINITE ELEMENT ANALYSIS OF THE BONE RESORPTION IN THE HUMERUS AFTER SHOULDER ARTHROPLASTY

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Introduction

Cementless implant systems are successfully used in total shoulder arthroplasty. In a clinical study 148 cementless shoulder prostheses have been examined for three years [Spormann, 2010]. In 22% of the cases a reduction in cortical bone was detected on the lateral humerus (Fig. 1). The cause for this bone loss is not yet clear but the author supposes stress shielding. The objective of this work was to analyse the humeral stress in the region of interest (ROI) in order to clarify whether the bone resorption can be caused by stress shielding.

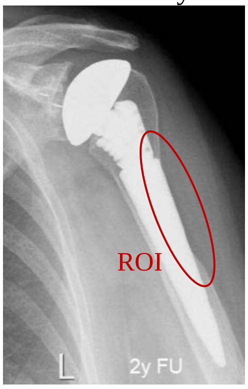

Figure 1: Anteroposterior x-ray of the bone resorption in the left humerus [Spormann, 2010]

Figure 2: Finite element model of the right humerus with prosthesis (anteroposterior section view)

Methods

The stress in the humerus with and without prosthesis is examined by a finite element analysis with ANSYS Workbench 14. For this purpose a patient-specific bone model was created from CT scans (Fig. 2). The modular prosthesis has a cementless stem with rectangular cross-section. The model includes the deltoid muscle because the bone resorption occurred proximal of its insertion and the rotator cuff muscles for realistic conditions in the proximal humerus. The abduction by 90° is selected as load case. To obtain the required muscle forces, the load case is simulated using the software package AnyBody. The software computes the forces of a musculoskeletal system using the principle of inverse dynamics. The deltoid exerts together with the reaction force of the shoulder joint a bending moment on the humerus. For that reason the normal stress in direction of the humeral shaft axis is evaluated.

Results

In the ROI the humerus acts as a bending beam. Tensile stress occurs on the lateral and compressive stress on the medial cortical bone. The stress in the bone model without prosthesis (Fig. 3a) varies between -3MPa and 6MPa and is reduced by the implant by up to 1.5MPa (Fig. 3b). The local peaks (1) are caused by the prosthesis. The maximum and minimum stresses arise at the muscle insertions.

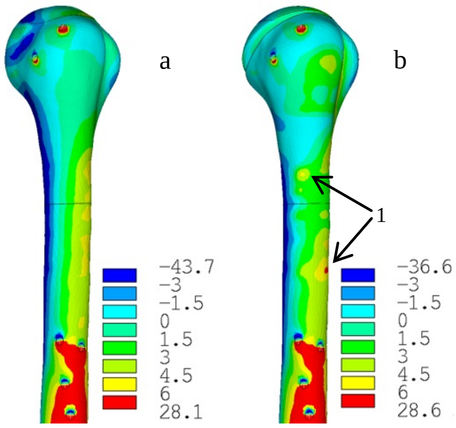

Figure 3: Lateral view of the simulated normal stress [MPa] in direction of the shaft axis for the model without (a) and with prosthesis (b)

Discussion

The use of the prosthesis decreases the stress in the ROI. However, whether this difference is sufficient for bone resorption could not be determined conclusively as the stress in the bone is rather small even without prosthesis.

The simulated joint forces have been successfully verified with experimental data from OrthoLoad [Bergmann, 2008]. The calculated forces correspond well with measured data in instrumented shoulder implants during abduction.

References

Spormann *et al*, in Vorträge Jahreskongress DVSE, 2010.
Bergmann (ed.), Charité Universitätsmedizin Berlin (2008) „OrthoLoad“.