8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

A 3D BIOACTIVE CONTACT ELEMENT FOR FINITE ELEMENT BONE REMODELLING SIMULATION

*** André Lutz[1], Udo Nackenhorst[2]**

[1] Institute of Mechanics and Computational Mechanics, Universität Hannover
Appelstr. 9a, 30167 Hannover, Germany
lutz@ibnm.uni-hannover.de
www.ibnm.uni-hannover.de

[2] Institute of Mechanics and Computational Mechanics, Universität Hannover
Appelstr. 9a, 30167 Hannover, Germany
nackenhorst@ibnm.uni-hannover.de
www.ibnm.uni-hannover.de

Key Words: *Biomechanics, Bone Remodelling Prediction, Bioactive Contact, Endoprosthetics.*

Summary. In this contribution a 3D bioactive contact element is presented. This contact element is able to describe the interaction between bone and i.e. hip joint endoprostheses more physiologically than the often used ideal contact approach does. Embedded in a finite element framework examples for bone remodelling prediction concerning hip joint implants are shown. A lineup between the bioactive contact element and the standard method compared with clinical results shows the advantage of the new approach.

Introduction. Every year hundreds of thousands hip joint endoprostheses are implanted to medicate fractures or degenerative joint diseases. Due to the change of the loading inside the bone and the much higher stiffness of the prosthesis, bone remodelling occurs, which often is disadvantageous. The phenomena like stress-shielding cause loosening of the implant which is connected with further surgeries. Computational methods for bone remodelling simulation are developed since more than 15 years and nowadays stable and reliable algorithms exist. With them it is possible to improve or to rate implant designs even before they will be evaluated in clinical studies. But the interaction between bone and implant is often modelled as ideal bonding in the interface. This approach is not suitable to represent the interplay of the counterparts physiologically and the prediction of ingrowth in rough prosthesis surfaces is neither possible. With a perfect bonding bone is also stressed in regions where tension occurs in the contact area. According to these disadvantages stress, strain or energy adaptive evolution equations for bone will predict bone growth instead of bone mass loss. The 3D bioactive contact element adjusts these problems (see [1]). It is not only able to simulate the pure mechanic contact, it is also able to simulate bone ingrowth in rough implant surfaces. The advantages of the bioactive contact element will be presented in this contribution.

Modelling Approach. The idea of the bioactive contact element is to represent the interaction of the counterparts in a physiological manner. The implant only can stress the bone if there no tension in the interface. So the contact element detects the stress state in its normal direction (see fig. 1 left) and reacts to it. If pressure is detected, the element has stiffness in its normal direction and also shear stiffnesses in plane. In contrast to a regular contact element the bioactive contact element has the feature of ingrowth. The material properties change with an evolution equation for bone mass density ϱ.

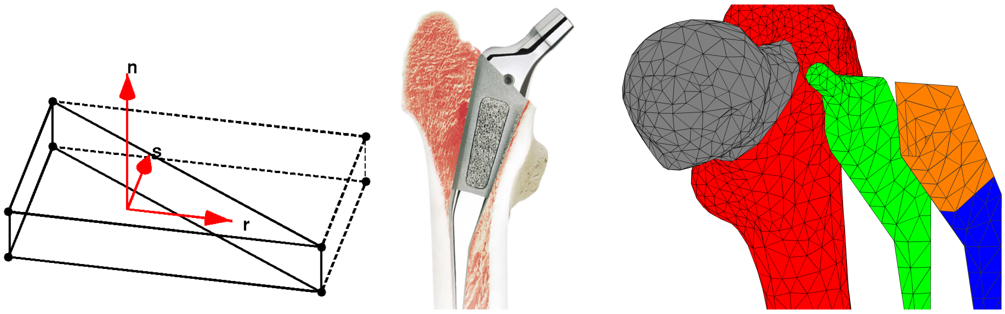

Figure 1: **bioactive contact element (wedge/brick); Mayo prosthesis [2]; parts of FE model**

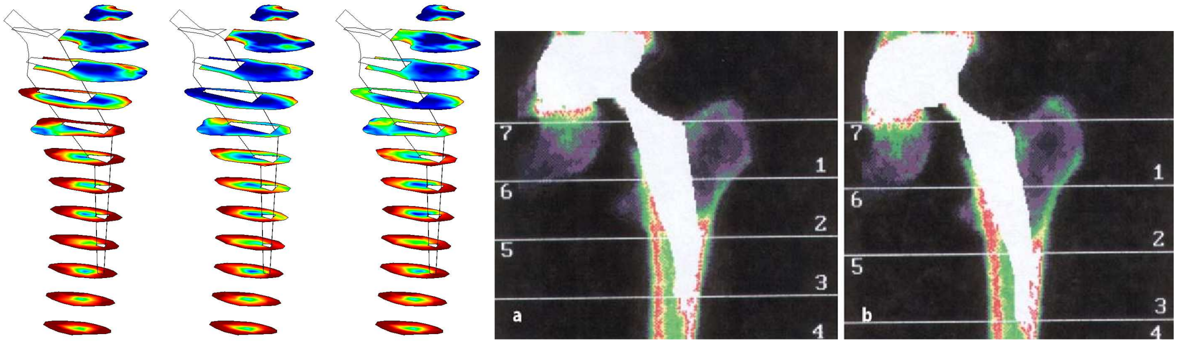

Figure 2: **numerical results: postoperative state, longterm state with perfect bonding and with contact elements; DXA measurement in postoperative state and one year after surgery [2]**

Numerical Example. On the right side of figure 1 the finite element model of a femur with a Mayo prosthesis (green) and the contact layer can be seen in a exploded view. The grey part of the femur is removed during the surgery. The Mayo prothesis contains rough surfaces in the upper part (see fig.1). This fact is treated with bioactive contact elements shown in orange colour. The blue part of the layer covers the polished part of the implant and consists of pure mechanical contact elements. Figure 2 (left) shows the postoperative state and the remodelling prediction for the standard method and the new method with bioactive and regular contact elements. The comparison with the clinical studies in figure 2 (right) illustrates the advantages of the bioactive contact element. The stress shielding predicted with the new method is much lower than with the standard method and reflects the clinical results. Even the bone mass density adsorption near the neck part of the implant matches well.

Conclusion. A 3D bioactive contact element for the interface between bone and prosthesis has been presented. It has been shown that the mechanical capability and the capability of simulating ingrowth has important advantages compared to the standard method of ideal bonding. On the basis of clinical results a comparison has been made that emphasises the benefits of this new approach.

References

[1] S. Lu ”Finite Element Modellierung des bio-aktiven Kontaktes zwischen Implantat und Knochen”. Master Thesis, 2007.

[2] R. Hube et al. ”Frühfunktionelle Ergebnisse einer Kurzschaftprothese des Hüftgelenks mit metaphysär-intertrochantrer Verankerung”. *Der Orthopäde*, Vol. **33**, 1249–1258, 2004.