A New Concept for Non-Invasive Radiation-Free Detection of Implant Loosening

INTRODUCTION:
The major reason for revision of total hip replacements remains aseptic loosening. Loosening of the femoral component is primarily diagnosed by standard radiographs and clinical symptomatology. Uncertain diagnosis may necessitate exposition of the hip joint to verify the actual implant anchorage in the femoral bone stock. Moreover, if the loosening is detected too late, large bone defects can occur, resulting in complicated revision surgery. In order to optimize detection of implant loosening, different research groups proposed diagnostic approaches based on vibrometry. The miniaturized systems with accelerometers placed inside endoprostheses combined with vibration analysis reached a 20% higher sensitivity than the sensitivity of radiographs. Disadvantages of these techniques appeared in signal distortion caused by soft tissue, limitation depending on patient position and twinges caused by the vibrator due to low frequencies. These circumstances require a new sensor approach to detect aseptic implant loosening.

METHODS:
For this in-situ diagnosis a new acousto-mechanical principle based on oscillators, which are placed inside the endoprosthesis, is proposed (Fig.1). A ferrite body fixed on a steel spring assures simple oscillator design. The magnetic poles of the ferrite body allow oscillations using an external alternating electrical field impulse. Thus, vibration of the oscillator is initiated using an external coil placed on the patient’s leg. After the ferrite body impinges on a membrane inside the endoprosthesis, the oscillations are transmitted to the adjacent tissue. The dampening of the oscillations of the ferrite body after impingement varies depending on the osseointegration of the implant.

RESULTS:
In an initial test, dampening of a titanium membrane was demonstrated using cortical bone from a porcine femur (Fig.2). The oscillator based on a steel spring with a soldered magnetic neodymium body was excited by a coil and oscillated against a thin membrane (Ti-6Al-4V). Signal detection was performed with a microphone and a custom Labview program (V 8.5, National Instruments, TX).

DISCUSSION:
With respect to the standard application of total hip endoprostheses the worldwide demand on a new system for valid diagnosis of implant loosening increases. Our initial test results show the potential usability of the described non-invasive method for detecting aseptic loosening in-situ by examining resonances. It is strongly believed that soft tissue between membrane and bone results in a harmonic sound. The harmonics produced only by the membrane resulted in much higher amplitudes than testing with adjacent bone. The first harmonic (0.65 kHz) and the second harmonic (1.3 kHz) could be detected in the amplitude-frequency-graph.