# An investigation of femoroacetabular impingement using motion capture, FEM and multi-body simulations

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**Abstract** – The Femoroacetabular Impingement (FAI) has become increasingly a common orthopedic disease caused by a non-physiological contact between the proximal femur and the acetabular rim due to bone deformities. This may lead to pain, limitation of movement, and long-term damage of the cartilage [1]. This disease may also lead to total hip replacement. The bone deformities can occur either at the femoral head (cam) or at the acetabular rim (pincer) or even combined. Diagnosing FAI radiological techniques such as MRI are requested. An arthroscopic surgery is done as a treatment in which the impinged bones are shaped. Unfortunately, nowadays this therapy is exclusively based on subjective interpretations, which is therefore an only semi-quantitative diagnosis. New techniques are required to get further evaluations, thus allowing a more exact planning of the surgery. The aim of this novel approach for the evaluation of the FAI is to develop a model that combines motion capture, pain detection, MR-Imaging, FEM and multi-body simulations as well as to navigate the bone removal to ensure no pain.

In order to quantify the FAI a physical examination is conducted by a doctor while the patient is lying in a dorsal position. The examination is separated in six different movements: flexion, abduction/ adduction, internal-and external rotation and a FAI provocation test. The maximum angles for these movements are computed using marker-based motion capturing, applying Plug-in gait‘s lower body model. Furthermore the pain is measured simultaneously using a handheld device, which the patient compresses according to his sensation of pain. After this investigation, an MRI scan is performed using a Siemens Magnetom 1.5T with a comprehensive thin layer protocol and a slice thickness of 1.5mm. The patient is lying in the 0° position to ensure no rotation of the femur. A high resolution STL model can be manually extracted from the MRI data using MIMICS©. This STL data is finally convert into a CAD model (Figure 1) which is synchronized with the motion capture data to simulate the impingement of the femur against the acetabular rim using ANSYS© and appropriate material properties. Furthermore a coordinate system must be placed in the center of the hip joint to control the simulation. This whole procedure is performed before and after the surgery to allow patient-specific pre-and post-operative comparisons.

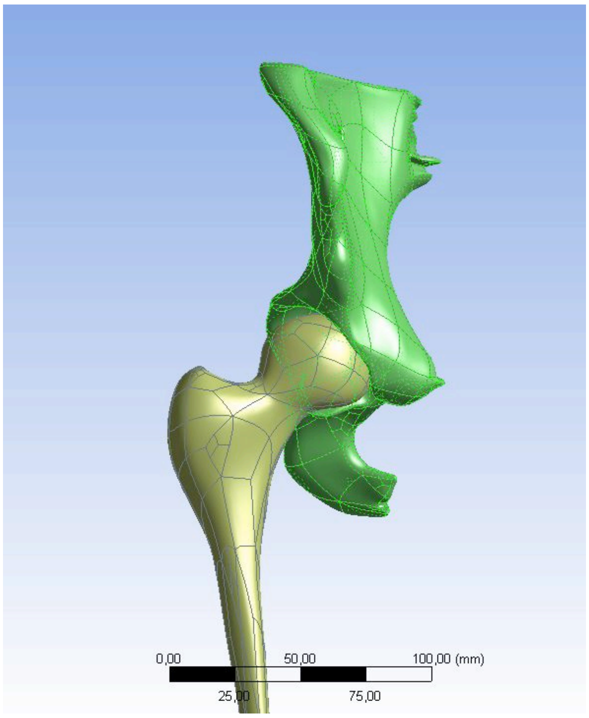


*Fig.1: Patient specific model of the hip joint extracted from MRI data.*

Using the simulations the movement of the patients' hip can be very good visualized. But the bony contact between proximal femur and acetabular rim could not be detected, which leads to the hypothesis that the labrum is squeezed and may induce the pain. A patient-specific model of the hip joint is transferred from the MRI data and the femur is moved using functions implemented in ANSYS©. Additionally, stresses in the area of pain are calculated using FEM (Figure 2). The simulation in combination with a computer-controlled navigation will support a more exact patient-specific bone removal and may have the advantage that the removed bone is enough in aspects of stability and no limitation anymore. In the next step, an automated MRI segmentation tool is planned for faster processing of this MRI data.

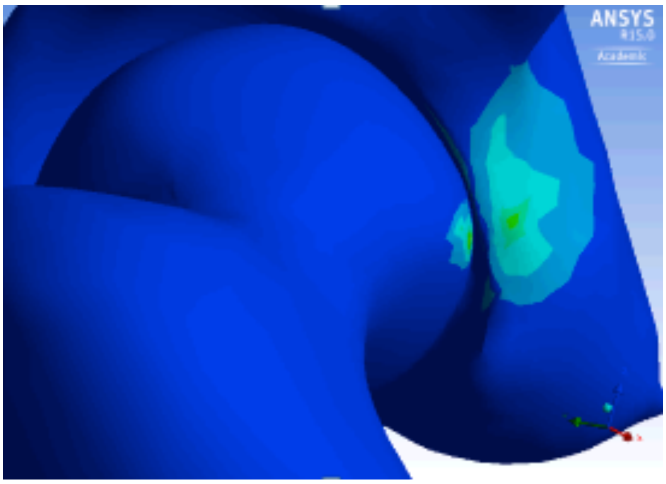


*Fig.2: Stresses can be visualized using FEM: Femoral Head is getting very close to the acetabular rim.*

## References

[1] O. Marin-Pena, Femoroacetabular Impingement (Springer-Verlag, Madrid, 2010)