Introduction:
Numerous analytical techniques have recently been applied to determine knee kinematics with and without TKA. These have included investigations under in vitro conditions and different in vivo techniques like external marker systems, gait analysis and the video fluoroscopy. The latter allows quantification of femoro-tibial kinematics under almost physiologic, weightbearing conditions. Due to the two-dimensional nature, motions perpendicular to the fluoroscopic images are difficult to evaluate reliable. Therefore the femoro-patellar 3D kinematics and especially the relationship to changes in femoro-tibial motion patterns remained less clear (1). However, patello-femoral disorders due to changes of the patellar kinematics are responsible for up to 50 % of all revisions after TKA (2). The reason for alteration in patellar kinematics is frequently not only located in the patello-femoral joint, but can also be caused by unphysiological tibio-femoral motion patterns (3). Until now, however, there is no in vivo technique, which allows for simultaneous analyses of patello-femoral and tibio-femoral 3D kinematics.

The objective of this study was, to develop an in vivo technique which allows for the first time to determine and compare 3D-kinematics of all knee compartments simultaneously before and after TKA.

Material and methods:
The knee joints of 10 patients with severe osteoarthritis (64–82 y.) were investigated pre- and one year postoperatively after TKA (AMK, Alphanorm). Kinematics analysis was performed in an open MR system (0.2 Tesla) at different flexion angles with external loads being applied during imaging. In the preoperatively investigated knees segmentation and 3D-reconstruction of the bony structures were performed. Postoperatively computer assisted design models (STL-format) supplied by the manufacturer were converted into voxels models which were adapted to the resolution of the MRI-sequence (Fig. 1). A graphical user interface was developed to monitor the implant components together with the 3D images in different orthogonal planes. With a 3D fitting algorithm for rigid objects each TKA components were identified, which allows a full automated 3D registration of the TKA (Fig. 1).

In the natural knees a recently validated post-processing technique was applied to determine tibio-femoral and femoro-patellar 3D-kinematics (4). To determine the validity of the postprocessing technique after TKA the femoral and tibial component were mounted into a test apparatus that allows for each component to be translated and rotated into defined positions. The components were fixed in 10 different positions and the relative pose of the femoral component relatively to the tibial component was recorded. A lateral pivot shift was also enlarged, the difference being significant (p<0.05) at 0° and 90° of flexion (90°: 9.2±7.4 vs. 3.6±3.2mm). With respect to the patellar tilt, no difference was recorded at 0 and 30° of flexion, whereas at 90° of flexion high significantly (p< 0.01) increased values were observed (21.8±14.6 vs. 4.6±3.1°). After TKA the patellar height was in the mean increased in all investigated knee positions compared to the healthy knees (30°: 23.8±6.7 vs. 15.7±5.0mm). Increased values with a large standard deviation were also found for the patella tilt. The difference was significant at 90° of flexion with tilt angles of more than 30° (21.8±9.5 vs. 4.6±3.1°).

Conclusions:
We have developed and applied a 3D MR-based imaging and postprocessing technique to determine and compare patello-femoral and tibio-femoral motion patterns in patients with severe OA of the knee before and after TKA. It has been shown that this technique has a high reproducibility and validity and makes it for the first time feasible to investigate the entire knee kinematics simultaneously. The presented technique allows for advanced in vivo diagnostics, and may help to improve the design of TKA and to enhance the long term performance.

References:

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