Objective clinical performance outcome of total knee prostheses. A study of mobile bearing knees using fluoroscopy, electromyography and roentgenstereophotogrammetry

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Summary

In *Chapter 1*, a short introduction towards the aim of the work described in this thesis was given. The aim of this thesis was to assess with accurate and objective methods the function and fixation of total knee prostheses with special emphasis on mobile bearing total knee designs.

The four main methods that haven been used in this thesis are:

1. Fluoroscopy: imaging technique that takes a real time x-ray 'movie' of the body to study moving body structures
2. Electromygraphy: a method for measuring muscle activity via the electrical signals produced by muscles when they are stimulated
3. Roentgen Stereophotogrammetric Analysis (RSA): accurate stereo radiographic technique for the assessment of three-dimensional micromotion of orthopaedic implants
4. Scanning electron microscopy: a type of electron microscope capable of producing high resolution images of a sample surface at high magnification by means of electron lenses.

In *Chapter 2,* a description of the knee anatomy and knee disorder is given. When medicines, weight loss and physiotherapy fail, joint replacement is the intervention for patients with pain, limitation of motion, and/or deformities. Several types of total knee prostheses are introduced while the mobile bearing total knee prosthesis is presented in more detail.

Mobile bearing total knee prostheses allow the polyethylene insert to move with respect to the tibial base plate. Numerous variations are on the market but all are designed with two common purposes. The first is to increase contact area in order to reduce long-term wear. The second is to reduce implant-to-bone interface stresses and to allow good kinematics by the mobility of the polyethylene bearing on the tibial plate.

Chapter 3 introduces the fluoroscopy technique that is applied to reconstruct the 3D position and orientation of markers inserted in (body) segments. A thorough validation established that the in-plane accuracy of the technique is 0.1 mm and the rotational accuracy is 0.1 degrees. The simulated *in vivo* out-of-plane accuracy was about 1.9 mm. Accuracy of the marker models and image distortion showed to be the most important factors influencing the out-of-plane measurement error as the most sensitive direction for measurement errors.

In *Chapter 4* fluoroscopy was used to assess the axial rotation of a polyethylene bearing in a rotating platform total knee prosthesis during a step-up task. In all patients, the femur showed more axial rotation than the mobile-bearing insert indicating the femoral component was sliding on the polyethylene of the rotating platform during the step-up motion. The theoretical advantages of mobile bearing total knee prostheses are challenged by the *in vivo* measured movements in this study.

In *Chapter 5* the problem of soft tissue artefacts during gait analysis was addressed by using the fluoroscopic methodology. The measurement errors of two different external marker fixation methods commonly used in gait analysis were assessed. The measurement errors associated with the thigh were generally larger (maximum translational error: 17 mm; maximum rotational error: 12 degrees) than the measurement errors for the lower leg (maximum translational error: 11 mm; maximum rotational error: 10 degrees). Errors up to 10 degrees were observed for knee joint internal/external rotation and adduction/abduction. The large soft tissue artefacts when using clustered skin markers, irrespective of the fixation method, question the usefulness of parameters found with external movement registration and clinical interpretation of stair data in small patient groups.

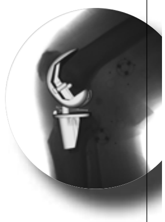
Another important parameter assessed during gait analysis is electromyography of muscles. In *Chapter 6* the differences of electromyography activity of the muscles stabilizing the knee joint between patients with a mobile bearing knee prosthesis and a posterior stabilized knee prostheses was assessed. The differences between the two groups group didn't only show an increase of muscle activity for the mobile bearing group but also an earlier activation of the flexor muscles which in turn may express compensation by coordination. In *Chapter 7* a new normalization method for electromyography data was used to study differences in co-contraction. Surface electromyography, kinematics and kinetics about the knee were recorded during a step-up task of a mobile bearing group, a fixed bearing group and a control group. The total knee arthroplasty groups showed a lower net knee joint moment and a higher co-contraction than controls indicating avoidance of net joint load and an active stabilization of the knee joint. Mobile bearing and fixed bearing patients showed no difference in co-contraction levels, although coordination in fixed bearing subjects is closer to controls than mobile bearing subjects.

In *Chapter 8* it was shown that periapatite augmentation on a tibial stem improved the fixation of the total knee prosthesis in a osteoarthritis group after two years follow-up. In *Chapter 9* the differences in migration between uncoated and periapatite coated groups groups did not differ in a rheumatoid arthritis patient group. The periapatite group showed less variability of micromotion. A trend could be detected toward a more stable fixation in the periapatite group.

In *Chapter 10* it was hypothesized that torque and shear forces in a mobile bearing total knee prosthesis would be better dissipated from the prosthesis-bone interface by the motion of the bearing and by load sharing with the ligaments and other soft tissue structures. A prospectively randomized RSA study comparing a mobile bearing total knee prostheses group and a posterior stabilized prosthesis group showed that the mobile bearing group had a significant lower variability in the subsidence and anterior-posterior tilting of the tibial component after two-year follow-up.

In *Chapter 11* scanning electron microscopy was used to observe wear mechanism on the surfaces of retrieved total knee prostheses. In the control polyethylene insert, large polyethylene fibrils next to the articulating surface were observed. Two mobile bearing inserts showed striations at the tibial articulating surface indicating rotational movement of the insert *in vivo*. The fixed bearing tibial inserts showed severe delamination at the posterior parts of the condylar articulating surface. Imaging X-ray microanalysis showed the expected composing elements Co, Cr and Mo. However, in three femoral components small round holes were visible in the surface at various locations. In one of these holes a Ti particle could be observed indicating severe pollution of the metal compound.

Grouping the main findings of this thesis led to a general discussion and conclusion in *Chapter 12*. The mobile bearing of a rotating platform design showed limited motion or no motion during a step-up task thereby nullifying the theoretical advantages of a mobile bearing prosthesis. Apatite coated implants show excellent mid-term RSA results and offer some clinical advantages above cemented total



knee arthroplasty. A prospectve RSA study also revealed that the studied mobile bearing design is more predictable and forgiving with respect to micromotion of the tibial component than a posterior stabilised prosthesis. However, mobile bearing prostheses showed to be more demanding for the soft tissue structures surrounding the knee joint.

The techniques used in gait analysis and fluoroscopy are sensitve for measurement errors. This restricts the applicability and interpretation of the results acquired when using these methods. In general one needs to be aware of the limitations of measurement tools since one needs accurate and objective methods to assess evidence about the clinical performance of (new) total knee prostheses.