BACKGROUND
Knee replacement by total knee arthroplasty (TKA) for disabling osteoarthritis is a widely used treatment (Table 1.1) and is successful under current ethical standards. National registries reported Patient Related Outcome Measures with at least 80 percent of the patients being satisfied on the short term. As far as the long term is concerned, the reference total knee prosthesis in the Swedish Knee Arthroplasty Register has a mean survivorship of 96 percent at 15 years. Comparative research is ongoing to find out how to achieve even better clinical outcome and longer prosthesis survival: uncemented versus cemented fixation, with versus without patella resurfacing, bone versus ligament referenced saw cuts, posterior cruciate ligament retention versus substitution, computer-assisted or patient-specific navigation etc. The same dilemma accounts for the polyethylene spacer between the metallic femoral and tibial component of the prosthesis: should this be a fixed bearing (FB) or a mobile bearing (MB)?

MB’s are originally part of the low contact stress concept

<table>
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<th>TABLE 1.1. TKA in The Netherlands (LROI Report 2013).</th>
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<td>• In 2013 23,738 primary TKA’s were registered in 100 hospitals, with a median number of 216 (range 14-677) per hospital</td>
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<td>• Almost 90% of the patients were treated in a general hospital</td>
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<td>• The mean age of the patients was 68.2 years</td>
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<td>• Two-thirds of the patients were female</td>
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<td>• 70% of the patients had an ASA score of II</td>
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<td>• 95% of the patients underwent TKA for the diagnosis osteoarthritis</td>
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LROI Landelijke Registratie Orthopedische Implantaten
ASA American Society of Anesthesiologists
The LCS concept comprises higher femoral side condylar congruency and compensatory tibial side freedom of rotation of the bearing (Left: FB, low congruency; Middle: FB, high congruency; Right: MB, high congruency). Reproduction from: Buechel FF and Pappas MJ, Orthop Clin North Am, 1989 (with permission).

(LCS), which was developed in the seventies as an attempt to extend the service life of the implant. Constraint forces lead to loosening of the prosthetic components and contact stresses lead to wear of the polyethylene bearing. The use of meniscal or rotating bearing elements would allow both mobility and congruency, producing low constraint forces and low contact stresses (Fig. 1.1). In vitro experiments demonstrated the presence of this load sharing principle, recording local strain magnitude and regional strain distribution in the proximal tibia after TKA. Under compressive loading only, there was no difference in cortical strain between the FB and MB variant of an otherwise identical knee implant. However, superimposing a torsional load induced less compressive local strain and less...
transmitted torque in the proximal tibia in the MB variant. In other words, MB TKA tolerates axial rotation better by transferring less shear strain to the bone-implant interface.

The first MB LCS knee was implanted in 1977 in the United States. In Europe it was implanted for the first time in 1984 in the Slotervaart Hospital in Amsterdam. The results of the LCS in the eighties with mostly meniscal bearings were good, but with the passage of time it appeared that the cruciate substituting Rotating Platform (RP) variant was not only easier to implant, but also yielded better survivorship with fewer complications. Nowadays the LCS RP knee is recognized as a successful prosthesis and a variety of MB/RP versions from different brands are available.

**PROBLEM STATEMENT**

A recent meta-analysis in the Journal of Arthroplasty showed comparable clinical outcome scores for the LCS RP and other MB/RP knees. This was also the first and single study to show a higher survivorship of the LCS RP knee than for all other knees in the Swedish register. An impressive clinical trial was published in 2012 in the Journal of Bone and Joint Arthroplasty. Patients younger than 50 years of age were randomly assigned to a LCS RP in one knee and a FB implant in the other knee, when being treated for disabling osteoarthritis. There were no significant differences noted in clinical outcome and prosthesis survivorship between the LCS RP knees (97%) and the FB knees (95%) at 17 years follow-up. Although these numbers support the success of TKA in general, they provide no evidence for the superiority of MB/RP. However, as the authors state, “It is possible that the follow-up was not
sufficiently long to reveal osteolysis. The concept that a mobile-bearing total knee prosthesis is associated with less wear and a lower prevalence of osteolysis than a well-designed fixed-bearing total knee prosthesis remains to be proven in the longer-term follow-up.” Meanwhile, the question arises how this apparent equivalence can be reconcilable with the clear conceptual difference in design between the two prostheses. It might well be that the constrained forces and contact stresses of both MB and FB are below the threshold of causing osteolysis, in other words that the principle of load sharing is not critical at 17 years. If this were the case, then longer follow-up studies comparing the two designs are required, as the authors suggested.

On the other hand, the concept of the LCS promoting load sharing depends critically on the ability of the MB/RP to rotate axially. Some in vivo kinematic studies found significant differences in axial femorotibial rotation between MB/RP and FB TKA variants in favor of mobile,15-17 while others did not.18-20 All of these studies had a certain limitation in that they used relatively low demanding task conditions (mostly knee bends during stance). If it were true that the LCS concept is being compromised in vivo, i.e. the mechanical behaviour of a MB/RP knee would be more or less identical to a FB knee, then all its potential advantages are impeded. So this leads back to the fundamental feature of a MB/ RP prosthesis, i.e. whether or not the bearing is actually functioning during every day use.
AXIAL KNEE ROTATION AND HOW IT IS MEASURED

A normal knee does not only rotate in the sagittal plane (hinge function), but also allows for some rotation in the transversal plane. Rotation between the femur (thigh) and tibia (shank) in the transversal plane is being defined as axial femorotibial (knee) rotation, which is either internal (tibia rotates inwards) or external (tibia rotates outwards). The sum of internal and external rotation is defined as range of rotation. In healthy persons the range of axial knee rotation during walking is 15 degrees; during the performance of a deep knee bend this range is 18 degrees. After TKA, the knee also allows for internal and external rotation. Depending on being a MB/RP or FB variant, this rotation occurs at the lower or upper surface of the bearing, respectively. Ranges of axial rotation have been measured in patients with different variants of TKA during walking and various knee bending activities. As mentioned above, the results were sometimes comparable and sometimes in favour of the mobile variant, but in all studies below normal knee values.

The measurement of in vivo axial knee rotation during functional every day tasks involves two experimental decisions: (1) the type of tasks to measure. Since every day tasks are not limited to straight walking or knee bending, a meaningful experimental setup should also involve tasks with a torsional load. It was shown, that during common everyday activities 50% of steps taken involved turning steps. So any clinically relevant experimental setup for knee kinematics evaluation, should involve a turning provocation as well. (2): the recording setup. The measurement of knee rotation (or any other joint kinematics for that matter) involves the use of either superficial
(skin based) or deep (bone based) markers and a detector. The most commonly used detectors are the cameras of an optoelectronic system or the fluoroscope in case of a roentgen stereometric analysis (RSA) system. RSA has the advantage that the metallic prosthetic components themselves serve as (deep) markers, but the disadvantage of having limited space in front of the fluoroscope for the subject of measurement. Furthermore, issues of radiation hygiene have to be dealt with. Superficial markers in optoelectronics are skin based (noninvasive), while deep markers need to be attached to percutaneous bone-pins (invasive). Noninvasive optoelectronics may have the advantage of freedom of movement for the subject, but has the disadvantage of a soft tissue movement artefact between the skin marker and underlying bone. Special constructions or compensation will be needed to enable accurate bony tracking with optoelectronic motion analysis.

**AIM OF THE THESIS**

The aim of this thesis is to establish whether or not the LCS RP prosthesis provides the knee with significant axial rotation *in vivo*. In order to answer this question we had to determine knee rotation in patients with a LCS RP knee and compare the results to patients with a FB knee and people with healthy knees. For these clinical studies we found it necessary to select an axial rotation-provoking task, and, along with this requirement, it was necessary to improve femoral marker placement for using an optoelectronic motion analysis system noninvasively. We looked in the literature for more mechanical results to either support or dismiss the LCS concept.
and explored its theoretical advantages from a clinical view and a future perspective.

This led us to the formation of a series of questions, which will be subsequently addressed to in the following chapters:

1. Is it possible to develop an epicondylar frame, which reduces the soft tissue artifact on the femoral side in noninvasive optoelectronic movement analysis? (Chapter 2)

2. Does adding turning steps to a sit-to-walk task, in order to make this task more discriminative in investigations on total knee performance, result in a larger amount of axial knee rotation in healthy knees? (Chapter 3)

3. Does the LCS Rotating Platform total knee prosthesis show a larger amount of axial knee rotation than a fixed bearing total knee prosthesis? (Chapter 4)

4. Does the amount of axial knee rotation in the LCS Rotating Platform total knee prosthesis maintain over a time span of 5 years? (Chapter 5)

5. Are the available mechanical study results sufficient to support the concept of load sharing in the LCS Rotating Platform total knee prosthesis? (Chapter 6)

6. Are the clinical results and prosthesis survival rate of the LCS Rotating Platform total knee prosthesis superior to fixed bearing total knee prostheses? (Chapter 6)
REFERENCES