MAIN FINDINGS AND CLINICAL RELEVANCE

In the opening sentence of this thesis it was mentioned how successful TKA currently is. So one may ask whether there is a need or possibility for improvement. However, higher standards are to be expected in the future, technical advancements take time to develop and study results require long follow-up. So, the answer should be that it is indeed desirable to put effort in further improvement of knee replacement. Prosthetic design is one part of this challenge. In chapter 1 the reader took notion of the principles of the LCS MB/RP concept, axial knee rotation and motion analysis. What followed was a description of the aim of the thesis, which also provided an outline for the following chapters.

Chapter 2 dealt with a methodological study. The use of the FEF as femoral tracking device for noninvasive motion analysis was validated, using model-based fluoroscopy as gold standard. Below 40 degrees of knee flexion the rotational measurement error of the FEF ranged from 6.2 degrees externally to 4.7 degrees internally; on average the precision was 3.3 degrees. Considering that the values of this femoral rotational measurement error were in the same range as the actual knee rotation, optoelectronic analysis appeared to be not suitable for assessing axial knee rotation in individuals. In addition, one must also take in account an amount of tibial rotational measurement error of 2 degrees.\(^1\) When axial knee rotation needs to be evaluated on a group level, however, optoelectronic analysis has several advantages over fluoroscopy. It is free of radiation and there is no spatial restriction for functional tasks. An additional advantage of an optoelectronic
laboratory is that it allows a comprehensive assessment using force plates, inverse dynamics and surface electromyography.

In chapter 3 a methodological study on the influence of turning on axial knee rotation was dealt with. Healthy subjects were measured in an optoelectronic motion analysis laboratory, while performing a STW task with and without turning. The addition of a turning movement resulted in an increase of the range of rotation up to 20.9 degrees, due to a significant increase of internal tibial rotation during crossover stepping and external tibial rotation during sidestepping. Sitting up and down associated with turning maneuvers had not been studied before. We believe there is a need for this, because turning steps make up a considerable portion of steps taken during daily life walking. Many patients after TKA have difficulty in performing them. MB/RP knees have been designed to maintain a more natural knee function, but a potential difference in axial rotation between replaced MB/RP and FB knees during a task known to induce rotation still needed to be investigated.

Chapter 4 covered a clinical study with patients after placement of either a LCS RP knee or a NexGen FB knee. They were measured in an optoelectronic motion analysis laboratory five years postoperatively, while performing STW tasks with and without crossover- and sidestepping. In the FB group, rotation gradually increased with higher task complexity (gait, STW straight, STW turning) to eventually 14 degrees. In the RP group, the range of rotation was 21 degrees and appeared to be already available even without turning. This direct available increase in rotation between gait and STW straight, without a further increase after adding turns, was apparent. STW is a merging of a discrete (rising from a chair) and rhythmic
(walking) task. The combination of such a complex transitional task and the low-friction articulation between bearing and tibial component may be the reason for this switch on/off pattern. Even without the initiation of gait the sit-to-stand (STS) movement is an important and challenging task of daily living, that requires relatively large joint torques and accurate balance control. Previous kinematic analysis of the STS movement after TKA had been restricted to the sagittal plane only, while STW after TKA had not been studied at all.

Chapter 5 was about a clinical study utilizing the same methodology as the former study. Patients with a LCS RP knee were measured either one year or five years postoperatively. The average range of rotation was not different between both groups. The LCS knee allows free bearing rotation around a central axis, while muscle activity, capsule and ligaments assure knee stability. Apparently these soft tissue restrictions do not change in the years following LCS RP TKA.

Chapter 6 encompasses a thorough non-systematic review in which the historical background and mechanical and clinical aspects of the LCS RP knee were explored in the available literature on Pubmed. In over 35 years of existence, the design of LCS RP TKA has not been changed significantly. Although there is kinematic support that the LCS concept promotes the principle of load sharing, RP knees still perform more like their FB counterparts than like natural knees. There is also kinetic and tribologic support that load sharing results in reduced loosening stress and PE wear. However, the issue of wear seems to be overtaken by material improvement and the clinical results do not show a superiority of RP TKA. So, if there is a potential advantage of higher survival against loosening
due to the LCS concept, it needs to be shown in follow-up studies of more than 20 years.

**LIMITATIONS**

On critical evaluation, there are three important limitations in this work to consider, which concern the absence of bearing tracking with optoelectronic motion analysis, the accuracy of noninvasive bone tracking and the retrospective study design. This lead to the following weaknesses:

1. In an attempt to find mechanical support for the LCS concept, we proved the existence of significant axial rotation in a RP knee under the assumption that most of the rotation happened due to the mobility of this bearing. This assumption is critical, because in case of absence of rotation of the bearing, high ranges of rotation on the congruent articular surface would suggest ligamentous instability. However, we considered this assumption to be acceptable, because studies using fluoroscopy with tantalum inserted mobile bearings proved that most of the rotation in MB/RP knees indeed occurred at the tibial surface of the bearing.9-10

2. In chapter 4 significant more range of rotation was found in favour of the RP over the FB design, when moving from sit to walk. Also during STW with turns more rotation was found in favour of the RP, although not to a significant level \((p = 0.51, \text{Table 4.4})\). If noninvasive bone tracking with optoelectronic motion analysis would have been more accurate and/or more patients would have been included in the study, this difference might have become significant. Although a higher
range of rotation of a RP over a FB knee would not be sufficient to prove success of the LCS concept, it would certainly demonstrate a shortcoming of the FB knee.

3. The findings in both our clinical studies (chapters 4 and 5) need to be seen in context of selection biases. These are partly subscribed to inclusion of patients in different hospitals and the use of prosthesis designs that share more differences than just mobility of the bearing. Since the design of the studies was not prospective and also not randomized, a variety of known (diagnosis, sex) and unknown variables were not controlled for. In the ideal study patients could be blindly randomized to a FB and MB variant of a material equivalent TKA design, each on one side of the body. A number of publications of such studies exist, but they all focused on clinical outcome instead of mechanical performance.

FUTURE PERSPECTIVE

Underlying mission of the thesis was to motivate whether or not the LCS concept should have a place in further TKA development. We found support for the mechanical functioning of the concept, but not for its potential superiority in clinical outcome. Published survival data simply did not exceed 20 years of follow-up, which makes the ultimate comparison between MB/RP and FB undecided. Meanwhile, the quality of PE has been improved making prosthetic wear less of a problem. So, what is the use of exploring concepts that promote load sharing? The answer is that as long as prosthetic fixation is not being improved, the onset of aseptic loosening will still be at risk. This, and the
limited knowledge of functional performance of TKA under relatively complex loading conditions, justifies keeping the LCS concept involved in further research. This being the case, future comparison studies using MB/RP variants should use a uniform quantifying measure to describe condylar congruency at the femoral side of the bearing. Simply stating that a bearing is mobile is not sufficient to classify a MB/RP variant under the LCS concept.

Another reason to keep MB concepts involved in future research is the solution of a theoretical problem that we would like to refer to as the Kinematic Conflict. Load sharing depends on a certain freedom and amount of axial rotation of the bearing and is not depending on any pattern of rotation. Patterns of rotation in MB/RP TKA have been the subject of study and were found to be ‘unnatural’ or even ‘reversed’, so there is a conflict between concept (amount of rotation) and natural kinematics (pattern of rotation). The term kinematic conflict originally dates back to the days of the debate on posterior cruciate retention versus substitution in relation to sagittal plane kinematics. It refers to the choice of either creating a clinically less successful total knee in which natural knee kinematics are fully restored, or creating a successful total knee without natural kinematics (sagittal plane kinematic conflict). The LCS was not designed to fully restore transversal plane kinematics, but to be a clinically successful knee replacement (transversal plane kinematic conflict). However, if all kinematic conflicts were to be solved eventually, it would be with a design depending on bicruciate ligament retention or reconstruction and mobile meniscal bearings.

Irrespective of concepts and clinical success of TKA in
the future, this thesis has shown that incorporating certain loading conditions can assist in making a distinction in comparative studies. This requires adjustments in current laboratories of motion analysis. Superficial marker placement in optoelectronic systems needs to be further improved to reduce soft tissue artefacts; detector mobility to allow for more freedom of activity would be advantageous in model based fluoroscopic systems. Ideally, *in vivo* derived kinematic and kinetic parameters should be integrated in a mathematical model, which reconstructs for three-dimensional loading conditions representing daily life activity.

**CONCLUSIONS**

In this thesis, the global objective was to test whether there is mechanical support for the functioning of the LCS concept. The more specific objective was to establish whether or not the LCS RP prosthesis provides the knee with significant axial rotation *in vivo*. In order to do so, the investigators had to perform two methodological studies before conducting two clinical studies. Besides the epidemiological shortcomings of the clinical studies, the work is merely contributively on a basal science level. Together with mechanical and clinical results from the literature we found support for the functioning of the LCS concept, although superior clinical results in comparison to the FB concept have not been shown.
The following statements or proposals are the result of this work:
1. The measurement of \textit{in vivo} axial knee rotation with non-invasive optoelectronic motion analysis at a group level is possible by using the Femoral Epicondylar Frame.
2. Complex three-dimensional loading conditions are helpful to explore the geometric constraints of TKA variants.
3. The range of axial knee rotation after TKA is not necessarily inferior to the normal knee during the performance of relatively complex loading conditions.
4. The range of axial knee rotation in LCS RP total knees remains constant from one to five years postoperatively.
5. The LCS RP knee, with free rotation of a highly congruent bearing around a central axis, was designed to promote load sharing and not to solve a so-called kinematic conflict.
6. Comparison studies with RP TKA variants should make use of a uniform quantifying measure of condylar congruency, to discriminate LCS derivatives from others.
REFERENCES


