# Diplomarbeit

The Influence of the Tibial Slope on the Postoperative Range of Motion After Total Knee Arthroplasty

eingereicht von

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Eingereicht am 01.12.2013

## Eidesstattliche Erklärung

Ich erkläre ehrenwörtlich, dass ich die vorliegende Arbeit selbstständig und ohne fremde Hilfe verfasst habe, andere als die angegebenen Quellen nicht verwendet habe und die den benutzten Quellen wörtlich oder inhaltlich entnommenen Stellen als solche kenntlich gemacht habe.

Graz, am 1.12.2013 ……..

Simon Sternbauer, BA

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# Directory

## Abbreviations

| | |
|---|---|
| ACL | anterior cruciate ligament |
| ATC | anterior tibial cortex |
| BMI | body mass index |
| GI | gastro intestinal |
| KSS function | knee society score – function |
| KSS pain | knee society score - pain |
| NSAID | non-steroidal anti-inflammatory drugs |
| OARSI | osteoarthritis research society international |
| OA | osteoarthritis |
| PCL | posterior cruciate ligament |
| PPI | proton pump inhibitor |
| PTC | posterior tibial cortex |
| RA | rheumatoid arthritis |
| SD | standard deviation |
| ROM | range of motion |

| | |
|---|---|
| THA | total hip arthroplasty |
| TKA | total knee arthroplasty |
| TPPA | tibial proximal anatomical axis |
| WHO | world health organization |

## Legend to Figures

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## Abstract

## English

## Background

In vitro studies indicate a correlation between the posterior tibial slope and the range of motion (ROM) after primary total knee arthroplasty (TKA). Impeded flexion after TKA is one of the main concerns of a surgeon, as a limited ROM leads to patients' dissatisfaction due to constraints in movement. Long-term data in arthroplasty are increasingly important as a growing number of patients are supported with prosthesis for decades. The present study investigates the correlation of the tibial slope and the actual active ROM after primary TKA in patients with a minimum follow-up of 10 years.

## Patients and Methods

The presented retrospective correlation analysis investigates 83 knees in 66 patients who underwent TKA at the Medical University of Graz, Austria, with a minimum follow-up of 10 years. The study population comprised 50 female and 16 male patients with an average age at the time of the examination of 76 years (standard deviation (SD) 11 years, range from 37 to 95 years). The average age at the time of surgery was 62 years (SD 12 years, range from 21 to 78 years). A lateral X-ray was taken at follow-up in order to analyze the tibial slope. The tibial slope was defined as the angle between the tibia plateau and the tibial proximal anatomical axis. Two independent observers repeatedly conducted measurements on different days and the inter- and intra-observer reliabilities were observed. The active and passive ROM was measured with a standard goniometer and correlated with the tibial slope.

## Results

The mean knee society score was 68.58 (SD 30.98) for function and for 70.71 (SD 22.35) for pain. The mean WOMAC score was 80.77 (SD 15.12). The posterior tibial slope and the ROM

were not correlated. In this analysis the correlation coefficient was 0,152 with a p-value of 0,076.

## Discussion

In the present study we did not find a correlation between the tibial slope with the ROM and believe that the slope is a system immanent factor, which should only be slightly altered in TKA. We conclude that the tibial slope is not the primary influencing factor for the absolute postoperative ROM in patients 10 years after primary TKA. Defining the tibial slope as the single responsible variable for postoperative ROM ignores impeded agility, overall health and physical status of the elder patients.

## Abstract

## German

### Einleitung

In-vitro-Studien zeigen einen Zusammenhang zwischen dem posterioren Tibiawinkel und der maximalen Beugung des Kniegelenks nach der Implantation einer totalen Knieendoprothese. Eine postoperativ eingeschränkte Flexion wird von den Chirurgen/-innen ungern gesehen und bedeutet für den Patienten/-innen eine eingeschränkte Bewegungsfreiheit und ein wenig zufriedenstellendes Ergebnis. In dieser Studie wollten wir den Zusammenhang zwischen dem tibialen Slope und der Bewegungsfreiheit im Kniegelenk darstellen. Da Langzeitergebnisse in der Endoprothetik an Bedeutung zunehmen, wurden Patienten/-innen untersucht welche bereits vor mehr als 10 Jahren mit einer totalen Knieendoprothese versorgt wurden.

### Patienten und Methodik

In dieser retrospektiven Korrelationsanalyse wurden insgesamt 83 Knie von 66 Patienten/-innen untersucht, davon 50 Frauen und 16 Männer. Das Durchschnittsalter bei der Untersuchung betrug 76 Jahre (Standardabweichung (Stabw) 11 Jahre, von 37 bis 95 Jahre). Das durchschnittliche Alter bei der Operation war 62 Jahre (Stabw. 12 Jahre, von 21 bis 78 Jahre). Vor der Untersuchung wurde ein seitliches Röntgen aufgenommen. Die Vermessung des tibialen Slopes wurde mittels der TPAA (tibial proximal anatomical axis) und des Tibiaplateaus durchgeführt. Von zwei unabhängigen Untersuchern wurden die Bilder zweimal an verschiedenen Tagen vermessen. Die aktive und passive Beugung im Kniegelenk wurde mit einem Standardgoniometer ermittelt. Der Bewegungsumfang wurde mit dem tibialen Slope korreliert.

### Ergebnisse

Der Knee Society Score (KSS) für die Funktion war 68,58 (Stabw. 30,98), der KSS für Schmerz war 70,71 (Stabw. 22,35). Der WOMAC Score ergab 80,77 (Stabw. 15,12). Wir konnten keinen signifikanten Zusammenhang zwischen dem tibialen Slope und der

Beugung im Kniegelenk finden. In dieser Studie war der Korrelationskoeffizient 0,152 und der p-Wert 0,076.

## Diskussion

In dieser Arbeit konnten wir keinen Zusammenhang zwischen dem tibialen Slope und der ROM finden und glauben, dass der tibiale Slope ein systemimmanenter Faktor ist, welcher intra-operativ nur gering angepasst werden sollte. Wir denken nicht, dass der tibiale Slope der einzige Einflussfaktor auf die postoperative Beweglichkeit ist. Vorallem die eingeschränkte Gelenkigkeit, der körperliche Gesamtzustand und die momentane Befindlichkeit haben einen großen Einfluss auf den Bewegungsumfang der älteren Prothesenträger.

# 1. General Part

## 1.1. Anatomy of the Knee Joint

### 1.1.1. Introduction

The knee joint, the biggest joint in the human body consists of the femorotibial articulation and the femoropatellar articulation.(1) From a functional point of view it can be divided into three compartments, the medial-, the lateral, and the retropatellar compartment. The joint is designed as a mobile trocho-ginglymus, where the articular bodies of the femur and the tibia as well as the patella move against each other. Unlike any other joint of the body the knee joint needs to balance the demands for stability against an utmost range of motion (ROM). Muscles forces, strong static ligaments, intra-articular menisci and a special bone morphology provide stability of the joint.(2) This is most important for the knee joint, as the articular partners, especially femur and tibia appear to be highly incongruent in their designs.(3) As it supports the whole body weight, this articulation is in many cases subject to osteoarthritis and due to its wide ROM, trauma occurs frequently, traumatic dislocation, however, is a rare condition.(4) Especially in the femoropatellar articulation pressure forces might exceed 100 kg/cm$^2$, which is an enormous amount for biological tissues and therefore causes the patellar cartilage to be one of the thickest in the body.(4,5)

### 1.1.2. Osseous Anatomy of the Knee Joint

The articular bodies of the femur, which is the longest and strongest bone in the human body, are the medial and lateral condyles. The two condyles unite in the distal part of the femur building an asymmetric, saddle-like sliding surface for the patella.(1) The patella is the largest sesamoid bone in the body. Concave on its superficial surface, the articular surface of the patellar contains a vertical central ridge articulating with the femoral sulcus, which is formed by a connection of the lateral and medial condyles. The articular surface is slightly concave on the lateral side and convex on its medial facet.(6) As part of the extensor

mechanism the patellar receives insertion of the patella ligament distally and the vastus intermedius proximally.(2)

The tibia´s corpus is nearly triangular and its caput is wide to support the weight transmitted by the femoral condyles.(1) Centered by the eminentia intercondylaris the articulation surface of the medial tibial plateau is concave, whereas the lateral part has an anteroposterior convexity. Having this in mind one can explain the screw-home mechanism of the femur on the tibia when it comes to full extension.(2) This is crucial for the amuscular stance. The tibial plateau is not located orthogonal to the anatomical axis of the tibia. A slight posterior slope of 8° in the average can be detected. The posterior slope affects shear forces in the knee joint. A tibial slope will increase varus and valgus laxity, antero and posterior laxity and rotational laxity in the knee joint. Furthermore a larger angle increases the ROM by loosening the posterior cruciate ligament (PCL) when the knee is flexed.(7)

## 1.1.3.Ligamentous Anatomy of the Knee Joint

Generally speaking the ligaments engaged in the formulation of the specific motion of the knee articulation might be divided into two groups. Firstly the external ligaments like the tibial and fibular collateral ligaments, which account for guidance and inhibition of movements and secondly the crucial ligaments trying to establish contact among the articulating partners in the femorotibial articulation.(4) From a topographical point of view the formulation of four groups can be considered.

### 1.1.3.1. Ventral Ligaments

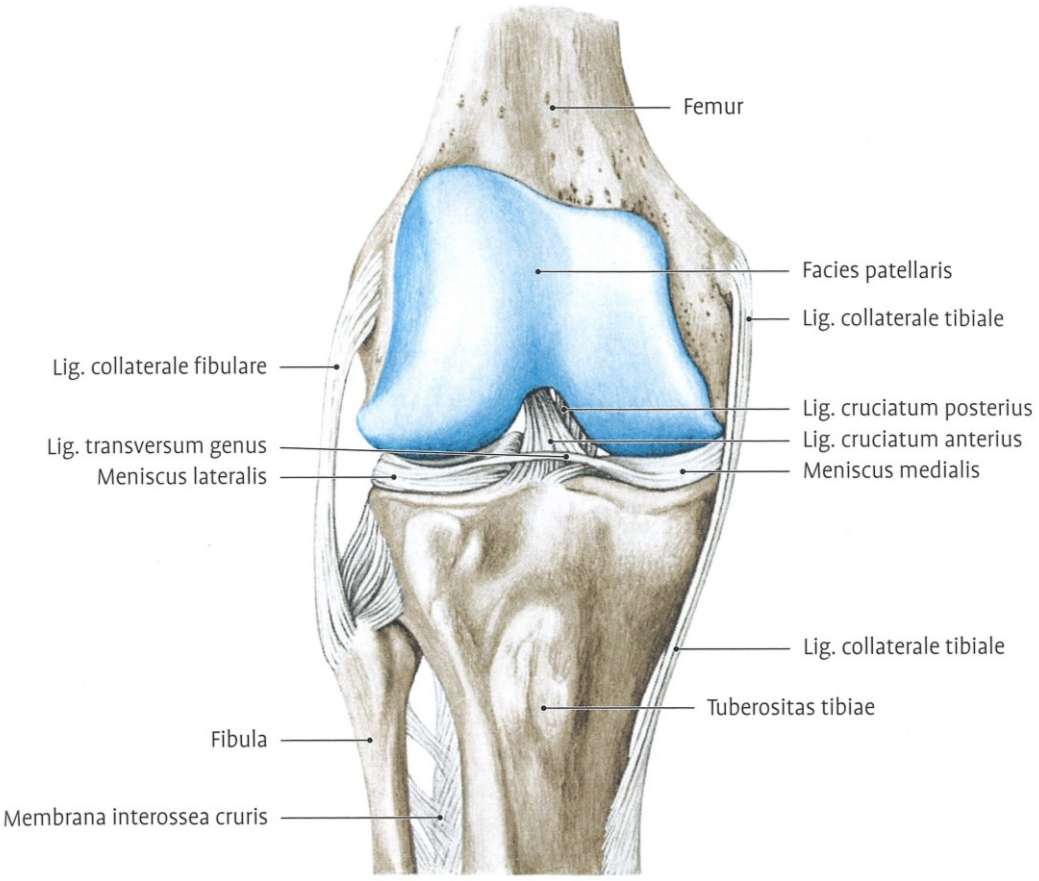


Fig. 1 Ligaments of the knee joint from ventral.(1)

The ligamentum patellae originates from the musculus quadriceps femoris, continues distal of the patella and inserts at the tibial tuberosity. The superficial fibers of the tendon cover

the patella. Fibers medially and laterally from the patella partly merge with the fibrous capsule and build what is called the medial and lateral patellar retinaculae. In case of a functional loss of the ligamentum patellae these fibers might be able to fulfill an extension in the knee joint with decreased force and are therefore known as the reserve extensor mechanism.(1,3)

### 1.1.3.2. Dorsal Ligaments

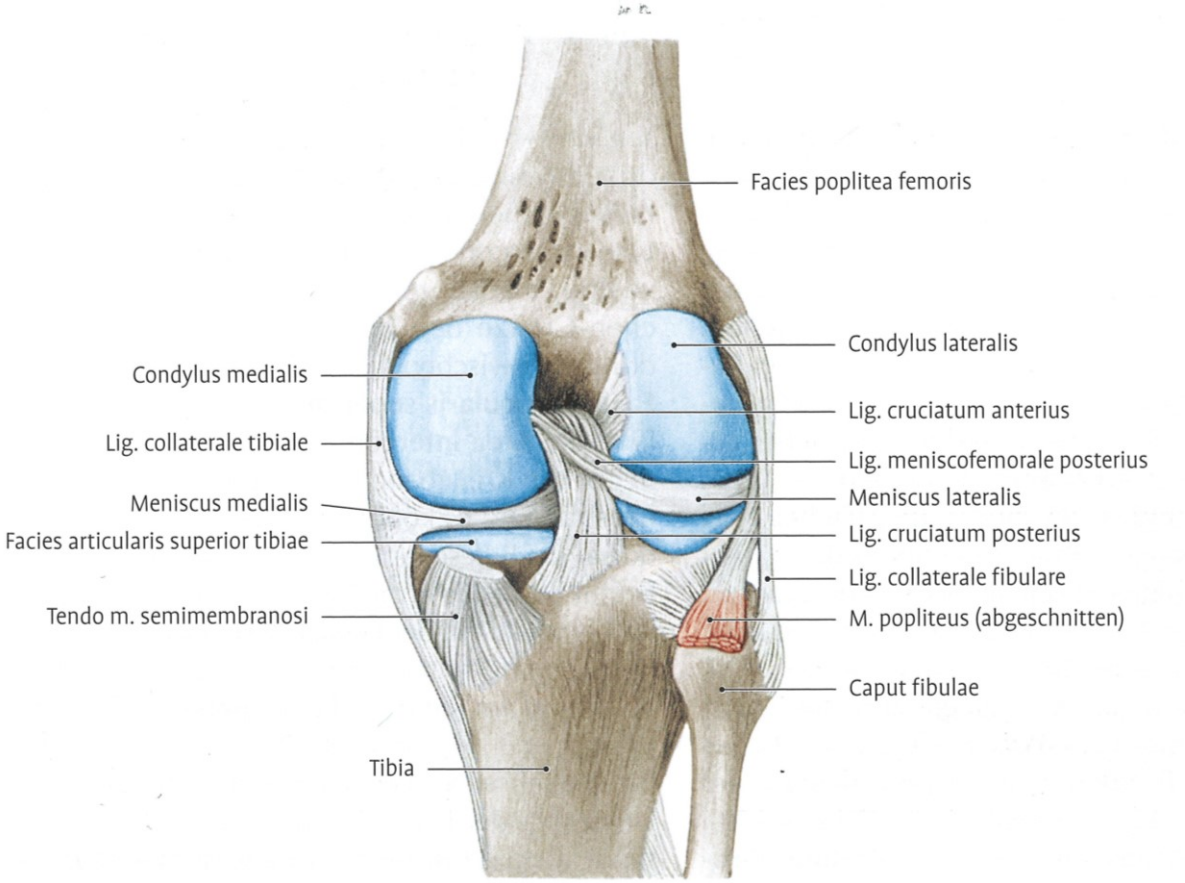


Fig. 2 Ligaments of the knee joint from dorsal.(1)

The oblique popliteal ligament expands from the musclus semimembranosus amplifying the dorsal part of the knee capsule and turns towards the lateral femoral epicondyle. Functionally it blocks external rotation and extension of the knee.(3,8)

The arcuate popliteal ligament expands crosswise to the oblique popliteal ligament and ends at the caput fibulae. It inhibits knee extension.(8)

#### 1.1.3.3. Collateral Ligaments

The tibial collateral ligament, approximately 10 cm in length, expands from the medial femoral epicondyle, immediately distal to the adductor tubercle of the medial condyle to the tibia. Attached dorsally to the pes anserinus, the band limits abduction and medial joint opening. The anterior part of the ligament rather inhibits external rotation whereas the posterior part limits internal rotation. The dorsal part of the tibial collateral ligament is connected to the medial meniscus, causing simultaneous injury of both parts when it comes to medial knee trauma.(1,3,8) Extreme external rotation combined with valgus forces leads to multiple injuries of the knee. The so-called unhappy triad consists of meniscus lesions and traumatic rupture of the ACL and the tibial collateral ligament.(8)

The fibular collateral ligament, separated from the articular capsule by connective tissue, is a strong cord expanding from the lateral femoral epicondyle to the fibular head. Like its medial partner the tibial collateral ligament, it's tense in extension and loose in flexion of the knee. Its function is to limit adduction and lateral opening of the joint, as well as external tibial rotation.(3,8)

#### 1.1.3.4. Central Ligaments

Both cruciate ligaments can topographically and functionally be found in the middle of the knee joint. Their connection to the synovial membrane makes them intra-capsular, but as they are not surrounded by synovial fluid their position has still to be described as extra-articular. Part of their job is to secure the knee joint at the sagittal, as well as the horizontal and frontal plane against transition and on the vertical axis against rotation. Deficient cruciate ligaments will allow horizontal, either anterior, or posterior transition of the tibia against the femur causing a feeling of instability. The anterior cruciate ligament is tense in case of an internal rotation whereas the posterior cruciate ligament is tight when external rotation of the tibia takes place.(1,3,4,8)

The posterior cruciate ligament is stronger than the anterior cruciate ligament. It ascends from the posterior intercondylar area of the tibia and is fan-shaped attached to the lateral side of the medial femoral condyle. An anterolateral and a posteromedial bundle compose this strong band.(1,3)
The anterior cruciate ligament is attached on the dorsomedial side of the lateral femoral condyle and descends to the anterior intercondylar area of the tibia. Its position is anterolateral to the posterior cruciate ligament.

The ligamentum meniscofemorale anterius and posterius originate from the posterior cornu of the lateral meniscus and attach at the lateral surface of the medial femoral condyle.

#### 1.1.3.5. Menisci

The menisci are of a semilunar form, feature a wedged profile and therefore deepen the articulation of the tibia, which receives the condyles of the femur. They distribute mechanical forces from the femur onto a larger articulation area, help to guide rotation and stabilize translation. Mechanical resistance and endurance is granted by their fibrocartilage structure. Their thick peripheral borders are attached to the synovial membrane. The lateral part of the menisci is nourished by the arteria media genus. In contrary, the free floating central part of the menisci is nourished by diffusion and receives nutritive substances from the synovial fluid. Short and tight bands attach the ends of the menisci to the intercondylar area of the tibia granting flexibility and stable connection to the tibia. Due to its morphology and tight connection to the tibial collateral ligament, the medial meniscus is more often subject to lesions than the lateral one. On the ventral side, the menisci are connected by the transverse genual ligament, which secures an adequate and coordinated motion of both menisci.(1–4,8)

### 1.1.3.6. Articular Cavity

Compared to other articular cavities of the human body the knee joint owns the most complex and spacious joint cavity.(8) The fibrous capsule is extensive, partly deficient and in some areas augmented by adjacent ligaments and tendons. Its posterior part is proximally attached to the superior margins of the femoral condyles and the intercondylar fossa. Distally, the fibrous capsule is connected to the posterior margins of the tibial condyles. Medially it's attached to the femoral and tibial condyles just beyond their articular margins.(3) Laterally the fibers are covered by the tendon of musculus popliteus and reach from the femoral condyle to the tibial plateau. The synovial membrane complex forms a large suprapatellar bursa, covered by the quadriceps tendon. The recessus subpopliteus, which is found under the popliteus tendon , is always connected to the capsule and can reach the articulatio tibiofibularis. Other bursae are found under the tendons of the musculus semimembranosus and musculus gastrocnemius to facilitate the sliding of these structures. The bursae prepatellares do not have a connection with the articular cavity but serve as a sliding support for a smooth motion of skin against the patella.(1,3,8)

The tibial collateral ligament and the oblique popliteal ligament fortify the fibrous capsule from outside and the cruciate ligaments are covered by the synovial membrane on the inside of the capsule.(1,3)

## 1.1.4.Functional Anatomy of the Knee Joint

Movement can be described as flexion and extension as well as medial and lateral rotation. In utmost extension, the femur and tibia are in stable position and due to the screw-home mechanism the knee joint is locked. This is mandatory for the amuscular stance. The anterior cruciate ligament and the geometric form of the medial condyle cause this mechanism and allow a final rotation of 5° – 10°. The maximum range of extension is about 10° beyond the vertical femorotibial axis.(3) Due to the tight collateral ligaments no further rotation is possible in this extended position. Passive flexion is possible up to 120° - 150°. During this movement, the menisci gradually glide backwards to the posterior part of the tibia. Stabilized by the cruciate ligaments, the femur rolls and glides backwards as well shifting the area of contact further posterior. Active flexion is limited by ischiocrucral

muscle insufficiency.(8) In orthogonal flexion the ligamentous system allows an internal rotation of 10° and an external rotation of 30°. Adduction and abduction are not possible in a stable healthy knee. In external rotation, the cruciate ligaments unwind and the collateral ligaments are tight, whereas in internal rotation, the cruciate ligaments coil and remain tense and the collateral ligaments stay loose.(1) The patella moves in the intracondylar groove of the femur and experiences a secure osseous gliding area. In extension the patella remains slightly proximal to the facies patellaris of the femur and in flexion it migrates distally, remaining about 6 – 7 cm from its starting position.

## 1.2. Indications for Total Knee Arthroplasty

### 1.2.1. Introduction

Primary TKA is mainly performed in cases of severe and painful osteoarthritis, rheumatoid arthritis, trauma, and apparent radiographic changes combined with end-stage disease with exposed bone in at least one compartment of the knee. Patients with these conditions usually do not gain much benefit from arthroscopic surgery.(2) This procedure, which widely includes joint lavage, removal of loose bodies, mobile fragments of articular cartilage, unstable torn menisci, and impinging osteophytes, is controverse regarding the efficacy in the management of osteoarthritis. However, arthroscopic surgery is still indicated in case of persistent knee catching and locking. TKA is the ultimate relief in a long history of knee joint osteoarthritis.(9)

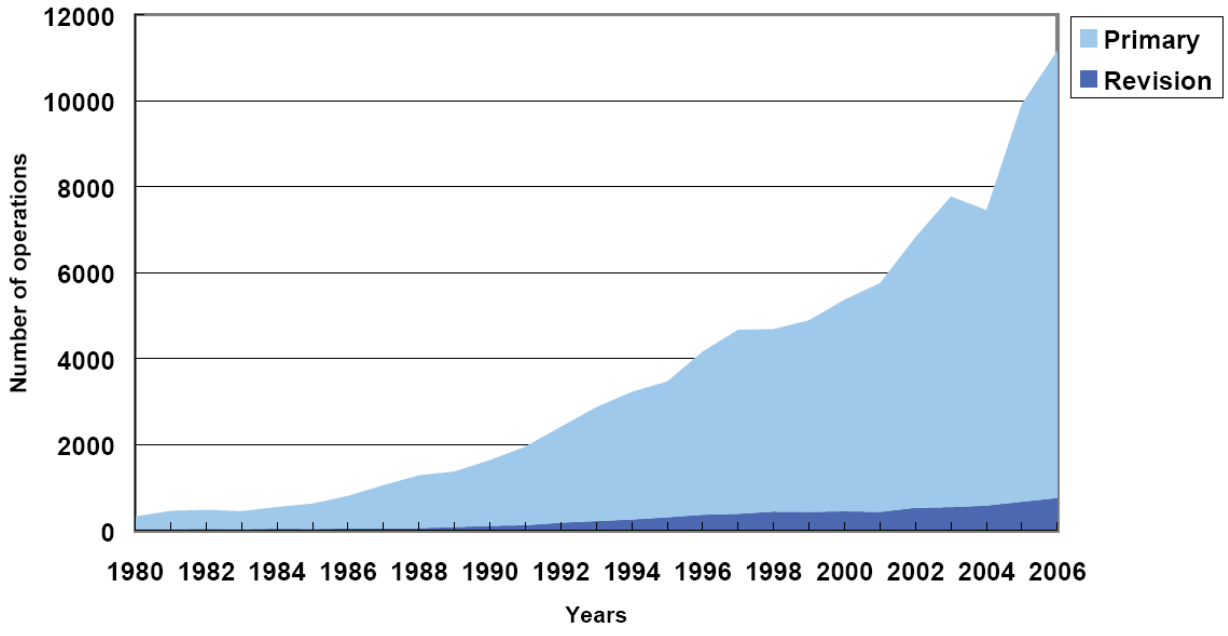


Fig. 3 Primary and revision of Total Knee Arthroplasty from 1980 to 2006 from Finish arthroplasty register(10)

Patients suggested for elective TKA should have gone through professional non-surgical management of their knee symptoms. They should have clinically significant functional limitations and therefore a reduced quality of life (QoL). As TKA is an elective procedure, the patient has to be informed about all possible outcome scenarios after surgery and his expectations and fears have to be discussed in advance.(11) Although TKA is a high volume surgical procedure no clear consensus among surgeons exists about when to start with a surgical intervention.(12)

Recent studies unveiled the common indications for a surgical intervention at the knee joint. In about 90% of cases, primary osteoarthritis was the primary reason for TKA while in about 5% rheumatoid arthritis caused the surgical approach to resolve persistent problems of clinical loss of function and severe pain.(13) Patients should have a history of longer lasting episodes of pain, either during the night or while bearing weight and this situation cannot be addressed in a satisfying manner with conservative treatment.(14)

### 1.2.2.Osteoarthritis

Osteoarthritis, known as degenerative arthritis or degenerative joint disease, is the most common joint disorder worldwide and the main cause for musculoskeletal pain and disability.(15)

#### 1.2.2.1. Epidemiology

Radiographic signs of osteoarthritis appear in the majority of people aged above 65 years and in about 80% in those aged 75 years and above. These signs include joint space narrowing, osteophytosis, subchondral sclerosis, cyst formation, and abnormalities of the bone contour. The disease mainly affects the hip, knee, spine, and foot. Patients essentially suffer from osteoarthritis of the hip and knee as these joints widely bear heavy weights and pain and stiffness in this area is conflicting with the mobility of the individual. Since western world population is getting older and rates of obesity are rising, so an increase in osteoarthritis is inevitable.(12)

#### 1.2.2.2. Etiology

The onset of osteoarthritis is connected to various causal factors. Among these risk factors obesity and age rank in the first place, but also bone morphology, bone density, sex, hormones and trauma play a role.(16) Osteoarthritis and age are inter-related not interdependent. Cartilage decline is to some extend normal in elder people. The development of osteoarthritis occurs more frequently in the presence of a change in the musculoskeletal system.(5) Especially women after menopause are predisposed for degenerative joint diseases. Further metabolic irregularities might cause osteoarthritis in the first place, such as diabetes, hyperuricemia and hypercholesteremia.(4) In young patients osteoarthritis is mainly caused by an unfavorable alignment of the biomechanical axis and consequently strong forces on the articular cartilage. In the long run the joint cannot repair the damage that occurred which leads to premature degeneration.(5)

#### 1.2.2.3. Pathogenesis

Articular cartilage consists of chondrocytes, the extra-cellular matrix provided by these cell types and water. Proteoglycans bind water and collagen fibers interconnect the matrix proteins and stabilize the complex network, which accounts for the cartilages' viscoelasticity. To provide the mechanical features of this tissue in the long run, it needs to be constantly renewed. In a healthy articular cartilage the anabolic and catabolic systems are widely balanced and tissue can reshape after periods of intensive mechanical stress. The signaling for these systems is done by cytokines, growth factors and matrix metalloproteinases. In case the intra-articular cartilage synthesis and degradation get unbalanced over time the cartilage erodes through reduction of collagen type 2. The depletion starts at the surface first and continuous onto deeper areas. The chondrocytes react with the production of atypical cartilage components such as procollagen 2a, collagen 1, 3, 6 and proteoglycan, which leads to a higher absorption of water and soaking and weakening of the articular cartilage. Under these conditions further erosion takes place and the damaged areas expand. Throughout the erosive process chondrocytes may differentiate their phenotype and so called 'cluster' can be detected. The typical damage scenarios can be macroscopically seen and radiographic signs of joint space narrowing will appear.(4)

Recurring synovitis might lead to a tighter articular capsule and accounts for limited function throughout the development of osteoarthritis. In an end-stage osteoarthritis articular cartilage is widely removed and bone might be seen. Synovial fluid now enters bone structures and accounts for subchondral pseudo cysts surrounded by newly formed bone and scar tissue. Subchondral bone angiogenesis takes place and brings blood vessels to the damaged area. To consolidate the exposed bone, sclerosis in the marginal area of the bone takes place. Osteophyte formation is another reaction of the joint to bear the partially high pressures of the destructed knee.(17)

#### 1.2.2.4. Symptoms

The symptoms of osteoarthritis include pain, joint stiffness and loss of function. The pathology includes focal damage and loss of articular cartilage, abnormal remodeling, ligamentous laxity and periarticular muscle weakening.

Disease progression is usually slow, it can take several years and might remain relatively stable. The correlation of clinical evidence with radiographic signs is weak. Apparent pathological signs in the joint do not necessarily have to come along with severe pain. Whereas on the other hand little changes can strongly influence a patient's ROM, cause irritation and decreased mobility.(16)

Once joint space narrowing is detected it takes 12 years on average until the endpoint of osteoarthritis is reached. Although age and obesity are risk factors for the incidence of the disease, a correlation to the body mass index cannot be detected to predict the progression of the symptoms. The illness mostly progresses on its own. Long-term improvement in people with radiographic signs of osteoarthritis is rarely seen.(18)

With regards to the osteoarthritis research society international (OARSI) cases of osteoarthritis therefore can be addressed in a non-pharmacological, a pharmacological and a surgical way. (9)

#### 1.2.2.5. Non-pharmacological Modalities of Treatment of Osteoarthritis

Patients dealing with osteoarthritis of the knee should be given information about the opportunities of self-administered improvement of their conditions. Several impact factors such as weight and exercise can influence the level of pain and function significantly. (19)(20) When it comes to non-pharmacological treatment of conditions, simple exercises, such as aerobic walking or quadriceps – strengthening normally improve the symptoms.(21) As an additional idea to address a progressing osteoarthritis, physiotherapy shows positive results. With regular activities in focus groups, or as a single participant improvements in terms of pain and perceived QoL can be obtained by seriously conducted

therapeutic sessions.(22)(23) Especially local strengthening with aqua-therapy can be valuable to reduce pain and improve motion.(24) Improvement in muscle strength and proprioception may reduce the progression of osteoarthritis.(15) Another adjunctive therapy highly demanded by some patients is acupuncture. In this case no clear recommendation can be given, as the results of previously arranged studies strongly depend on study design and conduct. The pain reducing effects of acupuncture is due to the result of a placebo effect.(14)

#### 1.2.2.6. Pharmacological Modalities of Treatment of Osteoarthritis

The use of non-steroidal anti-inflammatory drugs (NSAIDs) is widely recommended as treatment for osteoarthritis. For a long-term use these drugs should always be given with proton pump inhibitors (PPIs) as a co-prescription. In order to avoid long-term damage to the gastro-intestinal (GI) tract, the lowest effective dose should be applied.(9) When it comes to side effects of a medication acetaminophen (paracetamol) is superior to NSAIDs, as it causes fewer peptic ulcers, bleedings and perforations of the GI-tract, but it does not guarantee the amount of pain reduction a traditional NSAID would provide.(25)(26) Cyclooxygenase-2 inhibitors do not outperform conventional NSAIDs and PPI in combination when it comes to the reduction of gastrointestinal adverse events.(27)

Another possibility to apply drugs is the intra-articular injection of corticosteroids. In this case the anti-inflammatory remedy is directly applied to the area causing pain. Patients dealing with medium to severe pain can particularly benefit from this treatment approach.(28) If oral application of NSAIDs and acetaminophen does not bring sufficient relief for the patient, the intra-articular application of corticosteroids as an adjunctive therapy can be chosen. Having in mind the injection of steroids in the knee joint, it is of importance to look for inflammatory signs in the joint area before placing the injection. Pain is also reduced by corticosteroids without being caused by an acute inflammation. In the short run this treatment can be applied for severe cases of osteoarthritis and reduces symptoms for at least one week.(29) Nonetheless, in order to avoid side effects of the therapy, the accurate application in the joint area has to be secured and steps to avoid

inflammation have to be taken. The administration of corticosteroids should not be repeated more than four times, as it is a short-term treatment for a chronic problem.(28,30)

In contrary to the short-term benefit of an intra-articular application of the above-mentioned corticosteroids, an injection of hyaluronic acid may provide a longer lasting benefit for the patient.(31) When hyaluronic acid is applied one has to take into account the delayed benefit and therefore one can count on a longer lasting benefit when applied frequently for several weeks.(9) Nonetheless its efficacy is still controversial.

#### 1.2.2.7. Surgical Modalities of Treatment of Osteoarthritis

Persistent pain of the knee joint might lead up to a surgical intervention in order to address the causal factors, ultimately decrease pain and re-establish function. Many procedures are known and can be taken into account to improve a non-satisfying situation in a patient's knee. Many years needle lavage or arthroscopic debridement and lavage have been performed and have not shown significant long-term improvement.(32) However short-term benefits are reported when it comes to the arthroscopic debridement of meniscal tears. Decent utility can be derived from this approach in cases of low grade osteoarthritis and recent trauma.(9,33)

High tibial osteotomy can be considered for young active patients suffering from unicompartimental osteoarthritis of the knee. The underlying idea of this surgical approach is to redistribute the body weight. Therefore the pathologically stressed compartment is released and a new biomechanical situation is established. In a varus situation of the knee, the medial compartment suffers higher pressure than the lateral does and a valgus alignment stresses the lateral compartment. In order to release the medial compartment, a valgus opening osteotomy is performed. In this case a total release of the medial collateral ligament is necessary to unload the pressure of the medial compartment.(34)

Although early results after surgery are very promising, the situation still deteriorates with time.(35) This procedure delays the need for total knee arthroplasty for about ten years and should only be applied for carefully selected young patients.(9,14)
In approximately one third of the patients suffering from osteoarthritis the disease is restricted to one knee compartment. Only 3% suffer from osteoarthritis of the lateral compartment, 30 % from the medial compartment, whereas in 67% the disease is located in the patella-femoral joint.(36) In case of a single compartment affection of the joint an unicompartmental knee arthroplasty can be performed and patients do benefit from this intervention in the long run. The risks for complications can be compared to those of TKA and are lower than after high tibial osteotomy. For patients with an unicompartmental pathology this procedure is a beneficial surgical procedure to improve function and reduce long-term pain.(37)

The ultimate approach to osteoarthritis of the knee is TKA. Knee replacement is a very reliable and effective surgery to relief pain and its outcome is mostly very good to excellent. During the last two decades the number of TKAs undertaken has multiplied and revision rates are as low as never before. For people with osteoarthritis and radiological signs of joint space narrowing this arthroplasty can deliver improvement of physical function and pain.(9)

### 1.2.3.Rheumatoid Arthritis

When it comes to TKA rheumatoid arthritis is only in 5% of the cases the cause for surgery.(13) Rheumatoid arthritis is a chronic systemic disorder, mainly causing symptoms in joint areas, the vascular system, the eyes and inner organs.

#### 1.2.3.1. Epidemiology

In western countries the prevalence of rheumatoid arthritis is about 1%, with women affected twice as often as men. Patients aged 40 to 50 years mark the peak incidence of this illness. This slow progressing disease is of huge economic interest, as it might lead to early retirement of patients due to loss of mobility and manual incapability to perform.(38)

#### 1.2.3.2. Etiology

Causing factors for rheumatoid arthritis might be external factors like previous viral or bacterial infections, or internal factors for example genetic disposition. Nonetheless the etiology of this systemic disorder in total is still unknown.(38)

#### 1.2.3.3. Pathogenesis

In the synovial membrane lymphocytes and plasmacytes produce IgG, which triggers immune reactions. In 80% of the patients rheumatoid factors can be found in serum and synovial membrane. The rheumatoid factor is an autoantibody against the Fc-part of the organism's own IgG, which then builds immune complexes and causes an inflammatory reaction.(17) Moreover an imbalance of cytokines like TNF-alpha and IL-1 might be a relevant detail in the therapeutic option of immune modulation.(4)

#### 1.2.3.4. Treatment Modalities of Rheumatoid Arthritis

In patients with severe progressed rheumatoid arthritis joint replacement might be the ultimate treatment strategy to address persistent pain and limited function of the knee. Once conservative treatment has reached its limits a surgical approach can be considered. Lately pharmacological therapies demonstrate increasing success rates due to a better

understanding of the disease and the application of TNF-alpha inhibitors as an addition to corticosteroids and methotrexate. Very much like osteoarthritis rheumatoid arthritis has additionally to be addressed with non-pharmacological modalities of treatment like physiotherapy, kryotherapy and psychological consultations. The pharmacological intervention should be quick and effective to reduce destruction of the joint in the first place. Common pharmaceuticals used for the treatment are NSAIDs, methotrexate, sulfasalazine and azathioprine, which are either applied as a mono- or combined therapy. This form of application strongly depends on the patients' response to the treatment scheme applied. If one drug is not sufficient it can be combined with others to achieve a better response rate. Re-evaluation of the treatment success usually takes place after 3 months, as some pharmaceuticals do need some time to unfold their full potential. If rheumatoid arthritis is still not under control with continued periods of pain, swelling and limited function as well as a severely damaged articulation, total joint reconstruction can be considered.(4)

### 1.2.4.Trauma

Trauma might be a reason for instant TKA, but that does not occur frequently. Although after trauma of the knee, torn ligaments, torn menisci and changed biomechanical parameters might lead to a changed performance of the joint. In this case some areas experience unusually high pressures and increased use and therefore their functionality decreases rapidly. Cartilage might be worn out and bone exposed, in this case the trauma finally leads to osteoarthritis of the knee and patients experience symptoms related to this disease.(4) If the non-surgical approach, like pharmacological therapy with NSAIDs, corticosteroids and hyaluronic acid does not address the symptoms properly a surgical intervention is demanded.(9)

As trauma might not occur suddenly, repeated micro-traumas can also lead to a severe damage of the joint with diminished cartilage cover and exposed bones. This might happen if sportsmen and professionals stress their joints repeatedly over a long time and then gradually experience signs of osteoarthritis due to the accumulation of frequent traumatic episodes.(4) As one of the few modifiable risk factors of osteoarthritis, knee injuries should gain more attention in prevention programs.(39)

## 1.3. Contraindications for Total Knee Arthroplasty

### 1.3.1. Absolute Contraindications

#### 1.3.1.1. Sepsis

In case of sepsis a surgical procedure has to be carefully evaluated whether or not it is immediately necessary for the patient. Therapy of sepsis or a septic shock can only be successful if the causal infection is detected and adequately handled. Therefore antibiotics and surgical intervention to correct the causing spot are most important.(40) If bacteria can be detected in a blood test an infection of the implanted prosthesis is highly likely. Apart from the specific downsides, the patient's overall condition might be alarming and he requires intensive care and surveillance.(41) Although hematogenous infection is rare compared to the overall rate of infection which is known for TKA, the out-come of this event is devastating.(42)

#### 1.3.1.2. Extensor Mechanism Dysfunction

Muscular guidance of the knee joint is important after TKA is performed. Once the knee joint's art of motion is altered, muscular strength is of utmost importance to regain ROM and stability. A functioning extensor mechanism is necessary for positive results after primary TKA, as instability is among the most frequent complications after knee surgery.(42) Difficulties in regaining function are correlated with muscle force and endurance before surgery and should therefore be considered before taking this surgery into account.(43)

#### 1.3.1.3. Peripheral Arterial Disease

Good blood supply is an essential factor for a fast and smooth recovery. A constricted limb will need far more time for healing and is more often subject to major problems than a well-supplied leg. Poor wound healing, higher risk of infections and loosening are the problems occurring most frequently. The range of vascular deficiency can easily be measured by the ankle brachial index. In case of a vascular deficiency this problems hast to be addressed first before a surgical procedures is planned.(44)

## 1.3.2.Relative Contraindications

### 1.3.2.1. Physical Constitution

The outcome of a primary TKA strongly depends of the constitution and physical abilities of the patient before surgery. Limited walking distance, restricted ROM and a weak extensor mechanism will lead to poor results after surgery. Age and decreased mental status are additional predictors of less favorable outcome. Within this framework of information a patient has to be evaluated before entering into surgery and needs to be informed about the influence his physical state brings into the decisions about surgery.(43)

### 1.3.2.2. Body Mass Index

Many surgeons require weight loss before surgery. A body mass index (BMI) of more than 40kg/$m^2$ is considered to be too high and therefore might cause exceptional risks. The prosthesis might suffer from additional load and cause troubles to the patient. A reduction of the BMI before the intervention is required by 19 out of 41 surgeons interviewed in a survey.(45) Numerous surgeons on the other hand do not consider a high BMI to be a restricting factor for TKA, as a painful knee considerably limits people in their daily exercises and ambitions to move. Pre-operative weight loss can be encouraged to ensure longevity and positive results of TKA, but more importantly to improve general health and well-being. Refusing surgery for obese patients might be difficult to justify, as they derive great benefit from it.(46)

### 1.3.2.3. Skin Conditions

Poor skin conditions are a relative contradiction for surgery as well. Proper wound healing requires good skin conditions, adequate circulation and sterile handling. Infectious sites at the area of incision can cause deep infections of the prosthesis. Previous osteomyelitis in the joint area might also account for subsequent inflammation and insufficient results.(47)

## 1.4. Surgical Aspects of Total Knee Arthroplasty

### 1.4.1. Prosthesis Design

In TKA basically two different types of prosthesis are used to address the patients needs. Depending on the expected stability after surgery either a constrained or an unconstrained design can be selected. Mobile bearing designs allow movement of the intra-articular inlay and create a dual surface interface. This approach is aimed at decreasing polyethylene wear by increasing the contact area.(48)

#### 1.4.1.1. Unconstrained Prosthesis

To fully understand the design one has to have in mind the femoral roll back. Physiologically the axis of the knee joint is shifting during flexion and extension. Therefore the femur moves forward and backward on the tibia. When extending a fully flexed knee, a stationary transversal axis via the posterior part of the condyles can be drawn. The more the extension continues the further the axis moves ventrally, allowing the knee to change it's motion from gliding to rolling and causing an anterior transition of the femur. This specific motion is mainly controlled by the anterior cruciate ligament (ACL) and the posterior cruciate ligament (PCL) and is made possible by the flat design of the tibia plateau.(48,49) The risk of bony impingement in total flexion is reduced and subsequently an increased physiological flexion allowed.

Older implant designs were meant to imitate the physiological movement receiving an anatomical shape of the femur shield. High rates of wear could be demonstrated caused by increased contact stress on the participating joint partners. Newer models therefore resign the femoral roll back in order to spare prosthetic substance and minimize the risk of catastrophic failure. Their interacting parts are having a more congruent surface to decrease contact stress and the contact point between femur shield and the tibia inlay was put more posterior to facilitate flexion.(48)

#### 1.4.1.1.1. Unconstrained Posterior Cruciate Ligament Retaining Prosthesis

These days the unconstrained PCL retaining prosthesis type is the most commonly used in knee arthroplasty. The design relies on the preserved PCL to grant stability of the knee joint. Due to the PCL femoral rollback is possible to some degree, allowing greater flexion, but it causes increased wear of the polyethylene inlay due to the combination of rolling and sliding. The partial loss of femoral rollback and subsequently compromised flexion is compensated by a posterior shift of the center or rotation.(48)

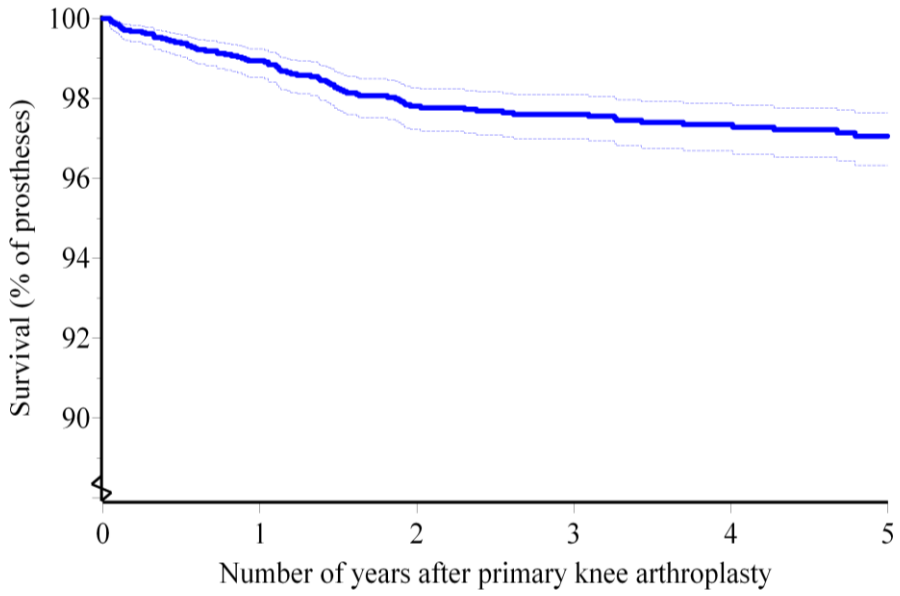


Fig. 4 Femoral Component: PFC Cruciate-Retaining;
Survival rate of unconstrained posterior cruciate ligament retaining prostheses after primary TKA. Endpoint 1. Revision; estimated survival at 95% confidence interval; (n=3424) from Danish arthroplasty register (10)

#### 1.4.1.1.2. Unconstrained Posterior Cruciate Ligament Substituting Prosthesis

Once the PCL is sacrificed its function needs to be substituted by the artificial joint. Either during surgery or in the patient's previous history the PCL can be attenuated or totally ruptured. A loss of the PCL leads to instability and anterior translation of the femur, especially during flexion, causing a feeling of instability for the patient. A tibial post and a

femoral cam will imitate the natural function of the PCL causing a rollback phenomenon of the knee joint. Once a designated point in flexion is reached the prosthesis will initiate a femoral rollback thus facilitating flexion. The additional element between the tibia and femur though is not capable of avoiding varus and valgus stress. Wide flexion gaps might lead to a dislocation of the knee, as the femoral cam might jump over the tibial pole in extreme flexion.(48)

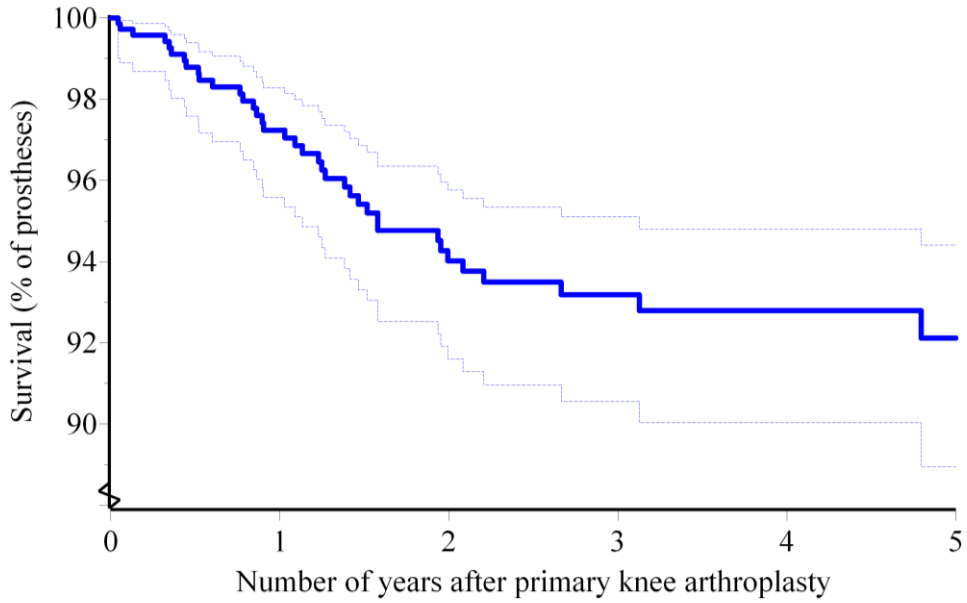


Fig. 5 Femoral component PFC Cruciate-Substituting

Survival rate of cruciate substituting prostheses after primary TKA.

End-point 1.revision; estimated survival at 95% confidence interval (=722); from Danish arthroplasty register (10)

#### 1.4.1.2. Constrained Prosthesis

##### 1.4.1.2.1. Constrained Non-hinged Prosthesis

In case the stability of the knee joint is at risk after surgery, its degrees of freedom need to be constrained to provide stability. The collateral ligaments fix the knee in extension. Their insufficiency will either cause varus or valgus instability.(1) In order to provide protection against opening of the joint the constrained prosthesis has a large central post that substitutes for the medial and lateral collateral ligament. This design does not only oppose varus and valgus stress but also provides rotational stability. Still the prosthesis is not hinged yet.(48)

##### 1.4.1.2.2. Constrained Hinged Prosthesis

A connection by bar and bearing features a constrained hinged prosthesis type, which is used if the ligamentous system is completely insufficient. A hyperextension phenomenon, or a complete medial collateral ligament deficiency are indications for a hinged prosthesis in order to provide stability. Newer prosthesis designs allow rotation, to limit rotational stress to the implanted stem.(48)

#### 1.4.1.3. Unicompartmental Prosthesis

If only one of the knee's three compartments is destroyed unicompartmental prosthesis is an option. In most cases the medial compartment is the reason for pain and discomfort, whereas the other compartments perform well. TKA might be an excessive intervention to address the problem, whereas the sole correction of the affected compartment leads to satisfying results. Compared to TKA the unicompartmental approach is less expensive, leads to quicker recovery and causes less blood loss during surgery.(48) Additionally the natural motion of the joint is rather preserved as one condyle still has its natural shape and is able to guide the knee's movement. Contraindications need to be considered. If the ACL is deficient, or a fixed varus or valgus deformity is present one should hold back from implanting unicompartmental prosthesis. Especially if the patient is still young and physically active, or overweight, the unicompartmental approach should be carefully discussed. The overall revision rate for unicompartmental prosthesis is high when compared to TKA, as the other compartments might degenerate as well, components get loose and component wear is high.(48)

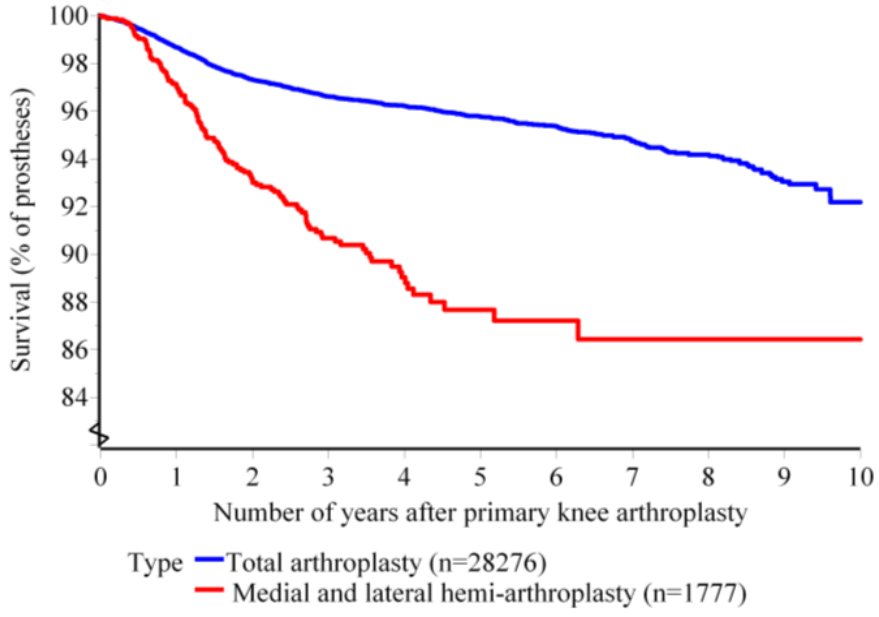


Fig. 6 Survival of prostheses by type of arthroplasty

Endpoint 1. Revision; (n=30053), from Danish arthroplasty register (10)

## 1.4.2.Surgical Techniques

TKA can be performed in various approaches. The patients expectations in TKA have increased in the last few years. Long rehabilitation regimes, delayed return of motion and strength and prolonged pain are the main causes for dissatisfaction after TKA.(50) Patients demand quick recovery and sometimes even ask for a return to high level sports. Surgeons are put under pressure to continuously improve their offers of validated solutions for quick and stressless operational techniques. As quality in life gets more and more important to people they are not willed to tolerate a decline in their physical capacity. Immediate surgery is demanded often as techniques become more reliable and easier available.(51)

### 1.4.2.1. Standard Parapatellar Approach

This approach is not only used for TKA, but also for synovectomy, medial meniscectomy, ligamentous reconstruction and patellectomy. A skin incision is done about 5 cm above the superior pole of the patella towards the level of the tibial tubercle. After dividing the subcutaneous fat along the skin incision, the surgeon either continues by lifting the muscle belly of the musculus vastus medialis or extends the arthrotomy into it. These are the so-called subvastus and midvastus approaches. Subsequently the incision is deepened between the musculus vastus medialis and the quadriceps tendon and a medial arthrotomy is performed. The infrapatellar fat pad is removed and the patella gets dislocated and flipped laterally. Attention needs to be paid to the insertion of the patellar ligament at the tuberositas tibiae, as it should be constrained or damaged as little as possible.(52)

### 1.4.2.2. Minimal Invasive Approach

Today an incision length of less than 14 cm is defined as a minimally invasive approach. On average, it is twice the length of the patella and can be adapted during surgery if needed. Sure enough the smaller incision is not the only benefit for the patient. The results are also widely influenced by the amount of soft-tissue resected, the patellar retraction or eversion and the tibiofemoral dislocation. The minimally invasive approach should not be considered to be a cosmetic approach only, it also speeds up recovery and offers an early return to daily

habits. Patients receiving minimally invasive TKA experience less pain, have decreased rehabilitation needs and a reduced duration of their hospital stay.(53)

Other authors questioned the superior results of a minimally invasive approach by showing no difference in quadriceps strength, or flexion strength two month after surgery. Additionally benefits from an earlier recovery might be negligible as walking speed and stride length do not show a significant difference in either surgical approach. It might be in question whether or not the minimally invasive approach is advantageous for the patient if both techniques are coupled with advanced anesthetic, pain management and rapid rehabilitation.(50)

### 1.4.3.Cement Use in Total Knee Arthroplasty

Whether or not cemented prostheses are superior to cementless is subject to intense debates among orthopedic surgeons. The long-term results of TKA are strongly influenced by the design of the prosthesis, mechanical alignment of the axis, soft-tissue balancing and the way of fixation. Biasing factors are the patient's age, BMI and his level of activity.(54) Patients receiving their prosthesis by the age of 60 are prone to experience revision surgery, whereas patients aged 80 years at the time of implantation are hardly at risk for prosthesis failure.(55)

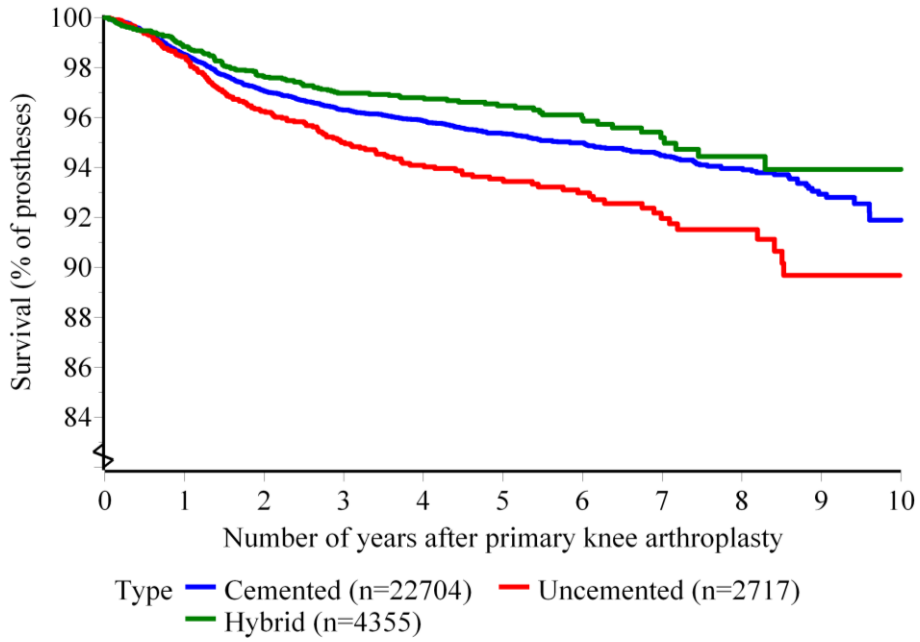


Fig. 7 Survival of prosthesis including all types of implantation
End point: 1. Revision (n=29776); from Danish arthroplasty register (10)

Cementless designs aim at younger, physically more active patients. The hope was to minimalize osteolysis and disintegrations that were observed in the cemented types. Another advantage is the reduced operation and tourniquet time as well as the potentially reduced risk of infection. Younger patients place far higher demands and stresses on their implants subsequently the revision rates for young patients are higher. Micromotion is one factor influencing the bony ingrowth of the prosthesis and its long-term fixation. All

cementless types are therefore designed to increase stability in order to prevent aseptic loosening which accounts for most of the prosthesis failures. Complete radiolucent lines shown on x-rays, correlate with fibrous instead of a bony ingrowth due to extreme micromotion.(56)

There is considerable evidence indicating the superiority of cemented fixation versus the cementless approach. Orthopedic surgeons use cemented fixation by far more often. Cemented fixation is more durable and has a longer survival, therefore it is the gold standard in TKA nowadays.(54)

### 1.4.4.Patella Resurfacing

When performing TKA the surgeon can decide whether or not he will resurface the facies articularis patellae. If he decides to implant a third component to renew the patella he puts the patient at risk for experiencing problems with the prosthesis, whereas a non-resurfaced patella leads to higher revision rates due to anterior knee pain.(57)

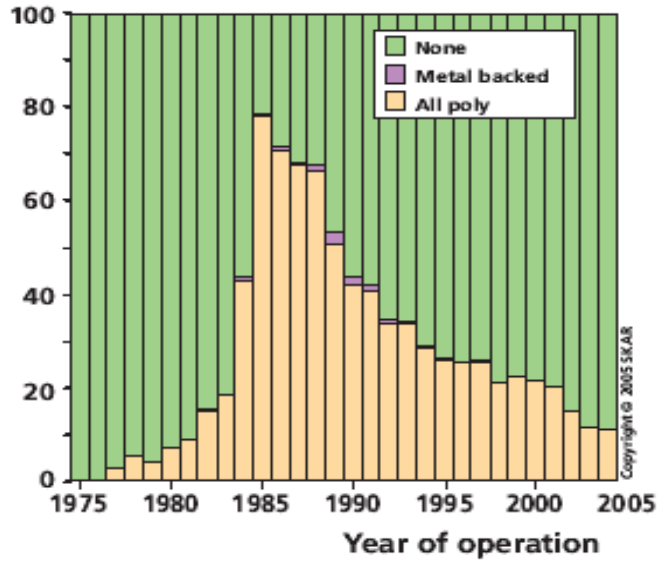


Fig. 8 Yearly distribution regarding the patellar button in TKA
from Swedish arthroplasty register (10)

Resurfacing the patella in TKA is still under debate. It is not clear yet whether or not patients gain from an additional treatment of the patella. With regard to the patients satisfaction no significant difference is reported between a non-resurfaced and resurfaced patella. It is a matter of fact that an untreated patella is causing slightly more anterior knee pain than a treated one. With respect to larger cohort studies this difference is not considered to be significant. Nonetheless in many cases anterior knee pain is the reason for consecutive surgery and therefore causes significantly more revisions than in the resurfaced group.(57) In terms of operation time, infection and functional scores no differences between the two approaches can be detected. Overall nine out of ten patients undergoing TKA surgery are satisfied with their result, regardless of the patellar intervention.(57,58)

## 1.5. Complications in Total Knee Arthroplasty

### 1.5.1. General Part

Overall TKA can be described as a reliable approach in terms of pain relief and functional improvement. Previously highly limited and severe pain suffering patients are able to return to their habits and lead active lives. Some authors report satisfied patients in more than 90% of all TKAs performed.(59) Despite having scored very high on the knee society score (KSS) only 35% percent of the people who underwent TKA surgery stated that they had no limitations at all.(53)

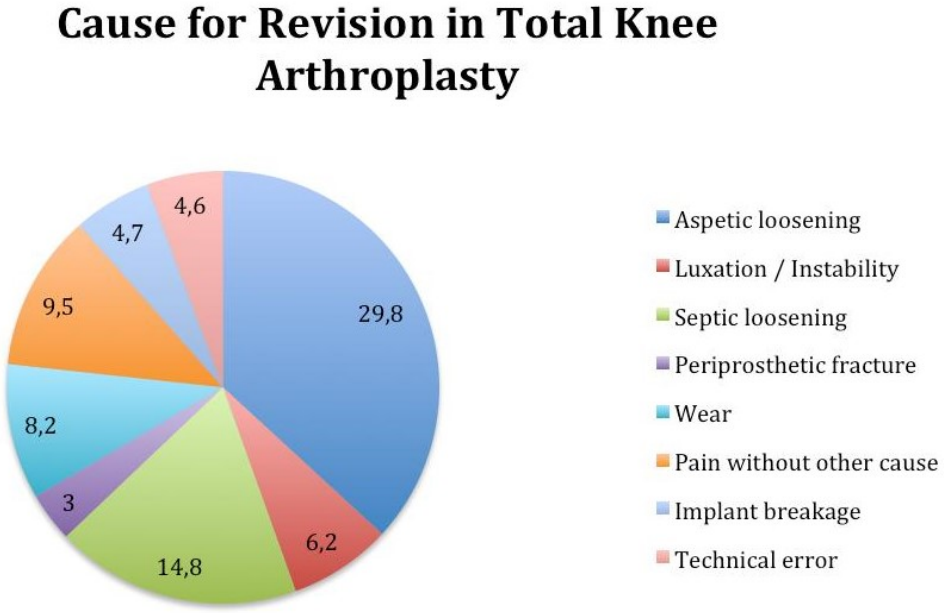


Fig. 9 The Cause for Revision in Total Knee Arthroplasty
from worldwide arthroplasty register.(60)

Aseptic loosening is the most common reason for revision in TKA, followed by septic loosening and pain without any other cause. Infection is a very important topic in arthroplasty. A high volume center reports an infection rate of less than 1% for all implants done. Most of the challenging cases do unite more than one cause for failure and are subsequently subjected to revision.(42)

### 1.5.2.The Elder Patient

Compared to younger patients elder patients experience nearly the same benefits from TKA. The overall amount of pain reduction and their gain of activity are almost as high as in younger patients. Nonetheless, complications are more common in the elder patient. The group aged over 80 years is more prone to develop postoperative problems than younger patients receiving TKA. Especially cerebrovascular events, prolonged wound healing and periprosthetic fractures are encountered as clinically significant complications. On the other hand, severe complications like infections, or pulmonary embolism occur less frequently.(61)

### 1.5.3.The Obese Patient

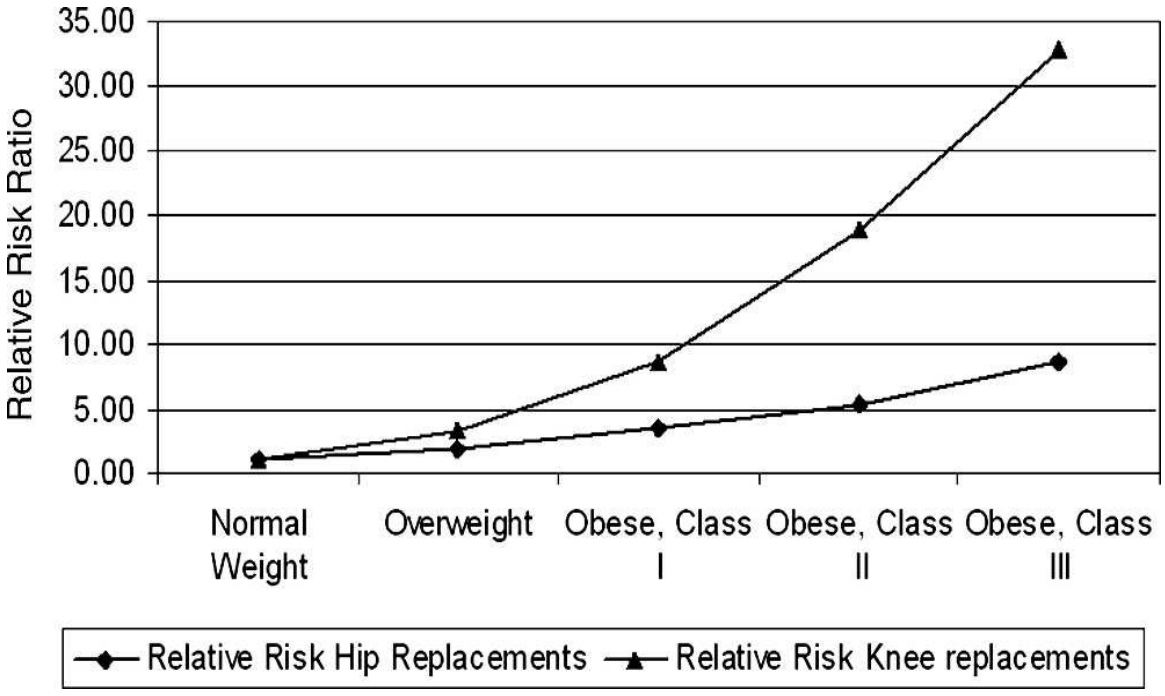


Fig. 10 Relative risk Calculated for THA (total hip arthroplasty) and TKA according to weight category.(62)

According to the world health organization (WHO) people with a body mass index (BMI) between 25 and 29.9 are considered to be overweight. Individuals are obese if their BMI is

above 30. This class can be subdivided into three categories, whereas class I ranges from 30 to 34.9, class II from 35 to 39.9 and class III defines a BMI greater or equal 40.

Obesity is a major health issue in our society. Excess weight stresses joints and accounts for OA of the hip and knee. Obese people are more likely to have a total joint arthroplasty. Secondly obese people do suffer more complications on the way to a satisfying total joint replacement. On average morbidly obese individuals face total joint arthroplasty 10 to 13 years earlier than their normal weight counterparts.(62) Demands are high on surgeons to address obese patients. Their peri-operative medical management is by far more complicated than the average and intra-operative techniques can be challenging. During surgery morbidly obese people lose more blood, nerve injury is more common, the risk of malpositioning of the prosthesis is higher and the risk of avulsion of the medial collateral ligament is reported to be higher as well. Problems with primary wound healing are a more frequent complication in the peri-operative management. Around 26% of these patients either suffer from poor primary wound healing or deep joint infection.(63)

Obese patients gain a lot from surgery, as they tend to have lower functional scores before surgery, as well as after surgery. Overall their total benefit is the same. The achieved ROM after the intervention does not indicated differences between obese and normal weight individuals.(63) 90% of all TKAs do deliver satisfying results, even in the obese population. But there is a tendency towards more complications along the way and a higher revision rate.(46)

# 2. Special Part

## 2.1. Rationale of the Study

The tibial slope is found to be crucial for the ROM of the knee joint. It is defined as the angle between the tibia plateau and the proximal anatomical tibial axis. In a human knee the average slope is about 8° with no significant differences among women and men, but with differences among ethnic groups.(7)

In TKA an increased posterior slope is held responsible for a greater ROM. In-vitro studies showed a correlation of the cutting angle of the tibia and the resulting flexion. Prosthesis implanted with 0° tibial slope showed significant less ROM, than the ones cut with increased slope of 4° or even 7°. With every degree of additional slope 1,7° of flexion can be derived.(64) However an excessive tibial downslope should be avoided, as it leads to anterior instability since the ACL is resected during surgery. Indeed it has to be questioned to what degree these findings can be applied in vivo and what long-term result will be obtained facing the fact that after TKA the physiological knee kinematics will not persist and PCL retaining TKA show specific motion patterns.(64)

The number of people having their knees resurfaced by TKA is constantly rising and the survival expectancy of prosthesic designs is becoming greater and greater. Meanwhile, a large number of patients lives with their prosthesis for a decade and longer. The long-term outcome become more interesting to the surgeons as their current patients will be using their implants for decades. The influence of the tibial slope on the long-term range of motion (ROM) has been poorly studied. The ROM is an important factor of patient satisfaction and the degree of freedom after TKA. Whether or not the postoperative ROM is linked to the tibial slope, as indicated in *in-vitro* studies is shown in this study.

## 2.2. Hypothesis of the Study

The study is a retrospective analysis of the correlation of the current tibial slope with the current range of motion in patients with a minimum follow-up of 10-years after primary low contact stress (LCS) – TKA. We hypothesized that there is a correlation between the posterior tibial slope and the actual ROM at the time of examination. *In-vitro* studies have indicated a connection between the posterior tibial slope and ROM, stability of the knee joint and tension of the PCL. The angle of the tibia plateau is an important factor for physiological biomechanics of the knee joint, as it regulates femoral roll back and influences tension on the PCL. Impingement of the posterior femur is limiting further flexion and can be corrected by a steeper tibial cut. *In-vitro* studies clearly showed a connection between the tibial slope and the postoperative ROM, but it was unclear to what degree patients can benefit from an alteration of the cutting angle in the long run.

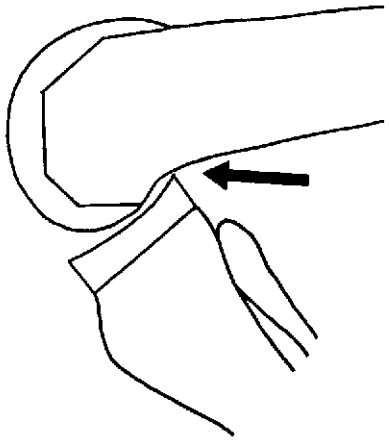

Fig. 11 Flexion limited by impingement of the posterior femur.(64)

## 2.3. Materials and Methods

In total we investigated 83 knees in 66 (50 female, 16 male) patients who underwent TKA in our clinic with a minimum follow-up of 10 years. Out of these patients we examined 50 female and 16 male patients. The average age at the time of follow-up was 76 years (standard deviation (SD) 11.39, range from 37 to 95 years) and the average age at the time of surgery was 62 years (SD 11.97, range from 21 to 78 years). The average follow-up was 14.6 years. (SD 2.83 with a maximum value of 23 years and a minimum of 11 years).
Knee society score for function (KSS – function) was 68.58 (SD 30.98) on average and the mean knee society score for pain (KSS – pain) was 70.71 (SD 22.35). The WOMAC score

averaged 80.77 (SD 15.12). All surgeries were performed using the LCS mobile-bearing total knee prosthesis (Johnson & Johnson, New Brunswick, NJ, USA; previously DePuy, Warsaw, IN, USA)

A minimum follow-up of 10 years after the primary implantation of the prosthesis was an inclusion criterion in this retrospective study, with knees that had been revised before the follow-up period excluded from the examination. In addition, we excluded patients with rheumatoid arthritis and secondary TKA.

A control X-ray in lateral view of every patient in the study was taken at the day of the investigation prior to physical examination. Measurement of the tibial slope was done according to the method published by Utzschneider et al. in 2011 in the KSSTA journal.(65) Two independent and blinded observers did all measurement of the tibial slope. The measurement was repeated on a different day and the intra- and inter-observer reliabilities were calculated. By comparing two different observers the inter-observer correlation is measured, whereas the intra-observer correlation is the comparison of data of one and the same observer at two different time points.

Fig. 12 Strictly lateral X-ray at the day of investigation.

Follow-up 12 years

To perform the measurements the following anatomical references were identified. On the ventral side of the tibia the anterior tibial cortex (ATC) and on the dorsal side the posterior tibial cortex (PTC) can be described. Two points, 5 and 15 cm distal to the tibia plateau were identified and a connection line between the ATC and the PTC was drawn. The mid points of these lines were connected and named the tibial proximal anatomical axis (TPPA). Thereafter the tibial slope was defined as the angle between the TPPA and the tibia plateau. In order to properly identify the tibia plateau, a strictly lateral X-ray of the knee was taken at the day of the examination. Measurement of all identified values was done manually on the imprinted X-rays by two independent and blinded observers on two different days.


Fig. 13 Schematic drawing
Proximal tibia and fibula in lateral view, showing the three anatomical references used to determine the posterior tibial slope: anterior tibial cortex (ATC), posterior tibial cortex (PTC) and tibial proximal anatomical axis (TPPA).(63)

At the day of the physical examination the active and passive ROM were evaluated using a standard goniometer. Active ROM was measured first and assisted passive ROM was consecutively measured. The patients were therefore placed on a standard investigation couch in supine position to be able to properly explore the real ROM.

## 2.4. Results

In our study we could not find a significant correlation between the posterior tibial slope and the ROM of the knee joint after primary TKA. We discovered a slightly positive correlation of 0.196 between the active ROM and the posterior tibial slope 10 years after primary TKA without a statistically significant value.

### 2.4.1. Range of Motion

In this study we found an average value for the active ROM of 96.1° (SD 18.8). The minimal flexion we investigated was 30° compared to a maximal ROM of 125°, accomplished by the patients themselves in a supine position. Active ROM was first, in order to observe the patients´ own functional limits, without putting stress and pain on the joint.

By measuring the passive range of motion the observer administered the utmost flexion tolerated by the patients. The investigation was not carried out to excess in order to limit the patient's exposure to stress and pain. The examined values for the passive ROM were 101° (SD 19.4) on average with a minimum of 35° and an observed maximum of 135°.

### 2.4.2. Tibia Slope

By measuring every X-ray taken at the day of examination four times, we found an average value of the tibial slope of 7,65° (SD 4.23) in 83 investigated knees. This number is very close to the indicated 8° posterior tibial slope in *in-vitro* studies previously published and ideally chosen for the LCS – TKA system.(7) Maximum values reached up to 22° of posterior slope. In contrary -10° was the minimum slope measured, implying an actual 10° anterior slope.

| | mean-value | SD | # of items |
|---|---|---|---|
| Obserer11 | 8,12 | 4.318 | 83 |
| Observer12 | 7,61 | 4.406 | 83 |
| Observer21 | 7,35 | 4.215 | 83 |
| Observer22 | 7,42 | 4.147 | 83 |

Table 1 Average tibia slope by observer

We calculated the reliability of the executing observers with the inter- and intra-observer correlations. The results measured by hand on the imprinted X-rays showed a high correlation of over 0.8 each, when comparing the observers with each other. The comparison of the results by one and the same observer showed a similarly high correlation of over 0.8 each, respectively thus indicating a very reliable value of the tibial slope in all investigated patients.

| | Observer11 | Observer12 | Observer21 | Observer22 |
|---|---|---|---|---|
| Observer11 | 1 | 0.956 | 0.934 | 0.940 |
| Observer12 | 0.956 | 1 | 0.968 | 0.975 |
| Observer21 | 0.934 | 0.968 | 1 | 0.995 |
| Observer22 | 0.940 | 0.975 | 0.995 | 1 |

Table 2 Intra- and inter-observer correlations

| | Observer11 | Observer12 |
|---|---|---|
| Observer11 | 1 | 0.956 |
| Observer12 | 0.956 | 1 |

Table 3 Intra-observer correlations, observer 1

| | mean-value | minimum | maximum | range | min/max | variance | # of items |
|---|---|---|---|---|---|---|---|
| Item mean-value | 7.867 | 7.614 | 8.120 | 0.506 | 1.066 | 0.128 | 2 |
| Inter-item correlation | 0.956 | 0.956 | 0.956 | 0,000 | 1,000 | 0,000 | 2 |

Table 4 Exact intra-observer correlations, observer 1

| | Observer21 | Observer22 |
|---|---|---|
| Observer21 | 1 | 0.995 |
| Observer22 | 0.995 | 1 |

Table 5 Intra-observer correlations, observer 2

| | mean-value | minimum | maximum | range | min/max | variance | # of items |
|---|---|---|---|---|---|---|---|
| Item mean-value | 7.386 | 7.349 | 7.422 | 0.072 | 1.010 | 0.003 | 2 |
| Inter-item correlation | 0.995 | 0.995 | 0.995 | 0,000 | 1,000 | 0,000 | 2 |

Table 6 Exact intra-observer correlations, observer 2

| | Observer11 | Observer21 |
|---|---|---|
| Observer11 | 1 | 0.934 |
| Observer21 | 0.934 | 1 |

Table 7 Inter-observer correlations, first measurement

| | mean-value | minimum | maximum | range | min/max | variance | # of items |
|---|---|---|---|---|---|---|---|
| Item mean-value | 7.386 | 7.349 | 7.422 | 0.072 | 0.101 | 0.003 | 2 |
| Inter-item correlation | 0.995 | 0.995 | 0.995 | 0.000 | 1,000 | 0,000 | 2 |

Table 8 Exact inter-observer correlations, first measurement

| | Observer12 | Observer22 |
|---|---|---|
| Observer12 | 1 | 0.975 |
| Observer22 | 0.975 | 1 |

Table 9 Inter-observer correlations, second measurement

| | mean-value | minimum | maximum | range | min/max | variance | # of items |
|---|---|---|---|---|---|---|---|
| Item mean-value | 7.518 | 7.422 | 7.614 | 0.193 | 1.026 | 0.019 | 2 |
| Inter-item correlation | 0.975 | 0.975 | 0.975 | 0,000 | 1,000 | 0,000 | 2 |

Table 10 Exact inter-observer correlations, second measurement.

### 2.4.3.Correlation of the Tibial Slope and the Range of Motion

The analysis of the measured values indicates no correlation of the posterior tibial slope with the active ROM. The correlation value for active ROM and tibial slope was 0.196 with a p-value of 0,076 thus showing no significant connection between the implantation angle and the post-operative active ROM in our examined patients. Therefore the hypothesis of our study is not supported by the data we obtained. The tibial cutting angle does not contribute significantly to the important active ROM. The improvement of the cutting approach will not result in superior outcomes in terms of flexion in the long run. Patients with a steep tibial cutting angle do not enjoy greater ROM than patients with a rather flat implanted tibial plateau.

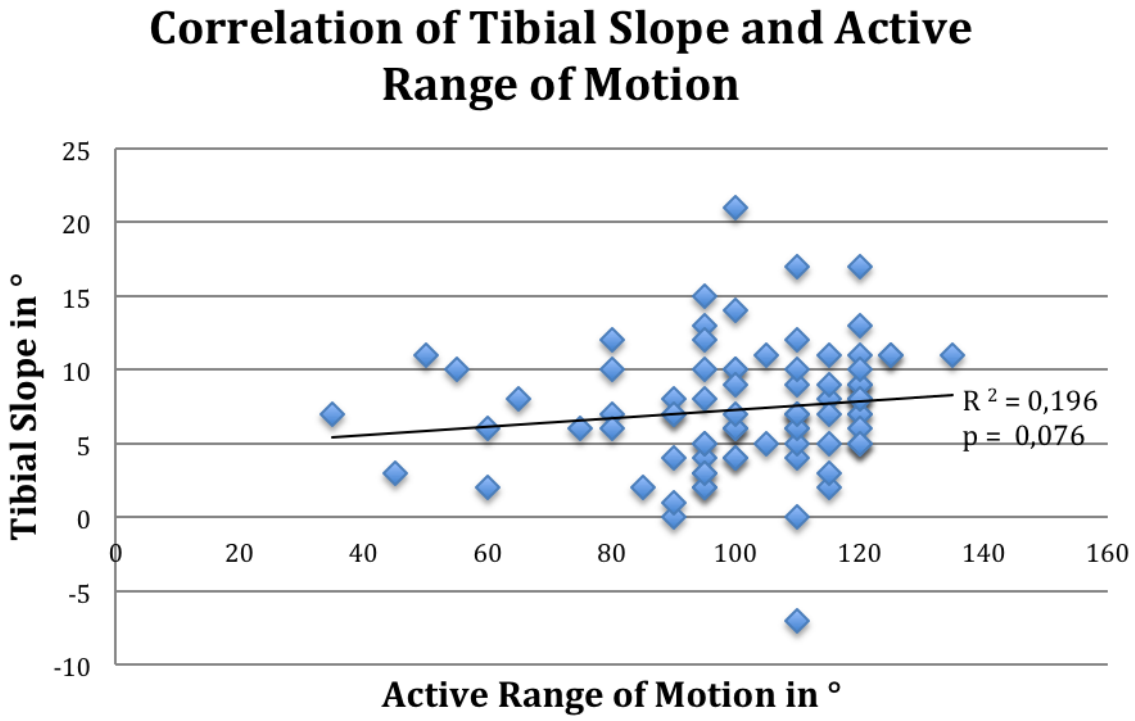


Fig. 14 Correlation of the tibial slope and active ROM in 83 knees with a minimum follow-up of 10-years after primary TKA.

Similar results were obtained when comparing the passive ROM and the tibial slope. In this analysis the correlation coefficient was 0,152 respectively. A rather positive correlation, but not strong enough to support the hypothesis of the tibial cutting angle being responsible for a greater ROM 10 years after the primary TKA.

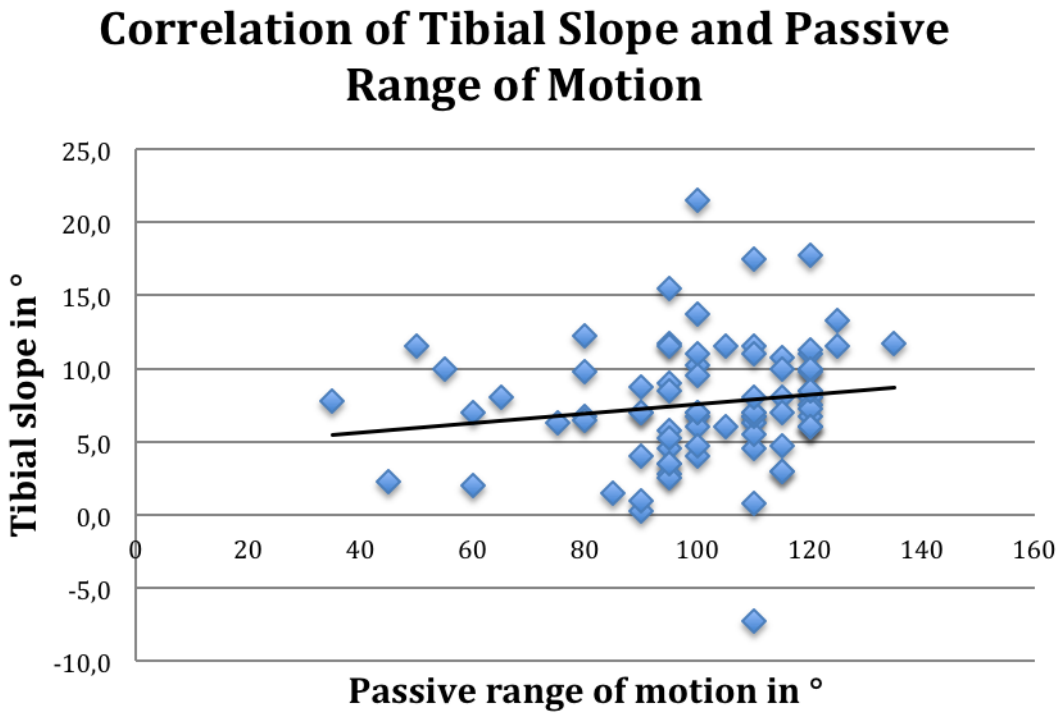


Fig. 15 Correlation of the tibial slope and passive ROM in 83 knees with a minimum follow-up of 10-years after primary TKA.

When comparing the KSS function and KSS pain with the tibial slope no correlation can be detected. Correlations are 0,053 and 0,097 respectively.

## 2.5. Discussion

The aim of the study was to analyze a possible correlation of the tibial slope with range of motion after TKA. The hypothesis was, that a steeper tibial slope would lead to increased ROM after a minimum follow-up of 10 years. We found, that the tibial slope did not correlate with the ROM and believe that the slope is a system immanent factor, which should only be slightly altered in TKA.

There is no evidence so far that changing the tibial slope during surgery has any significant influence on the postoperative ROM in the long run. An altered angle does not significantly influence the ROM or KSS, as shown by Seo et al.. The focus of the study by Seo et al. was on the absolute change of the tibial angle from the pre-operative physiological to the definite cutting angle for the implantation of the prosthesis.(66)

In our study we investigated the absolute posterior tibial slope 10 years after surgery and compared it to the active and passive ROM thus providing a different perspective on the discussed topic. Although the physiological process of motion clearly benefits from an increase in posterior slope, the operated knee does not gain any significant benefit out of a steeper cutting angle. Apparently PCL-retaining knees do not demonstrate normal knee kinematics anymore and the tibial slope is of less importance for the active ROM. As postoperative ROM depends on many variables the tibial slope cannot be the only factor held responsible for satisfying surgical results.

The patient's average age at the time of examination was 76 years, this might be considered a limitation of this study. Agility of the elder patient is naturally limited by age and therefore the ROM of an operated knee strongly depends on the patients' overall health and physical status. By defining the tibial slope as the single responsible variable for postoperative ROM many important influencing factors for mobility have to be ignored. Nonetheless a slightly positive correlation can be detected and the cutting angle does slightly influence the outcome of a primary TKA with regard to the ROM, but not with regard to KSS function and KSS pain.

Bellemans et al. report 1.7° gain in flexion for every degree of additional posterior tibial slope.(64) This approach is clinically limited as an excessive tibia cut might lead to implant loosening in the long run. In case of a very steep implantation of the tibia plateau subsequent sinking of the prosthesis can be observed. By conducting revision surgery this situation can be solved to ease the patient's pain and inability to fully extend the knee. Thus pursuing excessive tibial cuts is clinically limited by the knee's kinematics and the prosthesis design to support this implantation mode. As our findings do not support the hypothesis of a gain of flexion by applying steeper tibia cuts, avoiding excessive posterior tibial slopes can diminish the risk of loosening of the prosthesis. Figures 13 to 15 indicate a too step tibial slope (greater than 15°) resulting in early aseptic loosening of the tibial plateau.

Fig. 16a Excessive tibial cut after primary implantation of the press fit condylar total knee arthroplasty

Fig. 16b Consecutive aseptic prosthesis loosening due to an excessive tibial slope

Fig. 16c Lateral X-ray, 5 years after primary implantation of the revision surgery

## 2.6. Conclusion

This study shows a non-significant slightly positive correlation of the tibial slope with the postoperative ROM ($R^2 = 0.196$, $p = 0076$). By cutting the tibia plateau in a steeper angle only slightly more flexion can be obtained. We conclude that the tibial slope is not the primary influencing factor for the absolute postoperative ROM in patients 10 years after primary TKA. Overall health and physical status also play a major role in agility and flexion in this group of patients with an average age of 76 years at the time of examination.

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# 4. Appendix

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| **seit 10/2008** | Medizinische Universität Graz - Humanmedizin |
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| **02/2004 – 02/2005** | Zivildienst Rotes Kreuz Ried - Rettungssanitäter |
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## Medizinische Erfahrungen

| | |
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| **07/2012** | Medizinische Summer School - KH Ried i.I. |
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| | |
|---|---|
| **seit 10/2009** | Ausbildung zum Shiatsupraktiker an der Internationalen Shiatsuschule Österreich, Level IV von V abgeschlossen |
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| Ausbildungen | Rettungssanitäter, Einsatzlenker und Praxisanleiter |
| **Famulaturen** | Innere Medizin – KH Ried i. I. – 4 Wochen<br>Orthopädie – KH Ried i. I. – 4 Wochen<br>Anästhesie und Intensivmedizin – KH Ried i. I. – 2 Wochen<br>Kinderorthopädie – Helios Emil von Behring Berlin– 2 Wochen<br>Unfallchirurgie – UKH Graz – 4 Wochen |

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| **Auslandserfahrung** | **02/2007-06/2007** – **LUMS** Lahore University of Management Sciences- Pakistan – Auslandssemester |
| Kurse | Psychologie, Biologie, Pakistan Studies, Islamic Banking |
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| Tätigkeiten | Freiwilliger Mitarbeiter im Hygieneprogramm und der mobilen Klinik |
| | **07/2006-08/2007 - EXFO –** Quebec, Kanada |
| Tätigkeiten | Kundenservice, Angebotserstellung und Auftragsbearbeitung |
| | **07/2005-08/2005** – **ARGUSnet** – Luzern, Schweiz |
| Tätigkeiten | Softwareüberprüfung, Homepagedesign |
| | **04/2004 -Kauri Cliffs** – **Golfclub** – Neuseeland – |
| Tätigkeiten | Greenkeeper |
| **Sprachkenntnisse** | Deutsch - Muttersprache<br>Englisch – fließend in Wort und Schrift<br>Französisch – Fortgeschrittener Level<br>Spanisch – Basic Level |
| **Hobbies** | Karate, Ginastica Natural, Jogging, Schwimmen, Langlauf, Skifahren, Skitouren, Surfen, Klettern, Reisen, |