Influence of cement on the amount of blood transfusions in patients with primary total knee endoprosthesis

Submitted by Ewald Musser
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Diplomarbeit

Influence of cement on the amount of blood transfusions in patients with primary total knee endoprosthesis

Einfluss von Zement auf die Menge von Bluttransfusionen bei PatientInnen mit primärer Knietotalendoprothese

eingereicht von

Ewald Musser

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unter der Anleitung von

Dr. med. univ. Patrick Sadoghi

OA Dr. med. univ. Norbert Kastner

Ort, Datum …….. (Unterschrift)

Eidesstattliche Erklärung

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Graz, am …….. *……..*

Unterschrift

Preface

In 2011, I got the authorization to start my scientific project at the orthopaedic department at the Medical University of Graz. Because I was always interested in the musculoskeletal system, I decided to collect my first scientific experience in this fascinating and broad field of orthopaedic surgery. Basic knowledge about the functional anatomy of the joints led me to the admirable knee joint.

The knee joint is exposed to enormous forces, so that we can carry out our usual duties. However, which treatment options are available if the knee joint is worn out naturally or injured by trauma, so that pain makes the quality of life intolerable?

When all conservative treatment options are exhausted, a total knee arthroplasty comes into consideration.

The implantation of an artificial knee joint represents a major medical development, so that people can perform their work without pain, and even sports can be executed again.

Therefore, I wanted to delve into this topic scientifically by performing a retrospective data analysis. In my opinion, it is important to get an insight into scientific working, how clinical studies are made, to be able to practice good and current medicine.

I divided my work into a general and a specific part. The general part gives an insight, what belongs to the implantation of a total knee endoprosthesis. Indications, complications, which types of prosthetic components are used and which surgery techniques are performed, are described in the thesis. Specifically, the blood management is described. The special part includes the data analysis of 200 patients who received a total knee endoprosthesis in a correlation analysis of cementation technique with blood loss.

Acknowledgements

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Abstract

English

Background

The implementation of total knee endoprosthesis is a major surgical procedure, in which especially the blood management is an important topic among many other complications, which might arise. The blood management should begin timely before the surgery to determine current blood conditions, because sliced bones can lead to severe intra- and postoperative blood loss, which have to be compensated quickly by blood transfusions.

Patients and Methods

The study is a retrospective correlation analysis of 200 reviewed patients between 1996 and 2011 of the orthopaedic department who underwent primary total knee arthroplasty. The patients were divided into three main groups, the total cemented group, the non-cemented treatment group, and the hybrid treatment group. We recorded demographically the blood loss by using the bellovac system, the retransfused blood volume, and how many erythrocyte concentrates were administered to the patients in the three different cementing treatment groups.

Results

In our correlation analysis, we found a significant positive correlation with cementing of the tibial plateau and less blood loss without a correlation with retransfusions. We found no correlation with respect to cementation of the femoral shield.

Conclusion

The analysis shows, that cementing the tibial plateau significantly negatively influences the amount of postoperative erythrocyte concentrates after implantation of TKA.

German

Hintergrund

Beim Einbau einer Knietotalendoprothese handelt es sich um einen großen chirurgischen Eingriff, bei welchem speziell das Blutmanagement unter anderen möglichen Komplikationen von großer Bedeutung ist. Das Blutmanagement sollte rechtzeitig vor dem Eingriff stattfinden, um den aktuellen Blutzustand zu ermitteln, denn aufgeschnittene Knochen können intra- und postoperativ zu erheblichen Blutverlust führen.

Methodik

Die Studie ist eine retrospektive Korrelationsanalyse bestehend aus 200 bewerteten PatientInnen, welche sich zwischen 1996 und 2011 an der orthopädischen Abteilung einem Einbau einer primären Knietotalendoprothese unterzogen haben. Die PatientInnen wurden in drei Hauptgruppen eingeteilt, die totalzementierte Gruppe, die nicht zementierte Gruppe und die Hybrid Gruppe. Wir verzeichneten demographisch den Blutverlust mittels Bellovc Systems, das retransfundierte Volumen und wie viele Erythrozytenkonzentrate den PatientInnen in den drei Behandlungsgruppen verabreicht wurden.

Ergebnisse

In unserer Korrelationsanalyse fanden wir eine signifikant positive Korrelation mit zementiertem Tibiaplateau und weniger Blutverlust, ohne Korrelation mit Retransfusionen. Wir fanden keinen Zusammenhang in Bezug auf die Zementierung des Femurshieldes.

Schlussfolgerung

Die Analyse zeigt, dass ein zementiertes Tibiaplateau die Menge an postoperativ verabreichten Erythrozytenkonzentraten nach Implantation einer TKA signifikant negativ beeinflusst.

Contents

Glossary and Abbreviations

aPTT	Activated partial thromboplastin time
ASA	American Society of Anaesthesiologists
BMI	Body mass index
CRP	C-reactive Protein
CT	Computer Tomography
DVT	Deep Vein Thrombosis
e.g.	for example (exempli gratia)
GFR	Glomerular Filtration Rate
Hb	Haemoglobin
INR	International Normalized Ratio
Lig.	Ligamentum
LMWH	Low Molecular Weight Heparins
MRT	Magnetic Resonance Tomography
NSAIDs	Non Steroidal Anti-Inflammatory Drugs
PDA	Peridural Anaesthesia
PT	Prothrombin Time
RBC	Red Blood Cells
ROM	Range of Motion
SYSADOA	Symptomatic Acting Drugs in Osteoarthritis
TKA	Total Knee Arthroplasty

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General part

1 Introduction

The knee is a special, complex and fantastic joint in the human body. There are many interesting facts about this joint, so that many extensive books can be written. The general part of this thesis gives an overview of important basics of the knee joint and of the implantation of primary total knee prosthesis. In addition to the anatomy, the function of the joint and the indications of the surgery are described. Furthermore, the contraindications, the possible complications and the perioperative management, including the blood management, are explained. In this general part, the prosthetic components and how they can be implanted for a stable fixation are further described.

2 Anatomy and Biomechanics of the Knee

The knee joint is mainly composed of three bones, the femur, the tibia, the patella, and indirectly the fibula. The fibula is connected without any articular surfaces to the femur, just by ligaments. The fibula is attached to the tibia by the tibiofibular joint, so that the knee joint itself is formed by two cartilaginous articular surfaces: the tibiofemoral joint and femoropatellar joint, respectively. [1]

2.1 Development

The femur and tibia start their ossification approximately from the seventh intrauterine week, while the fibula begins one week later. The patella, also called knee cap, starts its ossification from the fourteenth intrauterine week. Once the cartilage model has developed from the mesoderm, the ossification begins. By means of endochondral ossification, the diaphyses are formed by a bony nucleus, so that they are at birth usually completely ossified. After birth, the epihyses also begin to ossify over a bony center, in which a cartilaginous gap remains for length-growth. The epiphyseal plate closes at the age of 18 for boys and 15 for girls, $\pm$ 2 years.[2,3]

2.2 Stabilisation

Ligaments and muscles are responsible for the necessary stabilization of the knee, which are further described below.

2.2.1 Ligaments

The stabilisation of the joint is ensured by seven considerable ligaments, among other smaller ligaments with four main ligaments (the anterior and posterior cruciate ligaments for antero-posterior stabilisation and the medial and lateral collateral ligaments for stabilitsation in varus and valgus stress). Table one, on the next page, gives an overview of the major ligaments of the knee. These ligaments restrain sliding of the bones to medial, lateral, ventral, dorsal, internal rotation and external rotation, as well as hyperextension. [1]

Ligaments	Functions
Lig. collaterale tibiale	for medial stabilisation
Lig. collaterale fibulare	for lateral stabilisation and inhibition of hyperextension
Lig. cruciatum anterius	postero-lateral part: restrains extension antero-medial part: restrains extension and it restrains internal rotation
Lig. cruciatum posterius	restrains flexion and some fibers external rotation
Lig. popliteum obliquum	for medial stabilisation and inhibition of hyperextension
Lig. popliteum arcuatum	stabilize the dorsal joint
Lig. patellae	for power transmission in the ventral part between patella and tibia and stabilisation

Table 1: The knees big ligaments and their functions; Source: [1]

Figure 1 and 2 shows the bony structures of the knee together with its ligaments. In figure 1 the patella, which would be ventral of the articulation is not pictured.

Figure 1: Right knee from ventral, without patella; Source: [1]

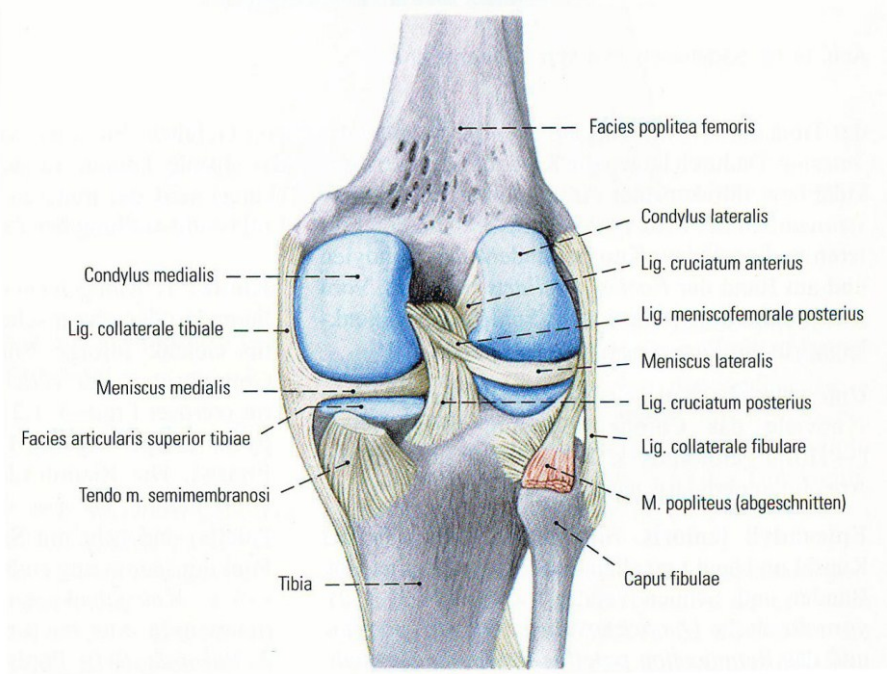

Figure 2: Right knee from dorsal; Source: [1]

2.2.2 Muscles

Ligaments as well as muscles are the stabilizers of the knee joint. They are divided into flexors, extensors, and are developed in different layers, so that they perform the complex movements of this unique joint. Most of the muscles cause movements in two joints. For example, the M. gracilis rises from ramus inferior ossis pubis and ends in the pes anserinus superficialis at the tuberositas tibia and fascia cruris. This muscle adducts/flexes 40° in hip joint and flexures/rotates medial in the knee. [1,2]

Table 2 (on the next page) gives an overview of muscles, their function, their neural innervation and their vascular blood supply.

Function	Muscle	Innervation	Blood supply
Flexors	M. gastrocnemius	N. tibialis (S2-S2)	A. poplitea, A. tibialis posterior, A. peronea
	M. plantaris	N. tibialis (S2-S2)	A. poplitea, A. tibialis posterior
Extensors	M. quadriceps femoris	N. femoris (L2-L4)	A. circumflexa femoris lateralis and Rr. perforantes of A. profunda femoris
Internal - Rotators ***(plus Flexion)***	M. popliteus	N. tibialis (L5-S1/2)	A. poplitea
	M. gracilis	N. obturatorius (L1-L2)	A. obturatoria
	M. sartorius	N. femoris (L2-L3)	A. femoralis
	M. semitendinosus	N. tibialis (L5-S1/2)	Aa. Perforantes of A. profunda femoris
	M. semimembranosus	N. tibialis (L5-S2)	Aa. Perforantes of A. profunda femoris
External - Rotators ***(plus Extension)***	M. biceps femoris	caput longum: N. tibialis (L5-S1/2) caput breve: N. fibularis communis (S1-S2)	A. circumflexa femoris medialis, Rr perforantes of A. profunda femoris, A. poplitea

Table 2: Muscles of knee-joint; Source: [1]

The next two pictures illustrate the muscles of the knee joint. Figure 1 is viewed from medial and figure 2 from lateral.

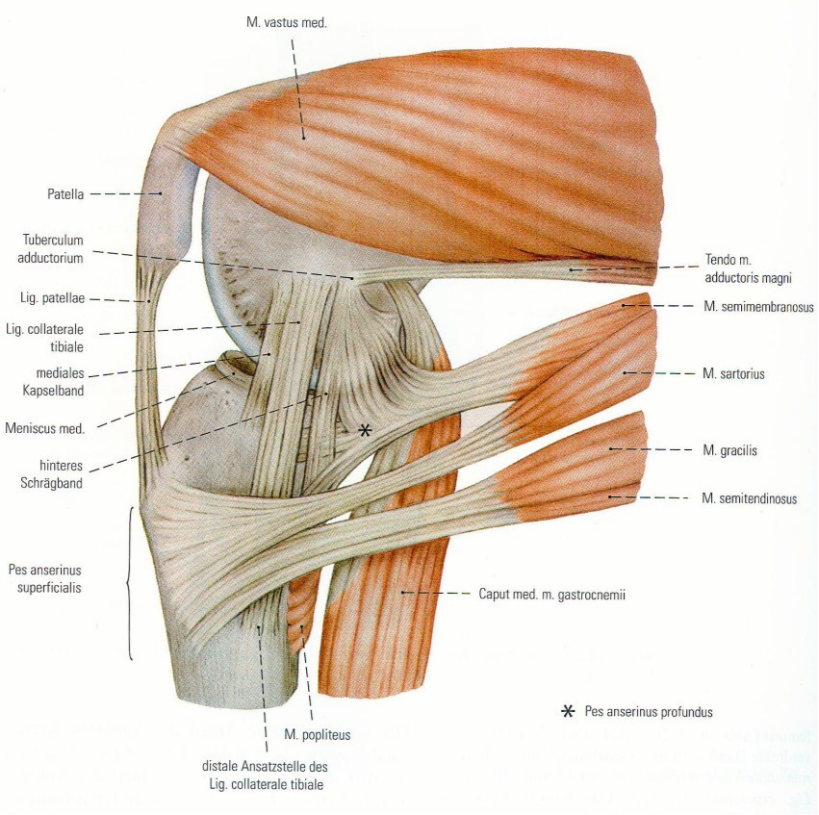

Figure 3: Right knee from medial; Source: [1]

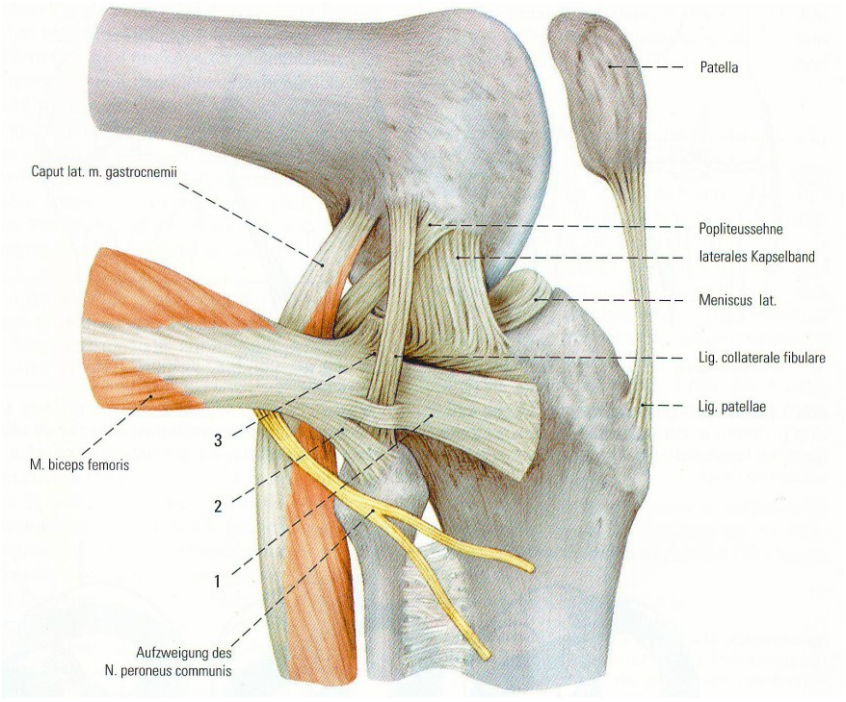

Figure 4: Right knee from lateral; Source: [1]

2.3 Function

2.3.1 Joint Cavity and Bursa

The joint capsule consists of two layers. The stratum synovialis is below stratum fibrosum and forms the wall of the joint cavity. This cavity is formed by the joint surfaces of femur, tibia and patella, and further by bags, called bursa or recessus. To ensure a good motion of the joint, a synovial membrane, the stratum synovialis, surrounds the articular surfaces. It originates immediately adjacent to the cartilaginous joint surfaces and forms a closed cavity. [1,2]

The membrane contains many blood capillaries and nerve fibres, produces the synovia for good lubricating properties of the articular surfaces, and has good properties of absorbability. [4]

Table 3 illustrates the bursae of the knee joint, their location around the joint, and whether they communicate with the joint cavity.

With contact to joint cavity	
Bursa suprapatellaris	Between Tendo m. quadricipitis femoris and femur.
Recessus subpopliteus	Between condylus lateralis femoris and Tendo musculi poplitei.
Bursa anserina	Under the Pes anserinus profundus.
Bursa subtendinea m. gastrocnemii medialis	Under the origin of the muscle.
No contact to joint cavity	
Bursae prepatellares (subcutanea, subfascialis)	For mobility between skin and patella. In front of patella.
Bursa infrapatellaris profunda	Between Tuberositas tibiae and Ligamentum patellae

Table 3: Bursae of knee joint and their location; Source: [1,2]

2.4 Axis and Range of Motion

The knee is a big ginglymus joint with two menisci (lateral/medial) between the articulating surfaces of femur and tibia, which is formed by condylus lateralis/medialis femoris and condylus lateralis/medialis tibialis. Anteriorly both condyli are more curved than in the middle part, and posteriorly they are again more curved. Generally, the surface of lateral femoral condyle is smaller, more curved and more flattened in the anterior area, than the medial condyle. The menisci are curved like a half moon, and its diameter is similar to a triangular shape, and they form a kind of joint socket, in which the lateral meniscus is rounder than the medial, in transverse plane, thus a good congruent connection is given. Both menisci are on the lateral and medial articular surface of tibia fixed by ligaments. [1,2,5]

The joint moves in transverse axis by flexion/extension and in longitudinal axis by internal/external rotation. During the movement, the axes are not fixed like in a ball joint, hinge joint or wheel joint, so that in extension the transversal axis shifts upwards and anteriorly, while in flexion it moves posteriorly and distally. [2]

In the flexed posture, the knee reaches up to 120-150 degrees, and an extension of 5-10 degrees. Furthermore, in flexion there are 40° of medial rotation and 10° of lateral rotation possible. [1] During the last degrees of extension, the femur even rotates inward. [2]

By the neutral-zero method the motion range is described and examined by a goniometer. First number describes the extension, the middle is the neutral position and the last is the flexion. E.g. for free motion: 5/0/130, and for extensor deficit of 20°, 0/15/130. [6]

The leg axis reaches from the middle of caput femoris, further through a point lateral of eminentia intercondylaris and down to the middle of the upper ankle joint. A shift of this axis to medial is called genu varus, and a lateral transfer is described as genu valgus. [6]

Further, a displacement of the sagital axis (genu flexus/genu recurvatum) can cause serious knee problems, like most axis dislocations. Normally the knee has a dorsal slope of 3-7°. [1,7]

3 Indications for a Knee Arthroplasty

Any kind of intervention on the humans body is not completely harmless, so that many and even fatal complications and side effects might arise. To keep the risk of possible complications as low as possible, it is very important to know whether the procedure is indicated or whether it would make more sense to postpone the surgery.

First, the main reason to undergo total knee arthroplasty is pain as part of degenerative knee joint disease, which results due to natural wear or because of injuries. Excruciating pain, which occur during the day, at night, during activities and even in rest is one indication for surgery. Further indications are limited walking distance, excessive attempts of conservative treatment without improvement over a 6 months lasting period. If the patients cannot longer keep daily activities, the quality of life is reduced and the pain cannot be treated differently, it is advisable to get a “new” knee. [8-10]

Mainly arthritic diseases are responsible for pain, called osteoarthritis or degenerative joint disease. Osteoarthritis is based on cartilage damage, because of traumas and/or rheumatoid inflammations of the hinge, which in the course of time has developed. When the cartilage of articular surfaces has worn down and has narrowed, it may come to very painful bone frictions. The most common types of arthritis include osteoarthritis, rheumatoid arthritis, with inflammatory processes, and posttraumatic arthritis. [10-13]

In addition, significant deformities are an indication for a total knee arthroplasty in case of impossible osteotomies. This includes mainly axis deviation like varus or valgus deformity of the knee joint. Because there are also other options for treatment of deformities, it is important to explore precise facts for the indication of

a knee replacement. Only when the radiological findings, like narrowing of joint space and the patients' symptoms are in connection, a surgery is justified. [9]

Radiological signs of osteoarthritis of the knee joint are narrowing of the joint space, osteophytes, subchondral cysts, and subchondral sclerosis. For a good and healing treatment, it is important to collect and to combine different findings from the patient. Therefore, tools were developed, for example score systems that facilitate the decision to perform knee surgery. There are points awarded for various decisive findings, like pain, the function of the knee, and the joint's damage, to optimize decisions. [14]

Generally, older patients are preferred to undergo total knee replacement than younger patients, with regard to the outcome, because young patients (under sixty years) have a higher life expectancy and higher risk of revision surgery. The main age for patients undergoing total knee arthroplasty is 70 years. Due to the longer residence time of the prosthesis in the body, more complications can occur, which leads to risky revision surgeries in the younger patient. Nevertheless especially young and active patients with chronic inflammatory polyarthritis could benefit very well from surgery after excessive conservative treatment. [10,15]

Finally, it is the decision of the patient, whether a knee surgery is performed, and therefore it's essential to elucidate the patient about the disease, the process of surgery and possible complications, which can develop intra- and postoperatively.

Because the indications cannot be located exactly in stages, the surgeon must assess and lead the situation. The surgeon is therefore responsible for the management, not for the decision, so that he has to make the benefit-risk assessment, also concerning the comorbidity of the patient. Only if all conservatives are optimized and non-operative treatments were excessively used, the knee prosthesis can be taken into account. It should be noted that the patient would decide on basis of his/her condition, and not just an abnormal X-ray. [10]

4 Contraindications

In order to practice good medicine, it is necessary in addition to therapy success and side effects, to discuss possible contraindications. Finally, the suffering of patients should be cured, and new diseases should not be caused. That is why it is important to decide in advance, whether an operation can be performed effectively, and whether the outcome can be kept correct. To think about a benefit to risk profile is as important as with any major surgery. Of course, there always might be complications, which must be avoided at all costs, but they should not arise because of contraindications. If so, surgery has to be rejected at an early stage.

Contraindications have to be taken into account already in the anamnesis. They are divided into two groups, the absolute and relative contraindications. If there are absolute contraindications, the knee replacement has to be denied. Relative contraindications may be influenced before the total knee arthroplasty is performed. Therefore, it is important to collect detailed findings to enable an adequate treatment.

4.1 Absolute Contraindications

4.1.1 Active Sepsis

In case of active sepsis, whether locally in the knee joint or systemic, concerning the whole body, surgery not may be performed, because various infections have a too high risk for failures. With the implantation of total knee prostheses, there would be further deep infections, which would be difficult or even impossible to treat with medication. The body would not tolerate foreign materials and may lead to more inflammation and even to rejection reactions, sepsis and death. Recurrent infections of the joint also deteriorate the outcome of a total knee arthroplasty. [9,10]

In order to rule out infections, a blood test is necessary. If ambiguous cases occur, antibiotic-coated prostheses and adequate perioperative antibiotics are used. [9,10]

4.1.2 Extensor Mechanism Dysfunction

In addition, extensor mechanism dysfunctions are evaluated as an absolute contraindication. The extensor muscles of the knee have an important function. Because the extensors contribute a large part to the stability of the knee joint, dysfunction leads to massive instability, which persists even after the implantation of a total knee arthroplasty. [9,10]

4.1.3 Peripheral Vascular Diseases

Peripheral vascular diseases constitute a high risk for complications. In order to achieve good recovery after the implantation a sufficient blood supply of the operational area is essential. Thus, the surgeon must ensure good blood flow of the patient's knee, which is determined by the ankle brachial index. From values below 0.9, the vascular disease should be treated first, and the knee replacement should be postponed initially. Poor blood circulation can cause impaired wound healing, which makes healing impossible and can lead to amputations in the worst case. Above all, surgeons should be particularly attentive to patients with risk factors of peripheral arterial disease, such as diabetes mellitus, smoking-anamnesis, hyperlipidaemia or hypertension. [9,10,16]

4.1.4 Arthrodesis

If the patient has a well-functioning arthrodesis, an implantation of knee prosthesis is discouraged, because the knee has not the necessary stability and may lead to increased incidence of complications. In addition, the soft tissue will not allow further movement, even after implantation of an adequate total knee arthroplasty. [10,17]

4.2 Relative Contraindications

If relative contraindications exist, the surgery can only be carried out if there is a clearly higher benefit than a risk. [18]

The suitability of anaesthesia is one of relative contraindications. The anaesthetist must consider whether the patient is at all suitable for a surgery, by examining the

patient’s vital functions and finding out if the patient takes medication, which could be a risk for the perioperative course. [6,9]

Furthermore, poor skin texture in the area of incision, which can not be rehabilitated after the surgery, recurrent osteomyelitis in the knee area, specific anatomical abnormalities, obesity and neuropathic arthropathy could also cause problems, so that they belong to the relative contraindications. [9,10,19-22]

For a good ingrowth of the prosthetic parts into the bone, a good bone quality is required. Therefore, patients with rheumatoid arthritis or osteoporosis especially around the knee area might face problems of bony ingrowth of the prosthesis. Therefore, there is an increased risk of loosening, so that the stability of uncemented components suffers and the parts cannot ingrow adequately. [23]

5 Alternatives to Total Knee Arthroplasty and Prophylaxis

Nowadays there is a range of therapies to treat an osteoarthritic knee joint. For the different diseases, there are various treatment options, so that there are also clear indications for total knee arthroplasty in degenerative knee joints, like end-stage osteoarthritis. Because arthritis is a progressive disease, doctors and patients should think about possible therapies in earlier stages to slow down or even to stop the progression of the disease.

Only when all conservative treatment options are optimized, surgery may be considered. Nevertheless, if there are anyway failures of these non-surgical options and the suffering of patients cannot be treated, the doctor has still to examine whether there are further alternative options. [22]

5.1 Conservative Alternatives

Although there are no treatments to stop or prevent cartilage degeneration, however, the symptoms of painful knee joint disease can be treated. Patients should obtain pain freedom and get available treatments, which can delay the progression of the disease at least. [22] This may be achieved using non-steroidal anti-inflammatory drugs or intraarcticular infiltrations. Furthermore, physiotherapies to strengthen the extensor and flexor muscles, avoidance of high impact sports such as tennis, squash, or volleyball, life style adjustment such as, swimming and cycling in combination with healthy diet and loss of overall body weight.

5.1.1 Physiotherapy

Especially in early stages of cartilage changes of the articular surfaces, it is important to be physically active. By physiotherapy, muscles and ligaments of the knee joint, the whole lower limb respectively, can be trained and strengthened. This increases the stability and serves to better coordinate the complex movements of the joint. In addition, pain can be treated by exercise training and the function of the joint may therefore stay maintained. [22,24]

5.1.2 Technical Orthopaedic Support

A walking cane on the opposite side or two crutches can also be used to treat pain. They provide relief in the knee joint. [22]
Hard shoe inserts are questioning critical in valgus and varus deformities, because they can cause stress in other joints, although on the other hand deposits with an absorbing property would be suitable. [22]
Orthotics and knee braces are used for ligamentous instability of the joint. [22]

5.1.3 Physical Therapy

Cryotherapy and electrotherapy with medium frequency and diadynamic alternating currents are used in osteoarthritis and may reduce pain. [22]

5.1.4 Drug Therapy

In the foreground, there is the therapy of pain. Analgesics such as paracetamol are often used and can be administered orally. NSAIDs act anti-inflammatory, analgesic, antipyretic, and are specifically used for inflammation with effusion. However, they can cause severe side effects that affect the gastrointestinal tract, among others.

By the aid of ultrasonic treatment, the transport of externally applied ointments or gels into the joint cavity can be improved. The next level of pain therapy, the group of opioids, could also be administered in tablets or in patch form. In severe degenerative joint changes, intra-articular corticosteroids are available. SYSADOA are still being tested in trials. Hyaluronic acid, glucosamine, and chondroitin sulfate should have also positive effects on the cartilage formation. [22,25]

5.1.5 Surgical Alternatives

Total knee prostheses are not implanted in all cases of degenerative joint changes. It depends mainly on the local situation of the knee joint surface what type of surgery is indicated, and which prosthesis can be used.

Various joint destructions have their own form of therapy, which are explained in the following.

For patients with varus deformity of the knee joint, there is the possibility of a proximal tibial valgus osteotomy, and those with valgus deformity may undergo a distal femoral varus osteotomy. These patients have only one morbid compartment, so that the target of the procedure is to restore the normal mechanical axes of the knee joint. This type of bone correction is preferred in young and active patients, because of the lower durability of a TKA. Most young patients have good bone quality, which is needed for a better bone healing. [9,22]

Unicompartmental knee prostheses are implanted if only one compartment is affected. [26,27]

In gonarthrosis with extremely incompetent ligament situations, insufficient extensor mechanism or rotational misalignments between the femur and tibia special axle-driven prostheses can be incorporated.[9,22]

Patients with uncontrollable and chronically sepsis or muscle paralysis like deficient extensor mechanisms get nowadays only rarely an arthrodesis. [9,22]

To perform an arthroscopic debridement should be reserved for only well-selected patients, who have a mild degenerative joint disease. Studies show that an arthroscopic debridement has no particular benefit in the therapy of osteoarthritis. The progression of the disease cannot be prevented, but anyway, pain can be alleviated in case of catching and locking. [28,29]

There are separate procedures to repair the cartilage, such as the abrasion arthroplasty, subchondral drilling, microfracturation, or implantation of autologous cultured chondrocytes. [22]

5.2 Prophylaxis - Preventing a Total Knee Prosthesis

An important aspect of the preventive approach is to do everything possible to load the joint adequately. Excessive exposure at work or during sports activities have to be kept low, but sports in general should not be ignored, because muscles stabilize the joint. Obese people achieve by reduction in weight a discharge in the knee joint, among many other benefits of weight loss. Various misalignments can lead to abrasions of the articular surfaces by unfavourable postures, therefore it should be considered to correct the axis with orthopaedic devices timely, to prevent one-sided incorrect loads. [22,30]

6 Preparing for Surgery

6.1 Preoperative Examination

To minimize the risk of possible side effects and complications, as well as to exclude contraindications, some examinations should be conducted before surgery. It must be ensured that the patient will be healthy again and will be free of pain after a total knee arthroplasty, by putting safeguards already preoperatively. Because these surgeries are more common in older patients, the doctor has to pay attention to comorbidities especially. Therefore, the surgeon makes the examinations and orders all further necessary preoperative investigations.

Internists respectively anaesthesiologists should early clarify comorbidities, such as cardiovascular disorders, pulmonary dysfunction, deficits of renal function and/or blood circulation problems. [9]

In addition to physical examination and laboratory tests, there are imaging techniques like X-ray, MRI and CT still available. Before the patients get tranquilizer, they have to confirm the consent of the pending surgery, after the procedure was explained in detail. Specifically possible complications and side effects that will arise due to the operation should be discussed.

6.1.1 Physical Examination

At the beginning of the studies, the anamnesis of the patient's symptoms is in the foreground. The age, the social status, weight, medical history, pain location, and the duration of pain and its intensity should be obtained in the examination. During the subsequent inspection of the anatomical axes, each leg should be viewed in the frontal plane and sagittal plane in relation to each side, and the gait should be assessed. This is to determine whether the patient has a normal straight leg, a genu varum, a genu valgum, a genu recurvatum, or there is an extensor deficit. Then the doctor examines whether scars, wounds, swelling, redness, and/or muscle atrophy are seen. This is followed by palpation, which examines whether there are joint effusions, warmings, crepitations, or pressure pains. In addition, the movement, the circulation and the sensibility of the leg should also be checked.

Subsequently functional tests are performed. Using the goniometer, the degrees of motion are measured as the neutral-zero method (see above). In order to identify extensor deficits, the position of patella, the course of patella, and the extensor functions are examined. The so called “Zohlen” – sign is used to evaluate retropatellar osteoarthritis. The collateral ligaments are investigated by varus- and valgus stress tests, and the cruciate ligaments are examined, among others, by “Lachman’s” test or “Pivot-Shift” test. For examination of the menisci, there are different tests such as “Steinmann’s” test, “McMurray’s” test, the “Apley’s” test and the “Payr”-sign. [31-33]

6.1.2 Laboratory Tests

Blood tests determine the current patient’s haemostatic status by analysing the complete blood count, the erythrocyte sedimentation rate, and the serum electrolytes. The coagulation status is checked by INR, aPTT or PT. Furthermore, the renal function is examined by GFR and creatinine clearance, and a urinalysis is indicated to exclude urinary tract infections. If there is any suspicion of inflammatory processes in the knee joint, the synovial liquid also should be tested for bacterial colonisation. [34]

Because there is a significant blood loss up to 1.5 l intra- and postoperative [35], the blood group should be identified timely and stored blood for transfusion should be ordered, respectively kept ready for donation. [9] Preoperative laboratory tests evaluate the inflammatory status, the haemostatic status and the haemoglobin level.

6.1.3 Imaging

6.1.3.1 X-ray

For the diagnosis of degenerative joint disease, the X-ray is of great relevance primarily, so that the pictures of knee joint are recorded with the a.p.-, side- and tangential ray path. Tangential views of the patellofemoral joint are done in 45 ° flexed knee joints to detect arthritic changes in the lateral and/or medial compartment. Additionally the “Rosenberg’s” p.a.-record can be carried out to assess lost of join space. [33,36]

To evaluate the X-ray images, pathological changes in knee joint can be diagnosed as single feature or they can be classified with the help of total-scores, for example the “Kellgren-Lawrence” classification. [33] Specifically joint space reductions, subchondral sclerosis, osteophytes, or cysts are focused. On the X-ray of the healthy knee as shown in figure 5, the joint space between femur and tibia can be identified clearly. The cartilaginous joint surfaces are not illustrated on the X-ray, so that the joint gap seems to be wide, because the bones are not directly adherent. Therefore, the joint space narrows because of the degenerated cartilaginous surfaces. In Figure 6 is illustrated how close the bony structures are already together. [22,33,37]

Figure 5: X-ray of a normal right knee.

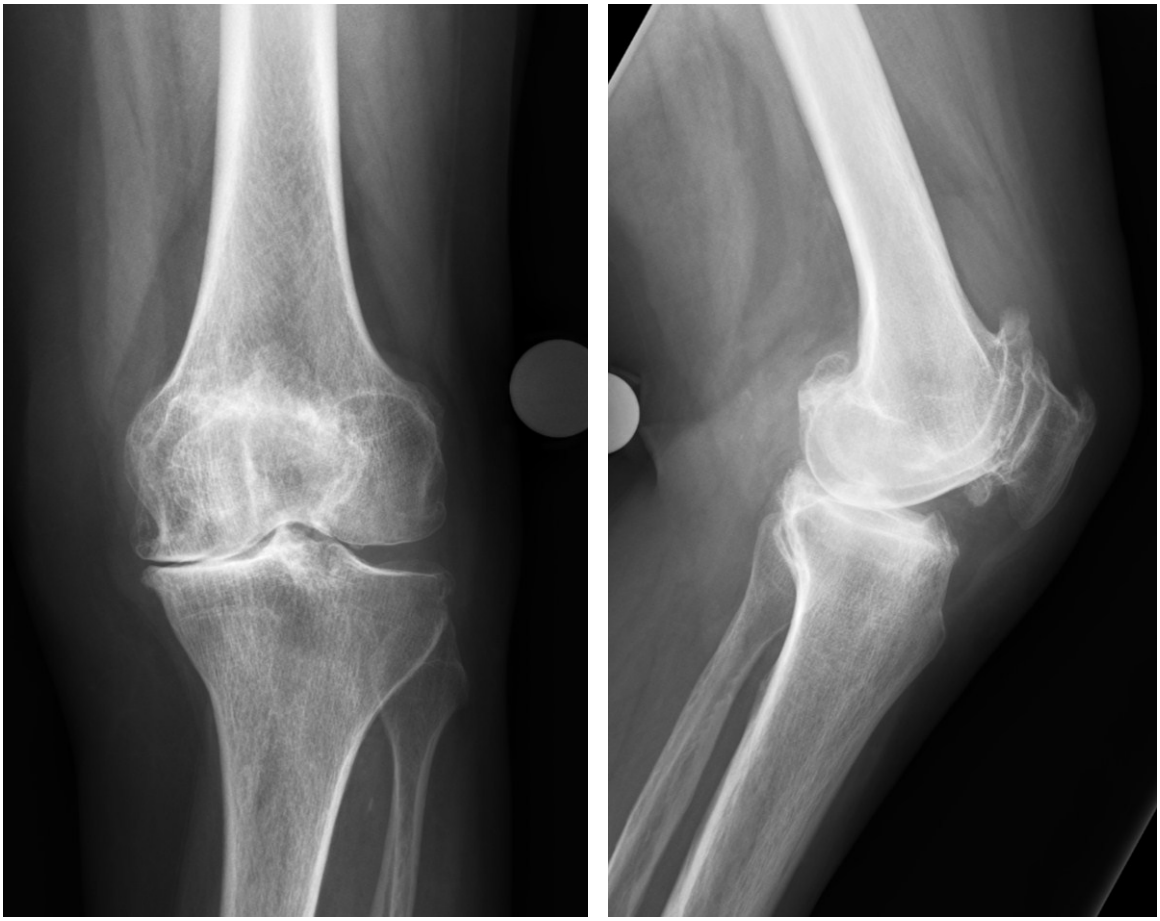

Figure 6: X-ray images of an arthritic knee.

6.1.3.2 Other Radiological Image Processes

If conventional radiography for the investigation is not sufficient, in addition, another magnetic resonance imaging (MR) is required to discover or exclude other differential diagnosis. Furthermore, there are ultrasound examinations, CT-scan or bone density measurements for further clarification. [22,33]

The MR imaging is a reliable way to assess knee joint cartilage status morphologically. This three-dimensional method is used for indication and monitoring the progression of degenerative changes and to plan treatments together with the course of therapy. [39]

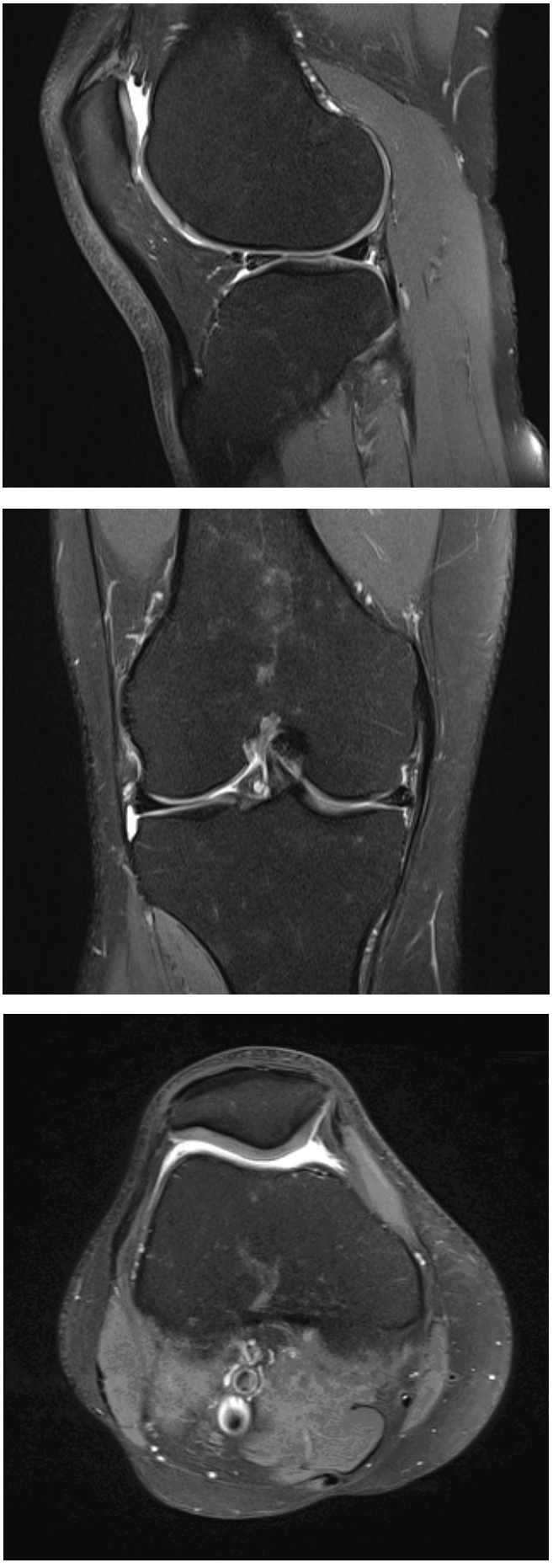

Figure 7: MR images of the knee cartilage.

With the ultrasound procedure it is possible to evaluate knee effusions (see figure7). [40] Because it is a gentle examination for the body, it would be beneficial to use it early in the cascade of examinations.

6.2 Anaesthesia

Before each surgery, a thorough preoperative examination of patients is necessary to capture the physical status, thus a kind of risk assessment can be summarized. Therefore, the patient is classified into the so-called ASA-classification (ASA I-V). The examiner should specially watch out for cardiovascular conditions, lung functions, kidney functions, surgery duration, kind and extent of surgery, and patient's age, because they may affect the perioperative risk considerably. [34]

Generally, total knee prostheses are implanted in general anaesthesia or by regional anaesthesia, e.g. plexus anaesthesia. The typical positioning of the patient during the surgery is the supine position. For interventions with risk of high blood loss, long uncomfortable positioning and restless patients, a general anaesthesia is suitable. [34]

Regional anaesthesia procedures are mostly used for shorter operations, which are associated with a low risk of bleeding. By preoperative inserted catheters, it is possible to applicate adequate pain medications postoperatively, what is of great advantage. Both anaesthetic techniques can also be combined, which are especially used for knee replacement surgery, with its long duration and strong manipulation of the patient's leg. In order to achieve early postoperative mobilization, in addition to general anaesthesia, peridural anaesthesia (PDA) or a nerve blockade of N. femoralis and N. ischidadicus can be performed. [34]

Macfarlane et al. investigated whether there is a difference between regional and general anaesthesia. He found that the use of regional anaesthesia, postoperative pain, morphine consumption and opioid side effects are reduced, and that a shorter hospital stay and improved rehabilitation opportunities are given. However, with regard to the amount of blood loss and duration of the surgery, there is no significant difference found. [41,42]

6.3 Prophylactic Antibiotics

Because the risk of wound infections in surgery of endoprosthesis is increased, to administer a preoperative antibiotic prophylaxis is important. There are broad-spectrum antibiotics used, mainly cephalosporins. Thirty to sixty minutes before the operation the antibiotic is applied, up to 10 minutes before inflation of the tourniquet, so that the drug also can reach the position of action. For operations, which take less than 3 hours, a single shot of the drug is enough. Most, staphylococcus aureus, staphylococcus epidermidis, coagulase-negative staphylococci and uropathogen bacterials are responsible for these infections. To contaminate the wound, the surgical team is the main risk factor, and therefore, sterile working is absolutely necessary. [22,43]

7 Surgical Technique

After sterile washing, sterile covering and inflating of the tourniquet, the surgery begins by skin incision after the team time-out. There are several approaches to implant a total knee endoprosthesis, so that the surgeon must choose which procedure is the best for an adequate intervention. This is an important decision with respect to intraoperative technical and mechanical reasons, cosmetic terms and for a better wound healing. Surgeons can choose between the medial parapatellar approach, lateral approach, midvastus approach, subvastus- or medial trivector-retaining approach. However, most used techniques are the medial parapatellar and the lateral approach. [44]

Additional to the standard techniques there are minimal invasive approaches available, which are reserved for patients without obesity and patients who have no severe bone deformations. [45]

If the access to the bony structures is dissected, the surgeon gets a good insight into the joint, so that existing exophytes can be removed. Then intraarticular structures such as cruciate ligaments, menisci, the Hoffa's fat pad, or portions thereof, can also be removed.
Next, it comes to the installation of the proximal tibial cutting device, with which, perpendicular to the mechanical axis of the tibia, the articular surfaces are removed by osteotomy, by the help of extra- or intramedullary alignment elements. These fixed cutting devices guarantee a straight cut the corresponding parts of bone are sawed off. By the help of an alignment tower the correct axial cut can be controlled. Finally, it is important to restore the mechanical axis in such a way, that the prosthesis withstands the everyday stresses and strains, when major axis deviations were present preoperatively.
Then the femur is measured and the anterior-posterior cutting devices are positioned, so that the ventral and dorsal cuts can be performed. The distal femoral osteotomy is undertaken by the aid of the distal femur-cutting block. By the use of introduced cap spacers, the ligaments stability can be checked, followed by the positioning of the finishing guide. Now, the tibial plateau is adjusted. If full extension and adequate flexion are adjustable, the original

prosthetic components, with their special design can be applied on the free bone surfaces. They are incorporated uncemented or by use of bone-cement. After tourniquet's deflation, the surgeon should control if there are still bleedings in the operation area, which must be stopped consequently. After the lavage of the joint, drains are placed, so that finally the wound is closed in layers.

7.1 Computer-assisted Surgery

By the help of new computer-assisted methods, the prosthetic components are implanted after measurement of the knee axis and additionally the size of the prosthesis, so that surgery can be carried out more accurately and faster. For a long-lasting prosthesis not only the ability of the surgeon and the anatomical characteristics of the knee joint of the patient are crucial, but also which technical tools are used to install the prosthesis. Here specifically adjusted cutting blocks are generated, with those more precise cuts can be made, so that the parts for the new joint can be adjusted more precisely. By preoperative CT imaging of the knee joint, a 3D-model is manufactured. During the surgery, the 3D-cutting guide is placed on the patient's bone, so that subsequently the measured cuts can be performed. Then the components are applied on the prepared bone. In addition of using this cutting template, further advantages like less blood loss, fewer infections, fewer thromboses, less embolisms, and an enhanced outcome should be reached. However, a definite advantage of computer-assisted surgery in TKA remains to be proven and therefore conventional implantation is still the gold standard procedure. [46-49]

8 Equipment / Different Types of Prostheses

A knee replacement consists of up to four components, the tibial plateau, the femoral shield, the inlay, and the patella component. The patella-resurfacing depends on the condition of the patella surface. There are various models, materials, anchor types, and installation techniques of the respective parts of the prosthesis. [50] Figure 8 shows the LCS system from DePuy e.g.

Figure 8: LCS prosthesis; Source: [51]

In the following, each Component is explained.

8.1 Femoral Component

8.1.1 Shape

Mainly, all femoral shields have the same shape, viewed from the side, and they resemble a "J". The ventral surface is higher than the dorsal, wherein the articular surface splits from anterior to posterior into a different lateral and medial surface, with the recess portion of the cruciate ligaments, the Notch. Generally, the shape of the prosthesis is very similar to the structure of a condylar joint, as in the case of a normal knee, additional there are also prostheses, in which the lateral and medial condyle are equal symmetrical. In addition, the radius of the joint surfaces,

viewed from the side, is either equal to the total course of the component, or it changes its length in course. [50]

Various models of prostheses can be selected in relation to the movement area by the surgeon, which is best suited for the situation. Especially in the area of the cruciate ligaments, there are different types that offer more or less freedom of movements, in which the posterior cruciate ligament is retained, removed or substituted. Furthermore, there are other versions of prostheses, such as the "Total Condylar III", which have less space for movement. In addition, there is the option for less medio-lateral diameter for female knees, such as the femoral shield 4 n (narrow) of the DePuy PFC system. [50,52]

8.1.2 Fixation Surface

Prostheses components can be implanted cemented or uncemented and they can be fixed by means of anchors or can be installed as press-fit implants. Especially, the contact between implant and bone is a very important point for a long durability in the body. For the use of compound cement, there are special indentations in the connecting surfaces, which serve as placeholders and thus provide better fixation. Most of the bone-prosthesis surfaces are not smooth, but rough. Especially those types that would be incorporated uncemented, have a reticular or granular surface to ensure better ingrowth of the bone tissue and a better grip. For additional anchoring there are boxes (open or closed) or pegs.

For patients with osteonecrosis or osteopenia separate prosthetic parts are developed with stems to achieve an even better fixation. They are usually used uncemented in revision surgeries due to infections.

Additional, there are enlargements, which are further implanted into medullary cavity of the tibial or femoral bone, for the use after trauma, for stronger defects and/or high instability of the joint. [50]

8.2 Tibial Component

In case of the tibia plateau there is a cemented or uncemented possibility of implantation, so that there are as well different types of prosthesis. Many components, which are cemented, have a stem or a keel in the middle of the contact surface, or they have only a plane surface. Viewed from above, most tibial parts have a kidney-like shape, wherein the rear and middle portion is recessed for the cruciate ligament. Implants for the cementless use have mostly stems, however they might have a prickle, and can even be screwed with the bone. [50]

Thus, the femur and tibia components not directly rub against each other, inlays are given in between, which mainly consists of polyethylene. There are thick or flat types, components with better properties of movement and in turn, some with more limiting conditions with respect to joints mobility. The best form is still under development in more details. The tibial part either is of pure polyethylene or is connected with metallic components. The metallic portion is used for bone contact and the polyethylene part has contact to the femoral component. [50]

8.3 Patella Component

If the patella reveals major degeneration, it can be exchanged or the articular surface can be replaced. The prosthesis has pegs or one center post, in which it has a round shape or a similar surface like the normal patella. It may consist of polyethylene alone or also of a combination of metal and polyethylene. {{89 Callaghan, John J. 2003}}

8.4 Mobile / Fixed Bearing Systems

The shape of the inlay and the way it is connected with the femoral and tibial component, are important. Divided into two groups, there are mobile-bearing systems and fixed-bearing systems.

Mobile systems may achieve flexion, extension, internal rotation and external rotation very well. With this free movement of the inlay, the wear of the surface is reduced, and simultaneously follows a reduction of prosthetic loosening. However, backside wear is reported. Particularly the fixed systems include two features,

which should be observed. Good matching articular surfaces have low contact stress, but they bring an increased risk of prosthetic loosening, however the polyethylene surface wears stronger. [52]

Despite this knowledge, mobile-bearing systems could not reach better results than fixed-bearings. Basically, fixed systems are proposed for the elderly and inactive patients, and mobile systems are more suitable for younger and more active patients. However, scientific community has not found a definite answer on this hot topic of TKA. [52]

8.5 Materials

Implanted prostheses must achieve several requirements in order to secure a good joint replacement. It depends very heavily on the material and its processing whether an endoprosthesis shows a long and constant residence time. Thus, three essential factors play a decisive role. Ideal biocompatibility, robust mechanical properties, and non-toxic chemical compositions of each prosthetic component should ensure maximum acceptance. [22]

Biocompatibility refers to e.g. the protection of rejection against the "new" body part, or the ability of tissue to growth into new and foreign structures, to generate a stable attachment. Chemical properties such as toxicity, solubility and corrosion are other important requests to prostheses and should be kept as low as possible. Therefore, endoprosthesis must withstand the severe mechanical stresses, frictions and pressures. [22]

Most prosthetic parts are made of metals with a polished joint surface, wherein newer prosthesis components have ceramic surfaces, which are indeed scratch-resistant, but have a certain risk of fractures. [53] For knee replacements are used titanium or cobalt chrome alloys most commonly, and occasionally even newer developments such as zirconium-niobium alloyed with a ceramic surface. [50]

Chrome-cobalt prostheses have a reduced corrosion, a hard texture, a very low abrasion and additionally they are not magnetic (MRT!). However, erosions of

particles of the surface can cause pathological reactions in patients with nickel allergy because of nickel components in the metal. [54]

Titanium alloys are corrosion resistant, also non-magnetic, are lower in density and have a good biocompatibility, concerning the abraded particles, compared with other materials. Surfaces of titanium prostheses can be changed to get different structures, such as fibre network, granulations or small pearl-like supplements. This allows an uncemented implantation of the components, eventual with the use of hydroxylapatite, to reach an adequate ingrowth. [22]

More recent femoral components are made of zirconium oxide. They have a metallic structure and a joint surface of ceramic. This combination has a high biocompatibility and elasticity, and is due to the polished and solid ceramic surface scratch resistant and abrasion-resistant. [53]

Hui, C. et al showed in their study, however, that there is no difference between oxides of zirconium and cobalt-chromium components, in relation to the abrasion of the polyethylene inlays. [53]

9 Fixation Methods

Prostheses can be implanted by the use of various fixation techniques in different ways. Technical developments, for example like the textured surface design, have led to connect the joint surface replacement better with the bone. Several new developments in knee prosthesis achieved more stability and thus greater durability of the components. New cemented techniques for the connection between implant and cement or between bone and cement have also shown positive results.

Generally, a total knee endoprosthesis can be implanted cemented, partially cemented (just tibia or femur parts are cemented, also called hybrid techniques) or generally non-cemented. In general, scientific community has reached consensus that it is important to cement the tibial plateau in TKA.

9.1 The Use of Cement

Since cemented installation methods show very good results, they are used on a regular basis nowadays. Especially patients with polyarthritic diseases benefit of these cemented components because they require no additional walking aids, which could strain on other joints. Simultaneously cemented prostheses have the advantage of reduced postoperative immobilization time. Cemented methods allow rapid full weight of the knee joint, and thus reduce the risk for postoperative thromboembolic events. [55,56]

If the surgeon chooses the cemented technique as the connection element, mainly the initial period after the implantation is crucial for a good long-term stability. [55,57]

Studies show that uncemented implants, in which all three parts were replaced, lead to osteolysis more frequently than the use of cemented total prostheses. Bone cement is stable in compression, but it has weakened in shear and tensile stresses, so that loosening in cemented prostheses cannot be excluded completely. In the course of this, it comes often to loss of bone stability or bone structures than to the failure of cement. [22,55,58]

For a long and stable anchoring of the prosthesis, the matching surfaces play a crucial role. This means the surfaces between cement and implant, and the connection between cement and bone. If these surfaces are not prepared appropriately this may lead to early aseptic loosening of the implant. [55]

For a successful fixation of components on the bony surfaces, the preparation of the bone is very decisive. This process must be executed adequately, so that later no loosening of the prosthesis arises. On X-ray images so called radiolucent lines are detectable. These areas are penetrated more unhindered by the X-ray radiations, which can be seen as dark lines in the picture. [55] These lines incur because of necrosis areas, misalignments, minimal movement of prosthesis and badly treated bone surfaces. [59]

By the execution of a jet lavage, the bony surface can be thoroughly cleaned. This type of lavage works with high pressure and large volume of liquid, thereby fat and coagulated blood components are rinsed and removed. Finally, the surfaces are cleaned by suction drying, so that the cancellous bone is exposed. [22,55]

Afterwards, next step is to apply the cement, wherein there are two different possibilities. The surgeon applies the cement either by fingers or with the use of a syringe. After that, the cement is fixed by pressurization. By stronger pressurization, the viscous cement can penetrate deeper into the bone. However, this is not determinative for a long durability of fixation. Thus, the surgeon decides how the cement is applied. [55]

For systems with PCL-retaining (posterior cruciate ligament - retaining) trays the tibial component is implanted first followed by the femoral part. Conversely, if the PCL sacrificing system is used, the femoral part might be implanted before to the tibial in some systems. [55]

Finally, the remnants of cement are removed around the edges, and a jet lavage of joint cavity is performed again. [55] The use of jet lavages can cause flushing of cement particles into the spongiosa, so that specific immunologic defensive reactions might occur. The grinding of cement particles of the bone/cement or

implant/cement surfaces can also lead to consequences of abrasion of implants surfaces, so that loosenings result. [22,55,57]

Cemented metal backed tibia platforms have lower bone stress properties, but by very high impact forces during instabilities and/or misalignment due to incorrect incorporation, they can cause detachments of the component. In regard to that, very much depends on the implantation method of the prosthesis by the surgeon. [55]

9.2 Cement Properties

Today there are many manufacturers who produce bone cement. The cement is mainly composed of polymethylmethacrylate (PMMA), wherein stabilizers, radiopaque constituents and antibiotic drugs are also introduced into the mixture. However, some substances have a negative influence on bone healing. The cement is a two-component mixture, which is mixed during the surgery in the operating room. Main components of the cement are a polymer powder and liquid monomer methacrylate, so that by mixing of these two components heat is produced. This polymerisation can produce temperatures of 40-56° C. Then the cement is gradually getting solid and is cured after 10-20 minutes. To work with the cement is divided into four sections. The first phase involves the mixing of methacrylate fluid with the polymer powder, where upon a viscous mass is created. During the next phase, the cement has very high adhesive properties. In the third step, called working phase, the cement is applied by fingers or by a syringe. Finally, the hardening process follows. By the heat production in this phase there is a risk of necrosis in the surrounding bone due to the high temperatures. [22,58]

Bone cement might have a very big advantage in terms of blood loss. Because by the use of bone cement between the superficial bone structures and the prosthetic parts it comes to sealing the leakages of the sawed bone. [60]

9.3 Uncemented Prosthesis

The first prostheses on the market were implanted without cement, which means that there is a direct contact between bone and prosthesis. Because they could not achieve sufficient positive results, e.g. in relation to early attainment of adequate stability, it came to new developments and further to the frequent use of cemented implants. Generally, cemented prostheses are implanted in elderly and inactive patients, however, due to the good results they are increasingly used also for younger and more active patients. However, after ten to twenty years, which viability the total knee prosthesis can reach, complications can still occur. Because cemented prostheses can lead to momentous complications, like brittleness by cement-aging or instabilities due to necrotic bone by tissue reactions, cementless techniques are further explored, developed and even used more frequently. The desired target is to design the prosthesis more biocompatible, so that they gain high initial stability, and to achieve a life-long dwelling time in the body without complications. [23,55,57]

Therefore, scientists develop newer prosthetic components with different surface structures for the use of an uncemented implementation technique, that they can perform the desired mission for long time. Uncemented techniques are executed, where the contact surfaces of the implants are rough, provided with pores or coated with bioactive substances. By the use of these special surfaces, bone and its matching implant can be anchored properly and as soon as possible. The quicker the patient retrieve its mobilization, the lower the risk of postoperative complications such as thromboembolic events, which may appear due to a prolonged bedded time. [55,57]

Thus, the bone can grow better in the prosthesis, as already mentioned, mainly the structures of the contact surfaces of components are essential. It was found that surfaces which have been provided with a specific pore sizes, have a very good influence on the in- and ongrowth of the bone. Pore sizes between 50 μm and 400 μm have provided good results and let the bone grow within 8 weeks. [23]

Another important feature is the material of the roughened implant, in which titanium parts are better suited than those of cobalt chromium, which relates to the ingrowth. [23]

Hydroxylapatite-coated parts, which are used in dentistry, among others, also are employed as a connecting element. It is assumed that as hydroxylapatite coating connection has a positive effect on bone ingrowth into the prosthesis, however, this newly formed bone consists of less solid mineral elements, and compared to cemented implants, hydroxylapatite coated have an increased risk of micro-movements. [22,23]

Pijls Bart G. et al shows that cemented tibial components (0.79 mm) have less micro-movement than those with hydroxylapatite coating (1.66 mm), and the non-coated tibial components have the largest movement of 2.25 mm, over a period of ten years. [61]

Contrary to cemented total knee arthroplasties, non-cemented prostheses need a longer time until they can be fully loaded. However, exactly this initial anchoring is critical for later success. A good fixation in the early postoperative time is important, because the slightest movement can decrease the ingrowth of the bone into the components. In order to reach rapidly a good stability the bone must grow fast and gliding has to be prevented. Therefore, cementless techniques must ensure a precisely and tightly attachment between the components and the bone. For this, a very accurate preparation of the bone by the use of precise cutting tools is essential. Because temperatures above 55 ° C might lead to necrosis of the bone during the sawing, it is necessary to cool the blades of the cutting tools to keep heat production as low as possible. [23,57]

Uncemented femoral components with structured surfaces have become established today again. They are either used in completely uncemented total knee replacements or in partially arthroplasties, which means that just the tibial part is cemented. By the oblique sections of distal femur the implant is fixed good and stable to the bone, so that this can be stuck on. [23]

To fix the tibial component for a stable and long retention time in the body is a greater challenge than to implant the femoral part. If screws or wedges are used additional, which also offer fixation, osteolysis can be caused easier.

Because the medial and lateral articular surfaces of the tibia have different shapes, better-suited tibial plateaus are produced for the cut surface of the proximal tibia. A metal-backed polyethylene inlay with a better-adapted form has the advantage, that the occurring forces can be transmitted better, and that a custom-made tibial plateau has a larger area to provide more stable bone ingrowth. [23]

Figure 9 shows a porous coated prosthetic component, in which the bone invades.

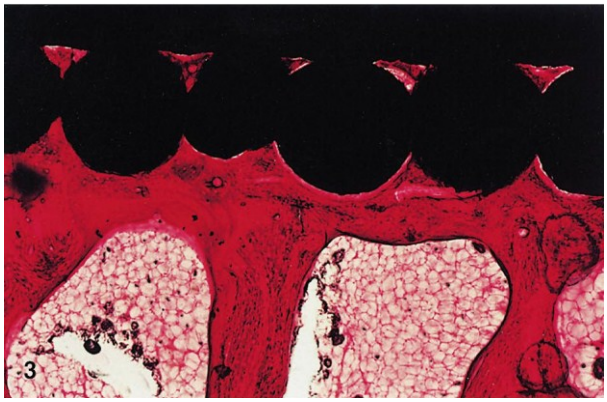

Figure 9: Porous coated and bone- ingrowth; Source: [57]

If the implant does not fit on the prepared bone, autologous bone grafts can be taken from the already sliced bone pieces to fill the gaps or to straighten the plateau, so that there is no more space between implant and bone. Autologous bone pieces are suitable for filling better than cement. [23]

9.4 Hybrid Techniques (Partially Cemented)

Hybrid techniques are fitting methods, in which only one component is cemented. Generally, the femur part is uncemented and the tibial tray is implanted by the use of bone cement. It was found that uncemented femoral components have a higher viability and lasts better than the parts of the tibia, which were incorporated uncemented. [50]

10 Complications and Risks

As with any surgical procedure, complications must be expected also by the implantation of a total knee replacement. Such a surgery is an extensive intervention wherein a variety of factors can lead to serious complications, apart from problems of anaesthesia. Some arising complications are often difficult to treat afterwards, or even can leave severe damages.

If one or more complications occur, an error analysis is urgently needed. On the one hand, to find out what is to treat, and on the other hand, not to make the same errors in the second operation, if a revision surgery is needed.

Very often, the patients complain about severe pain again in the knee joint, what causes a limited quality of life again, so that further treatments are indicated. If nothing is done, in the worst case even amputations can be necessary due to the severity of complications.

The first steps are algorithmically again and start with the anamnesis, especially with the anamnesis of pain, followed by the physical examination and eventual, if there is a suspicion of infection, laboratory tests (CRP, leukocytes, and aspiration sample of an effusion). Furthermore X-rays, or in special situations magnetic resonance images, are arranged. [23,62]

The mortality rate of TKA (total knee arthroplasty) with 1% is very low, but it increases with further additional comorbidities of the patient and it also depends on gender and age. Men and those who generally have poorer wound healing, such as patients with diabetes mellitus, are more severely affected. [9]

Therefore, detailed clarification is already before the operation important, to uncover all the risks and to prevent potential complications at an early stage or to observe them specifically. [63]

Major complications are described below:

10.1 Thromboembolism

Deep vein thrombosis and pulmonary embolisms are thromboembolic events, which can arise especially in the postoperative period. Patients, who receive thrombosis prophylaxis, have a prevalence of 45 % and those without prophylaxis a prevalence of 80% to get a deep vein thrombosis.

Due to a detached and displaced thrombus a, pulmonary embolism might occur, whose lethality rate is about 0.1%, as well as later a post-thrombotic syndrome can arise. Despite prophylactic measures, thromboembolic complications still occur commonly. In cases of suspected deep vein thrombosis (DVT), a targeted clarifying is essential, and if the suspicion is confirmed, an immediate treatment should be initiated. [34,64]

10.1.1 Deep Vein Thrombosis

The aetiology of DVT include injuries of the blood vessel wall, vascular stasis because of long inpatient time, hypovolemia, hypothermia, blood loss and hypercoagulability because of the activation of the coagulation cascade, known as Virchow's Trias. A DVT can be localized in one to four levels (lower leg veins, V. poplitea, V. femoralis and V. iliaca). [34,65,66]

Symptoms of DVT:

Calf pain, pressure pain, feeling of tension by swelling, and overheating are the major symptoms of a deep vein thrombosis. [9,66]

Important Risk Factors:

- Positive anamnesis
- Female
- Age > 40
- Hypovolemia
- Immobilisation
- Malignancy
- Obesity
- Serve varicose veins
- Smoking
- Coronary heart diseases
- Diabetes mellitus
- Oestrogen therapy
- Protein C deficient
- Protein S deficient

[9,66]

10.1.2 Pulmonary Embolism

A pulmonary embolism occurs in the pulmonary vessel due to a detached thrombus from peripheral veins. The following symptoms may occur caused by pulmonary embolism, which must be investigated and treated immediately. Sudden dyspnea, tachypnea, tachycardia, chest pain, hyperventilation, pathological blood gases, anxiety, shock symptoms are urgent signs for pulmonary embolism. [63,66]

The 3rd and 4th postoperative week are risky periods to get a pulmonary embolism. [63]

10.1.3 Diagnostics of DVT

The contrast venography represents the gold standard of examinations, however, this is an invasive procedure, which is expensive and painful for the patient, and anaphylactoid reactions can be triggered by injections of radiopaque material. So ultrasound is often used. Ultrasound is cheaper, safer, less painful, and it is well suited for the diagnosis of thrombosis between the inguinal ligament and the popliteal vein, but it is not appropriately for thrombosis proximal of the inguinal ligament. Using the Doppler method, a higher accuracy can be obtained. Because a large part of the deep vein thrombosis occur in pelvic region, MR venography or CT venography are meaningful, with which even further differential diagnoses can be excluded. As a clinical laboratory parameter, the D-dimer test is performed by using venous blood. [63,64,66]

10.1.4 Thrombosis Prophylaxis

In order to prevent thrombotic events early thrombosis prophylaxis should be administered. So, the therapy is a benefit-risk assessment, because on the one hand, thrombosis formations can be prevented, but on the other hand, the use of anticoagulant drugs increases the risk of bleeding. If, therefore, the hematocrit or the blood pressure falls unexplained in intra- or postoperative, the reason for bleeding has to be discovered or excluded immediately. As a vital threatening side effect, the heparin-induced thrombocytopenia is mentioned. [64]

10.1.4.1 Mechanical Prophylaxis of DVT

There are medicinal and mechanical therapies for a prophylactic treatment. In addition, patients will be adequately hydrated to prevent hypovolemic conditions. Furthermore, an early mobilization of the patient should be achieved by physiotherapeutic exercises.

For the transport of the blood, compressions stockings, shoes, or leggings are available to establish passive pressure in the veins. Foot pumps generate a periodically pressure of about 100 mmHg. The patient receives the mechanical possibilities before surgery until he or she is again able to walk after surgery. [34,63,64]

10.1.4.2 Drug Prophylaxis of DVT

For the drug therapy there are coumarins, which are administered oral and controlled by INR (international normalized ratio), low-molecular-weight-heparin and theoretically aspirin. Aspirin inhibits even the blood clotting, but it has severe gastrointestinal side effects, which can lead to ulcers. [64]

The American College of Chest Physicians (ACCP) recommends a thromboprophylaxis for 10 days postoperatively, which can be extended up to 35 days in special cases. [65]

The implementation of a spinal or epidural anaesthesia and the use of blood coagulation inhibitory drugs in the last 12 hours should be handled with caution. Because of the prolonged bleeding time, bruising can occur in the spinal canal, which can lead to paralysis. Only after the introduced catheter is removed, the injection of LMWH (low molecular weight heparins) can follow. [64,67]

10.1.4.3 Use of Tourniquet

The use of a tourniquet has two faces. On the one side, it prevents the excessive inflow of blood into the surgery area, what the installation of the prosthetic components will benefit, but on the other side, changes in venous hemodynamic conditions might lead to the formation of blood clots. After opening the tourniquet

fresh blood clots can tear off and can provoke pulmonary embolisms. Therefore, it is especially beneficial for patients with increased risk of thrombosis to activate the tourniquet only during the cementing. [64,67,68]

10.2 Infections

Infections are divided into early, late, deep, and superficial infections. Symptoms of an infection are pain, swelling, overheating, reddening, prolonged wound drainage, functional restriction and open wounds. In the period of the first 4 weeks early infections might occur, which are caused by contamination during or after the surgery. Superficial infections involve skin and subcutaneous tissue, while the knee deep infections affect the joints cavity and the new prosthesis components. Urinary tract infections might have a correlation with deep infections of the knee, and therefore a urinary catheter should be introduced under sterile conditions. In addition to urinary tract infections, diabetes mellitus, rheumatoid arthritis, prolonged wound drainage (over 6 days), no adequate clean work, obesity, previous knee surgery, steroid use, immunosuppressive drugs, malnutrition, peripheral arterial disease, and renal failure are important risk factors for knee joint infections. [9,64]

The treatment is an elimination of pathogens by pre- and postoperative antibiotics. If the healing fails in deep infections, wound debridement is indicated. Due to the recurrence rate, arthroscopic methods are less suitable than open methods. In severe cases one or two-stage revision surgery or in even worst cases amputations may be necessary. [9,64]

10.3 Aseptic Loosening

Loosening of prosthetic parts is a time-dependent process. In the X-ray they are detectable by radiolucent lines (Sadoghi et al. BMC, Kastner et al. IntOrthop), which arise due to decreased bone density of the surrounding bone tissue. Implanted prosthetic components have to withstand high forces and therefore they are highly exposed to get loose after time. By micro-movements, but also by inappropriate implantation it may come to loss of fixation, so that the instability increases. [63]

Periprosthetic osteolysis plays a very crucial role in cemented and non-cemented prostheses. Five to ten percent of the patients develop after 10 to 15 years bone loss phenomena. The reason is still unclear, although it is believed that abrasions of polyethylene fixtures cause cellular responses that promote a degradation of bone quality. [9,23,54]

10.4 Fat Embolism

Into the bone marrow introduced alignments or into the medullary cavity reaching parts of the prosthesis can cause a wash out of fat constituents into the bloodstream during the knee surgery. Consequently, free fatty acids may enter the lungs and increase the capillary permeability, so that the surface tension of the alveoli is reduced. By the destruction of the surfactant the alveoli collapse and respiratory gas-diffusion cannot be performed sufficient. Symptoms are tachycardia, tachypnea, mental disorders, petechial haemorrhage and respiratory distresses. [9,63]

10.5 Blood Loss

A total knee arthroplasty can lead to considerable loss of blood over 1000ml and more. Various methods to decrease the blood loss and the complications related to extensive blood loss are explained in more detail in the next chapter.

10.6 Other Complications

The peroneal nerve, which is often affected, is not in the area of surgery, but it may be injured in malalignment by straightening. Stretching causes nerve palsies, which in 50% of cases disappear spontaneously. However, for the other half further rehabilitations are required. Prolonged tourniquet might also cause nerve paralysis. [9,64]

Furthermore, patellofemoral instabilities might occur, which may result in retropatellar pain, fractures, dislocations, and ruptures of the quadriceps tendon. [9]

The popliteal artery is located in the knees' back area. Sharp instruments might injure this artery iatrogenically and excessive bleeding can be caused. It threatened ischemia, compartment syndromes, and even amputations in the worst case. [64]

Periprosthetic fractures are rare, but they occur in osteoporosis, rheumatoid arthritis, and revision surgeries. Arthrofibrosis are also rare, and bears the risk of a stiff knee, so that the total knee replacement remains without success. [9]

Finally, misalignments are also mentioned in the literature. Often there exist severe preoperative misalignments, which have to be adjusted by correction of the ligaments. However, because of the difficulty settings, renewed misalignments can arise. There are flexion, extension, valgus, and varus misalignments reported in the literature. [63]

11 Blood Management

During the implantation of total knee prosthesis, there may be considerable amounts of blood loss, which cannot be ignored. Larger amounts can be lost intra- and postoperatively. [69]

Patients tend to postoperative bleeding anaemia and can get a hypovolemic shock, which extends to circulatory failure, if no adequate treatment is initiated. [69]

Therefore, it is important to think about potentially high blood loss while planning the surgery and to inform the patient accordingly about necessary blood transfusions. The risks of blood transfusions must be included in the explanation of the intervention, so that the treatment of blood loss starts already preoperatively. [69]

The current coagulation status of the patient should be examined prior to the operation, because patients with preoperative low haemoglobin values require rather blood transfusions than patients with higher values. In case of a therapy with anticoagulant medication it should be discontinued or changed at least 7 days before surgery. Phenprocoumon has a longer half-life and should be stopped in timely, and aspirin should be stopped already 10 days before surgery. [60,69,70]

Important factors to minimize blood loss are reduction of the surgery duration, use of tourniquets, use of bone cement, precise management of coagulation status, regional anaesthesia, and to perform an atraumatic surgery as far as possible. In case of cemented prostheses, a blood loss of 1000 ml to 1500 is reported, and in case of uncemented prostheses, there is a 500 ml higher blood loss than in cemented prostheses. [71]

If it comes to increased blood loss despite all efforts, a blood transfusion is quite likely to compensate the loss again. To focus on values of under 10 g/dl of haemoglobin (Hb) is already out of date. Patients with values below 6g/dl Hb need certainly blood transfusions, wherein at values between 6-10 g/dl Hb, age, general health, current condition of the patient, any existing anaemia, changes in the Hb-

level, pre-existing cardiovascular conditions, or other previous diseases should be included and evaluated in the decision for the administration of blood products. [34,69,71]

Especially in high-risk patients with myocardial infarction, cardiac arrhythmia, hypertension, valve defects, congenital heart disease, and cerebrovascular insufficiency precise blood management is essential. [60]

Available are two types of blood transfusions. On the one hand, there are the allogeneic blood products, which blood is from other donors, and on the other hand autologous blood donation from the patients themselves. Due to the increased risk of infections transmitted by homologous blood products to the patient, autologous blood transfusions in orthopaedic knee surgeries are more and more used. Preoperatively donated autologous blood has in relation to the risk of communicable diseases a major advantage over allogeneic blood products, because despite of various screening tests of homologous blood and own security measures infections can arise. [69]

The following will explain in detail what options there are to refill blood losses.

11.1 Allogeneic Blood

Allogeneic blood products are quickly available, but they entail the risk of transfusion reactions and/or transmitted infections, which may end fatally. Therefore, allogeneic blood transfusions are considered risky, so that they have not proven to be ideal. Transfusion reactions occur because of the immunological defence reaction of the receiver without vicarious or because of iatrogenically errors of any kind. Preparation, transportation, confusions, and failures in the application are present and can lead to serious damages. [60,69]

Despite screening tests of infectious diseases such as HIV, Hepatitis A, B, C viruses, CMV, and bacterial pathogens can be transferred occasionally. [34,60]

An overview of possible symptoms and diseases that may result from allergic/immunological transfusion reactions:

- Itching
- Nausea
- Vomiting
- Hypotension
- Renal failure
- Chill
- Feeling of heat
- Cold, pale and sweaty skin (symptoms of shock)
- Urticaria
- Anaphylactic reactions
- Difficulty in breathing
- Tightness in the chest
- Tachycardia
- Purpura
- Septic shock caused by bacteria [34,69]

11.2 Autologous Blood

Autologous blood products have a better status, but the procedure involve the risk of excessive blood donations, that excessive stored blood is discarded, and have the disadvantage of high costs. Therefore, an exact management of donation and administration should be observed, not to waste the precious blood unnecessarily. [34,69]

Forty to seventy percent of preoperative blood donations are not used for the patients themselves, but they go into a pool allogeneic, what can lead to discontent and feelings of exploitation of the patient. [71]

Autologous blood donations have few side effects, nevertheless writing mistakes in the organization of blood preserves can still creep in, as well as bacterial contamination might occur. [71]

Different time points of blood collection have been established and can be used for the knee replacement surgery. This means, autologous blood donation prior to surgery, suctioning during surgery, collection of blood after the operation by drains, and stimulation of haematopoiesis by drugs are in use.

11.2.1 Preoperative Blood Donation

If the treating doctor has allowed sufficient time in relation to blood management, approximately 2000 - 4500 ml of blood can be donated at intervals of about 10 -14 days (the time is needed for the new formation of blood cells). To support the regeneration, iron supplements can be administered. For the blood donation, patients must be healthy, have no uncontrolled cardiac diseases, and have to be free of acute infections. [60,69]

Another advantage is the pre-operative stimulation of the blood-forming system to produce new cells by stimulating the reticulocytes. Thus, the body respectively the blood-forming system is prepared in advance. Furthermore, preoperative donations lead to less deep vein thrombosis demonstrably and to a reduction of erythrocyte mass, so that less erythrocytes mass is lost during surgery. In addition to the unnecessary wasting of blood products, induced anaemia by improper blood donations can lead to an increased requirement of blood preserves postoperatively. [60,69]

11.2.2 Preoperative Normovolemic Hemodilution

Hemodilution is a further alternative for blood transfusions. Shortly before the operation, the fresh blood is taken, then it is prepared, and after that, it is reinfused postoperatively. By the removal, it also comes to a reduction of red cell mass, so that there is also a fewer loss of the erythrocytes during the surgery. [69]

11.2.3 Intraoperative Salvage

An important measure to decrease the blood loss is to collect the leaked blood. By suctioning the operation area, the blood is collected for example by a cell saver, so that it can be re-transfused after the surgery. Sixty percent of the collected blood can be re-used free of noxious substances. In order to proceed it cost effectively, however, a certain amount of blood should be collected. For this method, about 1000 ml of blood and an expected blood loss of about 20% are suitable. Acute infections and neoplasms exclude this kind of blood reuse. [34,69]

11.2.4 Postoperative Salvage

Because in the first 24 hours after the operation about 85% of blood loss arises, especially this time period is important to collection it to compensate the blood loss by retransfusions. [71]

The extraction of the intra-articular hematoma prevents movement restrictions and is a protection against infections. Within the first 24 hours, the colonization of the drainage system is very low compared to 48 hours, so that the drainage should be removed as possible within 24 hours. [71]

After the implantation of the prosthesis the wound closure is performed, and still under sterile conditions, a drainage tube is introduced into the wound, so that further bleedings can be collected in special containers or pouches, like Bellovacs or Redons. Then the blood can be reinfused either washed or unwashed. To wash the blood free of fatty acids or other intraoperative resulting bone particles or possibly cement particles, in cases of cement use, is expensive but a very secure method to transfuse blood products to patients. To minimize the probability of complications as low as possible a maximum of two units are administered in a period of 4 to 6 hours. The only recorded side effects are febrile reactions. [60,69]

11.3 Drug Treatment

In order to increase the blood volume, haemoglobin concentration and the hematocrit value medicines can be used, which have a stimulating effect on the hematopoietic system. Erythropoietin, which is also mainly used in the therapy of renal anaemia, and vasopressin are available. Whether vasopressin has a positive and diminishing effect on blood loss is still being researched. [69]

Erythropoietin can be used either alone or in a more effective combination with preoperative blood donations. This has the advantage to minimize the use of allogenic blood products. In the body, the hormone erythropoietin is synthesized as a response to hypoxia and is produced in the kidneys and in the liver. Manufactured erythropoietin is administered either subcutaneously or as an intravenous injection. The treatment lasts three weeks, each injection per week.

However, this therapy is expensive and therefore less effective in terms of cost management. [60,69,71]

11.4 Tourniquet

As mentioned above, the use of a tourniquet assures less inflow of blood into surgery area, what is important for a good implantation, so that the bone is free of blood. By its use, there is the significant and important advantage of reduced blood loss. [34,60]

To deposit the tourniquet prior to closure of the wound is not necessary in principle, but it should be done during anaesthesia because of reperfusion pain. [34,60] Because hematomas in the knee joint arise, it is an argument to release the tourniquet prior to closure of access to the surgery area, to see if bleeding haemorrhages have to be closed. Because of little leakages, significant amounts of postoperative blood might be lost. [63]

Important keywords of testing blood preserves:

- Blood group determination
- AB0-blood group characteristics
- Rhesus factor
- Bedside testing
- Antibody screening test
- Serological compatibility test (major- /minor)
- Identity verification of patients

[34]

12 Postoperative Care and Life after Total Knee Arthroplasty

For a good long-term success of the implantation of knee prosthesis, further treatments are necessary in addition to surgery.

The elderly patient around 75 years of age will gain significant quality of life with targeted physiotherapy. [72]

The main aim is pain freedom and agility, so that the patient can provide again his/her daily duties.

To know what patients await them after surgery, an explanation of the post-operative rehabilitation and which goals can be achieved is important. It cannot be expected that the implantation only is sufficient to obtain a good joint function in all cases. Therefore, it must be clear that after the intervention patients must undergo important physiotherapeutic training. Therefore, targeted and effective pain management and effective physiotherapy exercises are the essential parts of postoperative treatment, which can be achieved by professional help. [71,72]

On the first postoperative day, the training begins with slight passive motion exercises to obtain sufficient range of motion (ROM). To achieve an adequate ROM (range of motion) is important for a lasting positive result. One hundred and five degrees from flexion to full extension should be obtained. In the first few days already safe going is possible, but to achieve this, slow-building training is necessary. When safe walk is possible, higher loads with low weights are practicable, however, just as much as of the patient tolerates and no pain comes up. For this, walkers, crutches, handrails, or handles can be used in various sectors to get closer again to fully load of the knee joint. [71,72]

For those patients who have sufficient bone substance and a cemented prosthesis, the knee joint can be fully loaded at an early stage by controlled assistance. [71]

Subsequently, on the following days, the strain is increased until more and more everyday duties can be done. Active and passive flexion and extension motions are the main exercises, which are teached by therapists.[71,72]

To lead the rehabilitation determinedly to a positive result, creating a treatment plan is meaningful. By a prepared construction program and consistently training, physiological degrees of motion, strength, stability, and balance should be achievable. When daily activities such as washing, to go to toilet, to climb stairs etc. are practicable, further charges like sport can be pursued. For this, anatomical and biomechanical accuracy is essential. [72]

Sports such as golf, swimming, sailing, cycling, and diving can be performed certainly with knee prostheses, but generally, stop and go sports (football, basketball, baseball, tennis, etc.) and running should be avoided. [72]

12.1 Follow up

The long-term outcome depends on the ability of the surgeon and the patient's conditions. If the prosthesis is implanted in the best way and if the operation could proceed together with their postoperative rehabilitation free of complications, longer durability of the prosthesis can be expected. Also depending on the conditions of the patient, regular monthly checks, which are getting longer, are necessary to control the further course. With 96%, cemented prostheses maintain for 15 years, and uncemented 12 years with 95%. [9,57]

Tags that affect the durability of prostheses:

- Bone quality
- Patient's conditions
- Patient’s lifestyle
- Age
- Comorbidities
- Complications
- Quality of the operational perform
- Prosthetic material
- Prosthetic design

[9,57]

Special part

13 Study aim & hypothesis

The aim of this study was a correlation analysis of cementation technique with the necessity of postoperative blood substitution. We hypothesized, that patients with totally cemented total knee arthroplasty (TKA) would need less substitution than patients with partially cemented or non-cemented TKA.

14 Patients and Methods

This study is a retrospective correlation analysis of 200 reviewed patients between 1996 and 2011 of the orthopaedic department who underwent primary total knee arthroplasty as the main selection criteria. Two hundred cases were randomly selected using our hospital database system according to a sample size estimation of previous investigations. [5]

The exclusion criteria were revision surgery or haematological disorders e.g. haemophilia. The data were retrieved and extracted from the medical records, especially from the surgical reports and were registered in an excel table.

We extracted demographical data on the patients as well as cementation technique and status (totally cemented, tibial only, femoral only, or non-cemented), and the postoperative blood substitution evaluated by erythrocyte concentrates and retransfusion volume.

The patients were assigned into three groups, the totally cemented group, in which both, the femoral and the tibial parts are cemented, the non-cemented treatment group (without any cemented part), and the hybrid treatment group, in which just one of the prosthetic components is cemented (mostly the tibial part). The different

sizes of femoral and tibial prosthetic components were recorded, and additionally the sizes of the rotating platform of the polyethylene were listed.

Furthermore, we recorded how much blood was retransfused to the patients by using the bellovac system for the postoperative blood collection, and how many erythrocyte concentrates were administered to the patients in the three different cementing treatment groups (see chapter results).

The patients were classified by the anaesthetists into ASA – groups with an average of ASA 3, and they underwent surgery in general and/or regional anaesthesia.

15 Results

The analysis includes 126 women and 74 men (see figure 10) with an average age at the surgery day of 71 years and 5 months (standard deviation 7 years and 11 months, range from 41 years and 10 months to 84 years and 7 months).

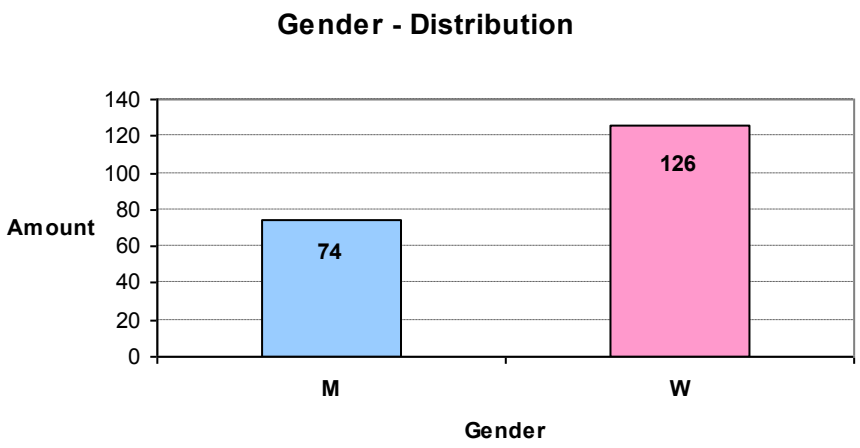

Figure 10: Gender Distribution

Figure 11 shows the age distribution and its rate of the 200 patients.

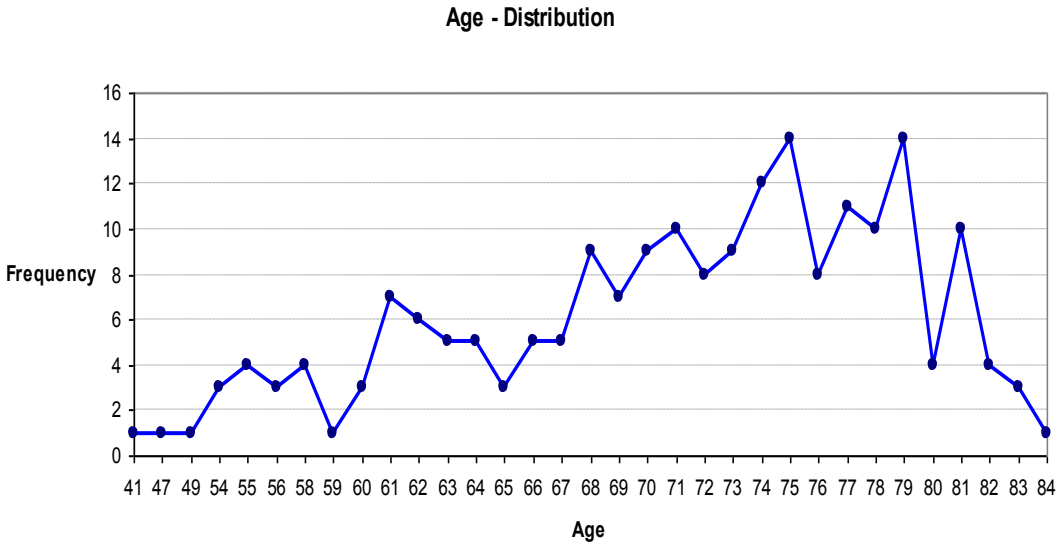

Figure 11: Age - Distribution

The average height was 1,66 m (standard deviation 0,08 m, with a range from 1,45 to 1,84 m), the average weight were 82 kg, with a range from 50 to 155 kg, so that an average BMI (body mass index) of 29,96 kg/m2 (range from 19,53 to 60,55 kg/m2) could be calculated (see figure 12).

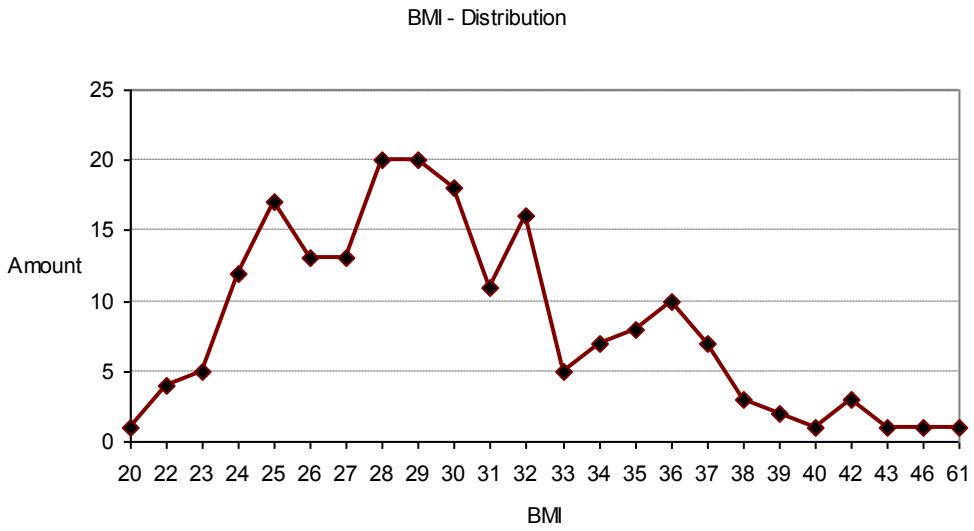

Figure 12: BMI - Distribution

Figure 13, 14 and 15 show the different sizes of the components, and how often they occur among the 200 patients in the data analysis.

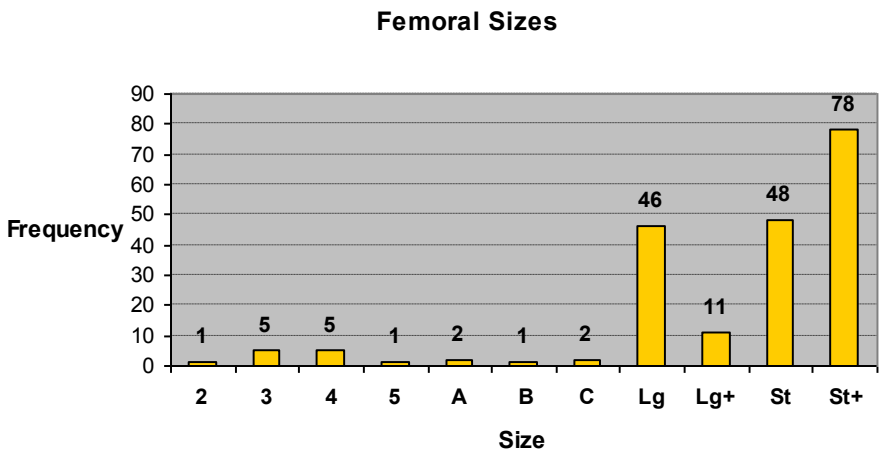

Figure 13: Femoral Sizes

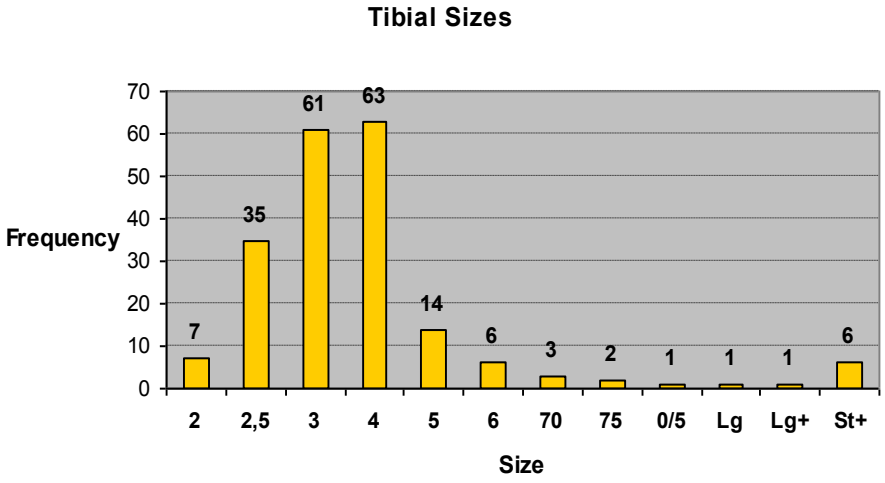

Figure 14: Tibial Sizes

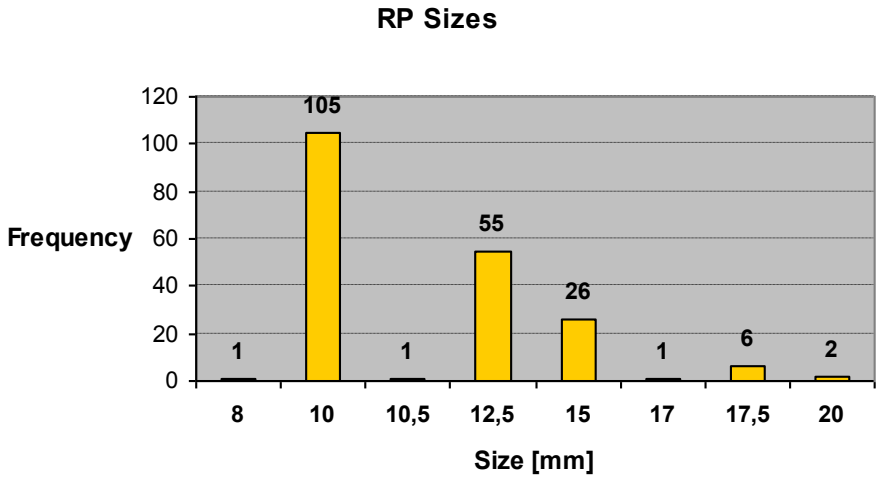

Figure 15: Sizes of the Rotating Platform

The main diagnosis to perform the knee arthroplasty was gonarthrosis, wherein 106 left knees and 94 right knees were operated. The surgical time revealed an average of 1 hour and 30 minutes (standard deviation 25 minutes), with an average tourniquet time of 1 hour and 22 minutes (standard deviation of 30 minutes).

The hospitalization time lasted on average 9 days (range of 1 to 28 days, standard deviation of 3 days).

Figure 16 shows the ASA-Allocation of the 200 Patients.

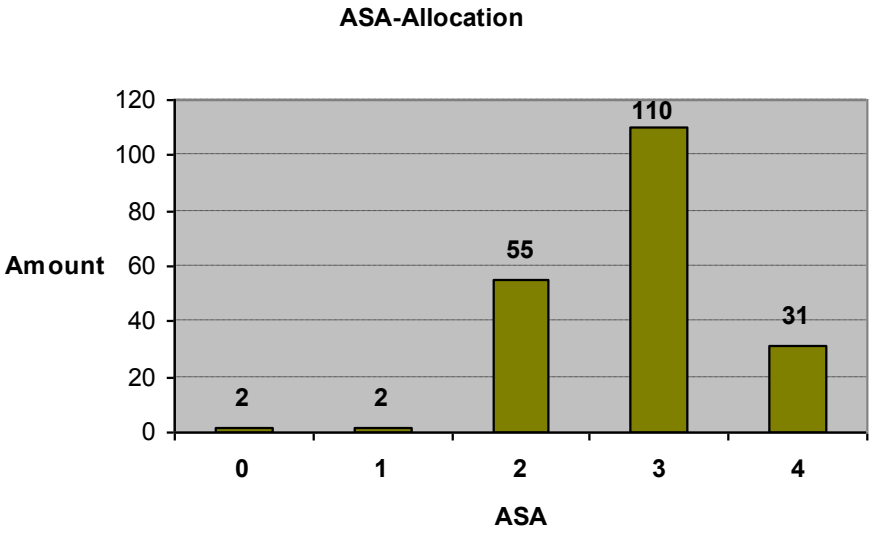

Figure 16: ASA - Allocation

In figure 17 there are the different blood groups illustrated and how often they were presented in the data analysis, wherein 6 blood groups are unknown.

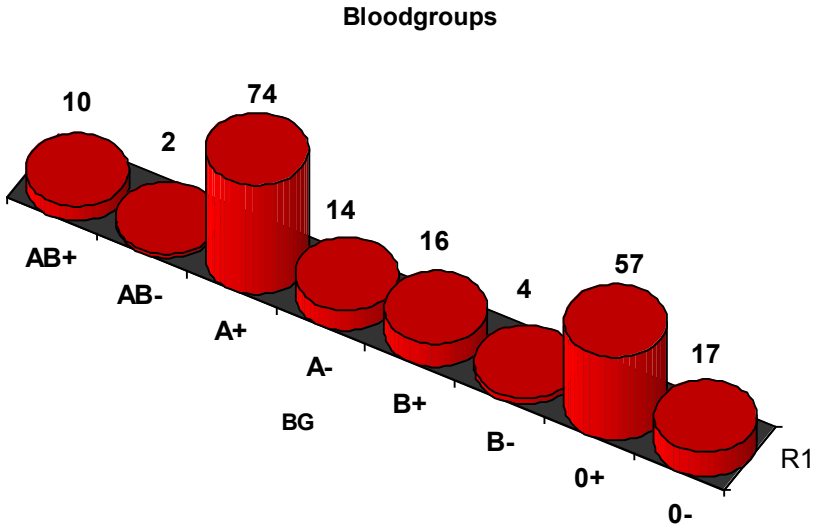

Figure 17: Blood Groups

One hundred fifty nine cases were partially cemented (97.5 % tibial only), thirty-three cases totally cemented, and eight cases of TKA non-cemented, which is shown in Figure 18.

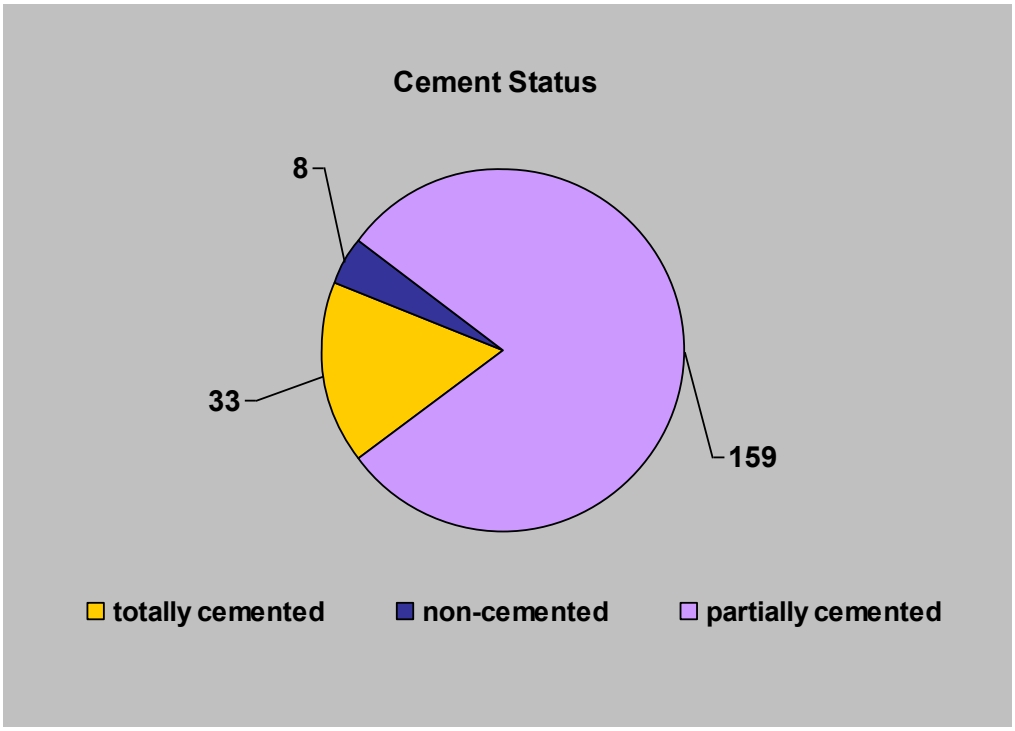

Figure 18: Cementation Groups

Forty-one Patients received allogeneic blood products, wherein 37 became 2 RBC (red blood cell) concentrates, 2 patients became 3 concentrates and 2 received even 4 erythrocyte concentrates.

Figure 19 (on the next page) shows on which days the RBC concentrates were administered.

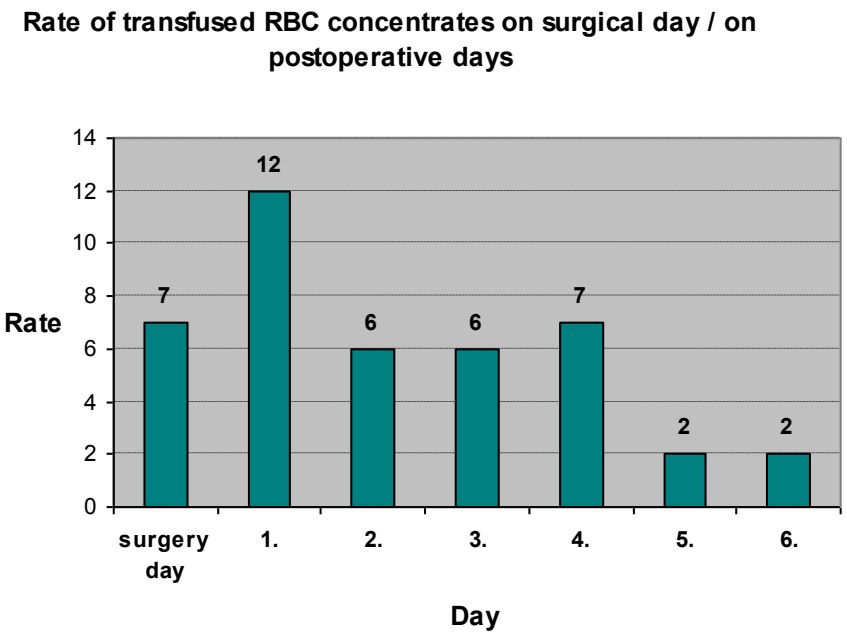

Figure 19: Rate of RBC concentrates on postoperative Days

We found, that the non-cemented group received an average of 1 erythrocyte concentrate, the cemented group an average of 0.5, and the partially cemented group of 0.4 concentrates (see figure 20).

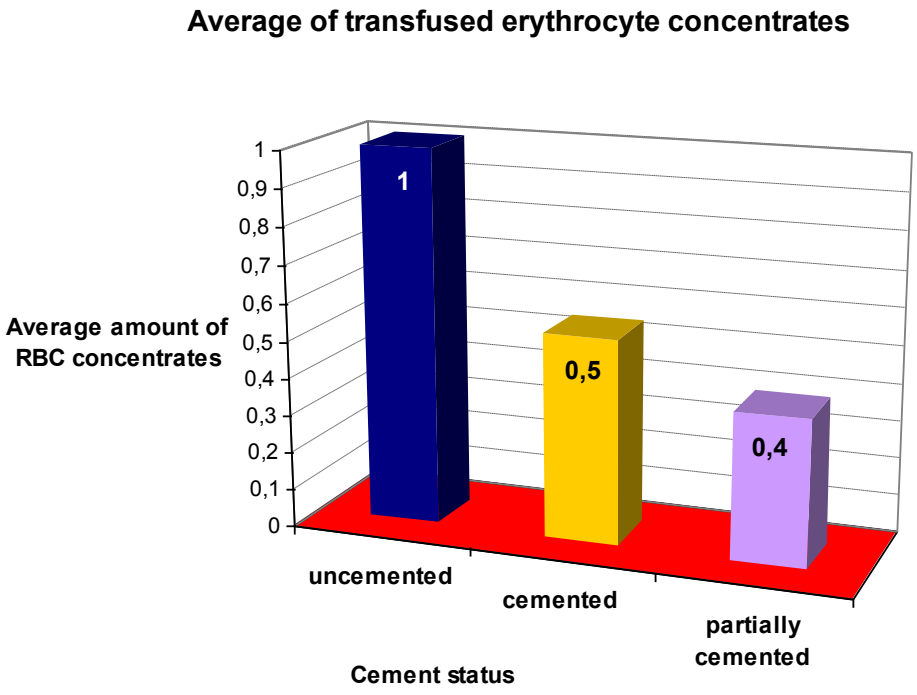

Figure 20: Average of transfused RBC concentrates

The average amount of retransfused bellovac (bvac) blood was 347 ml of the completely 200 patients, so that those with an uncemented total knee endoprosthesis received an average of 206 ml of bvac blood. Patients with total cemented prostheses received 107 ml more bvac blood (313 ml) than the uncemented group, and those with partially knee arthroplasties received an average of 361 ml (see figure 21).

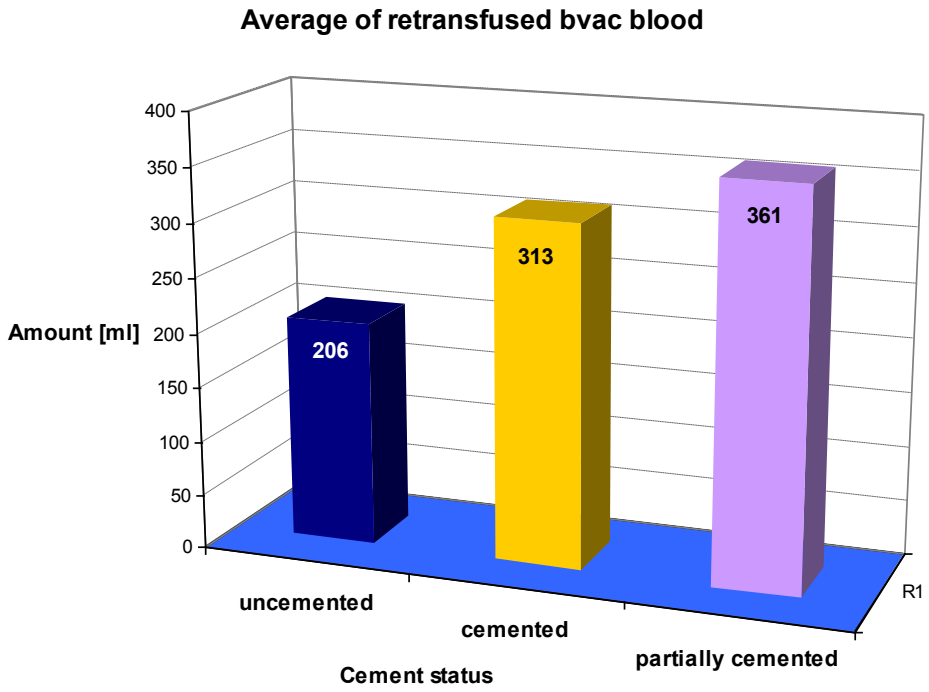

Figure 21: Average of retransfused bvac blood

The mean blood loss of the 200 patients was 282 ml. The uncemented group showed an average blood loss of 314 ml, the cemented group 212 ml, and the partially cemented group a blood loss of 295 ml on average.

Correlations

		femur part cemented	tibia part cemented	number of given EC's	Bvac blood loss; [ml]; on surgery day
femur part cemented	Pearson Correlation	1,000	-,097	,111	-,113
	Significance (2-tailed)		,174	,116	,149
	N	200	200	200	164
tibia part cemented	Pearson Correlation	-,097	1,000	-,206**	-,078
	Significance (2-tailed)	,174		,003	,320
	N	200	200	200	164
number of given EC's	Pearson Correlation	,111	-,206**	1,000	,047
	Significance (2-tailed)	,116	,003		,548
	N	200	200	205	164
Bvac blood loss; [ml]; on surgery day	Pearson Correlation	-,113	-,078	,047	1,000
	Significance (2-tailed)	,149	,320	,548	
	N	164	164	164	164

**. Correlation is significant at the 0, 01 level (2- tailed).

Table 4: Correlations

The correlation analysis between a cemented femoral shield and the number of given erythrocyte concentrates and retransfused blood revealed no statistically significant correlation.

The correlation analysis between a cemented tibial plateau and the number of given erythrocyte concentrates revealed a statistically significant negative correlation without statistically significant correlation with retransfused blood.

16 Discussion

Implantation of total knee arthroplasty is a major surgical procedure, wherein a complex and specific patient management is needed. Timely before the surgery, all preoperative examinations should be completed and all further perioperative preparations should be provided to ensure a high outcome for the patient. Conservative treatments must been carried out, contraindications excluded, the indication for the final surgery must been ensured, and treatments should be available.

In addition to many other complications, which might arise, especially the blood management is an important topic, which cannot be neglected.

Due to the implantation of the prosthesis, considerable amounts of blood might be lost. Therefore various techniques are used, which avoid a high blood loss, or methods, which compensate quickly an increased blood loss by blood transfusions.

The blood management begins timely before the surgery by laboratory tests to determine the current blood conditions, and ends when stable blood conditions are present.

Preoperative stable hemodynamic conditions, low intraoperative blood loss, the collection and preparation of intra- and postoperative blood loss, and retransfusions respectively allogeneic transfusions are major factors of the blood management.

To prevent a high intraoperative blood loss there are possibilities of using tourniquets. Zhang et al. [73] found in their study of 60 knee-operated patients, that less blood was lost intraoperatively by using a tourniquet, however, the postoperative blood loss was higher than in the group without a tourniquet.

This leads to a lower blood inflow into the surgical area by using a tourniquet during the surgery, so that a clean surgical field is given, and the implantation can be performed more gently. [64] But the postoperative increased blood loss should be taken into account by collecting the blood by drains for a subsequent retransfusion.

Because retransfusions of the own blood lead to a lower risk of fatal transfusion reactions and the risk of transmitted diseases e.g. HIV, it is essential to collect and to prepare the drainage blood for retransfusions. [74]

Atay et al. [75] reported in their study, that the amount of allogeneic blood products could be reduced by retransfusing drain blood.

Prasad et al. [76] found in his prospective randomized study of perioperative blood loss in patients who underwent total knee arthroplasty, a gender difference, in which men lost more blood than women did. Furthermore, he found, that the amount of blood transfusions depends on the preoperative haemoglobin value, the intraoperative blood loss, the use of a tourniquet, and the surgical time. Additionally, the study showed that patients with rheumatoid arthritis with low preoperative haemoglobin levels needed more blood transfusions than patients with osteoarthritis, although in relation to the intra- and postoperative blood loss there was no significant differences between the two groups.

A further method of preventing blood loss is the use of bone cement. Yashar and Colwell describe, that cemented prostheses have a blood loss of about 1000 to 1500 ml, in which non-cemented prostheses have a 500 ml higher blood loss than cemented total knee arthroplasties. This also Hays and Mayfield [77] found out in their study, in which the uncemented group had a 562 ml higher blood loss.

Porteous and Bartlett [78] found in their retrospective study of 100 patients, that there is a difference in blood loss between the cemented and non-cemented group respectively the cemented and partially cemented group, however, there is no difference between the non-cemented and the partially cemented group. Also in their study, cemented knee arthroplasties had a lower blood loss than non-cemented and partially cemented knees.

Jefferiss et al. [79] suspects a sealing effect of the bone cement ingredients, which results because of high temperatures caused by the chemical reaction by the cement preparation, so that small vessels can be sealed.

Ishii and Matsuda [80] found no differences in blood loss between the non-cemented and the hybrid group (non-cemented femoral and cemented tibial component). They suspected because of the size of an uncemented tibial plateau a good covering and sealing effect was given, however, the sliced cancellous femoral bone had an increased blood loss. Thus, both the non-cemented and the hybrid group have less blood loss from the tibial part than of the femoral part. [5]

These results, however, query the usefulness of bone cement in terms of blood loss.

Fujimoto et al. [81] examined the blood loss in a study of 274 patients by using four groups, the cemented osteoarthritis (OA) group, the non-cemented OA group, the cemented rheumatoid arthritis (RA) group, and the non-cemented RA group. They found a clear difference between the cemented and the non-cemented OA group, but no difference in the RA group, in terms of blood loss. But, in regard to blood transfusions, patients in the cemented RA group became fewer blood transfusions than the non-cemented RA group. This difference was not found in the OA groups, so that they suggested the OA patients have more stable haematological conditions.
Demey et al. [5] found in his prospective randomized study of 130 patients no differences in the amount of blood loss between cemented and non-cemented femoral components and no differences in the amount of blood transfusions.

In our correlation analysis, we found a significant positive correlation with cementing of the tibial plateau and less blood loss without a correlation with retransfusions. We found no correlation with respect to cementation of the femoral shield.

The study was composed of three main groups, the totally cemented, the partially cemented (97, 5% tibial cementations), and the non-cemented group.
We have summarized and analyzed the demographic datas, in which the prosthetic sizes, the cement status, the amounts of retransfusion, the number of EC's and the blood loss were included.

The main limitation of our analysis is that evaluation of the actual blood loss after TKA is not only dependent on the amount of retransfused blood volume or applied erythrocyte concentrates.

The blood loss was not calculated by a formula, such as those of Mercuriali and Inghilleri [5], but rather it was searched out and listed from the existing patient records. For the calculation of the blood volume by the formula of Mercuriali and Inghilleri, the patients' blood volume, the preoperative haemoglobin value, the haemoglobin value on the fifth postoperative day, and the transfused blood volume are important values [5].

The reason of a higher blood loss in cemented cases than in the non-cemented group is not statistically proven. We only used the surgery day for the calculations. With regard to the higher blood loss in the cemented group than in the non-cemented currently no conclusions can be drawn.

17 Conclusion and Summary

The study was a correlation analysis of 200 reviewed patients, who underwent primary total knee arthroplasty. Two hundred cases were randomly selected using the hospitals database system and were divided into three main groups, the totally cemented group, the non-cemented treatment group, and the hybrid treatment group, in which just one of the prosthetic parts was cemented (97.5 % tibial only). In total, thirty-three cases were totally cemented, one hundred fifty nine cases were partially cemented, and eight cases non-cemented. We hypothesized, that patients of the totally cemented group would need less substitution than patients of the two other groups. The postoperative blood substitution was evaluated by bellovac retransfusion volume and by erythrocyte concentrates, so that the mean retransfused bellovac blood volume was 347 ml. The mean blood loss in the cemented group was 212 ml, in the non-cemented group 314 ml, and in the partially cemented group 295 ml.

The correlation analysis showed a statistically significant negative correlation between a cemented tibial plateau and the number of given erythrocyte concentrates, and a significant positive correlation with cementing of the tibial plateau and less blood loss. Prostheses with a cemented tibia plateau had a lower blood loss, wherein the femur shield had no influence in the analysis.

The results showed, the more cement was used, the less erythrocyte concentrates had to be administered.

18 Literature

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19 Appendix

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Date of completion
July 21, 2012

Knee Society Score

Clinician's name (or ref) .....

Patient's name (or ref) .....

During the past 4 weeks.....

Click here for part 2 - FunctionScore

Part 1 - Knee Score

Pain

- None
- Mild / Occasional
- Mild (Stairs only)
- Mild (Walking and Stairs
- Moderate - Occasional
- Moderate - Continual
- Severe

Flexion Contracture (if present)

- 5°-10°
- 10°-15°
- 16°-20°
- >20°

Extension lag

- <10°
- 10-20°
- >20°

Total Range of Flexion

0-5	6-10	11-15	16-20	21-25
26-30	31-35	36-40	41-45	46-50
51-55	56-60	61-65	66-70	71-75
76-80	81-85	86-90	91-95	96-100
101-105	106-110	111-115	116-120	121-125

Alignment (Varus & Valgus)

0	1	2	3	4
		5 - 10		
11	12	13	14	15
		Over 15°		

Stability (Maximum movement in any position)

Antero-posterior

- <5mm
- 5-10mm
- 10+mm

Mediolateral

- <5°
- 6-9°
- 10-14°
- 15°

Print page | Close Window | Reset

To save this data please print or Save As CSV

Nb: This page cannot be saved due to patient data protection so please print the filled in form before closing the window.

Final Knee Score is 0

(NB: consider a negitive outcome as zero)

Click here for part 2 - FunctionScore

Grading for the knee Society Score

Score 80-100 Excellent **Score 70-79** Good **Score 60-69** Fair **Score below 60** Poor

Reference for score: Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res. 1989 Nov;(248):13-4. link to pubmed. Link SF36, SF12

Reference for Grading: Asif S , Choon DS . Midterm results of cemented Press Fit Condylar Sigma total knee arthroplasty system. J Orthop Surg (Hong Kong). 2005 Dec;13(3):280-4.

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Date of completion July 21, 2012

Knee Society Score - Function

Clinician's name (or ref) _____

Patient's name (or ref) _____

Please answer the following questions.

Part 2 - Function

Walking

- ○ Unlimited
- ○ >10 blocks
- ○ 5-10 blocks
- ○ <5 blocks
- ○ Housebound
- ○ Unable

Stairs

- ○ Normal Up and down
- ○ Normal Up down with rail
- ○ Up and down with rail
- ○ Up with rail, down unable
- ○ Unable

Walking aids used

- ○ None used
- ○ Use of Cane/Walking stick deduct
- ○ Two Canes/sticks
- ○ Crutches or frame

Function Score (Knee Society Score) is 0 **(NB: consider a negative outcome as zero)**

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Reference for score: Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res. 1989 Nov;(248):13-4. link to pubmed

Reference for Grading: Asif S , Choon DS . Midterm results of cemented Press Fit Condylar Sigma total knee arthroplasty system. J Orthop Surg (Hong Kong). 2005 Dec;13(3):280-4.

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Date of completion
July 21, 2012

WOMAC Score

Patient's name (or ref) _____

Clinician's name (or ref) _____

Patient's d.o.b 1 Jan 2002

INSTRUCTIONS: This survey asks for your view about your knee. This information will help us keep track of how you feel about your knee and how well you are able to do your usual activities.

Answer every question by ticking the appropriate box. If you are unsure about how to answer a question, please give the best answer you can.

Symptoms - These questions should be answered thinking of your knee symptoms during the **last week**.

S1. Do you have swelling in your knee?

○ Never ○ Rarely ○ Sometimes ○ Often ○ Always

S2. Do you feel grinding, hear clicking or any other type of noise when your knee moves?

○ Never ○ Rarely ○ Sometimes ○ Often ○ Always

S3. Does your knee catch or hang up when moving?

○ Never ○ Rarely ○ Sometimes ○ Often ○ Always

S4. Can you straighten your knee fully?

○ Never ○ Rarely ○ Sometimes ○ Often ○ Always

S5. Can you bend your knee fully?

○ Never ○ Rarely ○ Sometimes ○ Often ○ Always

Stiffness - The following questions concern the amount of joint stiffness you have experienced during the **last week** in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.

S6. How severe is your knee joint stiffness after first wakening in the morning?

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

S7. How severe is your knee stiffness after sitting, lying or resting **later in the day**?

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

Pain[1]

P1. How often do you experience knee pain?

○ Never ○ Monthly ○ Weekly ○ Daily ○ Always

What amount of knee pain have you experienced the **last week** during the following activities?

P2. Twisting/pivoting on your knee

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

P3. Straightening knee fully

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

P4. Bending knee fully

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

P5. Walking on flat surface

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

P6. Going up or down stairs

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

P7. At night while in bed

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

P8. Sitting or lying

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

P9. Standing upright

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

Function, daily living - The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

Al. Descending stairs

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A2. Ascending stairs

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A3. Rising from sitting

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A4. Standing

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A5. Bending to floor/pick up an object

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A6. Walking on flat surface

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A7. Getting in/out of car

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A8. Going shopping

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A9. Putting on socks/stockings

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A10. Rising from bed

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A11. Taking off socks/stockings

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A12. Lying in bed (turning over, maintaining knee position)

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A13. Getting in/out of bath

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A14. Sitting

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

A15. Getting on/off toilet

○ None ○ Mild ○ Moderate ○ Severe ○ Extreme

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

○ Never ○ Rarely ○ Sometimes ○ Often ○ Always

A17. Light domestic duties (cooking, dusting, etc)

○ Never ○ Rarely ○ Sometimes ○ Often ○ Always

Thank you very much for completing all the questions in this questionnaire.

Print page Close Window Reset

To save this data please print or Save As CSV

The Womac score is 0

Nb: This page cannot be saved due to patient data protection so please print the filled in form before closing the window

Reference for Score: Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. J Orthop Sports Phys Ther. 1998 Aug;28(2):88-96. **Link**

20 Curriculum Vitae

Personal Information

Name:	Ewald
Surname:	Musser
Date of birth:	04.04.1984
Place of birth:	Güssing
Citizenship:	Austria
Nativ language:	German
Current adress:	Tyroltgasse 18 A-8020 Graz

E-Mail: ewald.musser@stud.medunigraz.at

Education

September 1990 – July 1994	Elementary school Gabelsberger
September 1994 – July 1997	Grammar school BG/BRG & MG Dreihackengasse
September 1997 – June 2002	Grammar school BG/BRG Klusemannstraße with emphasis on natural sciences

Qualification: Matura

September 2002 – April 2003	Military service
October 2003	Start of medical study at the Medical University Graz
October 2012	I will finish the medical studies

Personal Skills and Competences

Languages:	English
	Knowledge of Italian (maturation level)
Social skills:	Team spirit
	Pleasures in working with people
Hobbies:	Sports (Sailing, Jogging)
Driving licenses:	A, B
	FB2 (Sailing)

Clinical electives

2005	Department of Emergency Surgery (3 weeks); Austria; Schwarzach; Organisation: Kardinal Schwarzenberg'sches Krankenhaus
2006	Department of Internal Medicine (4 weeks); Austria; Schwarzach; Organisation: Kardinal Schwarzenberg'sches Krankenhaus
2008	Department of Anesthesiology (2 weeks); Austria; Hartberg; Organisation: Landeskrankenhaus Hartberg
2008	Department of General Surgery (2 weeks); Austria; Hartberg; Organisation: Landeskrankenhaus Hartberg
2009	Department of Dermatology (4 weeks); Austria; Vienna; Organisation: Krankenanstalt Rudolfstiftung Wien
2010	Department of Orthopaedic surgery (2 weeks); Austria; Güssing; Organisation: Krankenhaus Güssing

Practical year

2011	Department of Pediatrics, Neonatal Intensive Care (3 weeks); Austria; Graz; Organisation: Medical University of Graz
2011	Gerneral Medicine (3 weeks); Austria; Söding; Organisation: General practitioner
2011	Department of Internal Medicine, Angiology (6 weeks); Austria; Graz; Organisation: Medical University of Graz
2011/12	Department of Visceral Surgery, (6 weeks); Germany; Ingolstadt; Organisation: Klinikum Ingolstadt

Date: Signature: