Unicondylar knee replacement

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Graduate thesis

Zagreb 2020

This graduation paper was realized at the Department of Orthopedic surgery, School of Medicine, University of Zagreb and Clinical Hospital Center Zagreb, under the supervision of Associated Professor Mislav Jelic, MD, PhD. And it was submitted for evaluation in the academic year of 2019/2020.

Mentor of the graduate thesis; Associated Professor Mislav Jelic, MD, PhD

ABBREVIATIONS:

- UKR: Unicompartmental/Unicondylar Knee Replacement
- UKA: Unicompartmental/Unicondylar Knee Arthroplasty
- PKA: Partial Knee Arthroplasty
- TKA: Total Knee Arthroplasty
- ACL: Anterior Cruciate Ligament
- PCL: Posterior Cruciate Ligament
- MCL: Medial Collateral Ligament
- LCL: Lateral Collateral Ligament
- AMOA : Anteromedial Osteoarthritis
- OA: Osteoarthritis
- AP: Anteroposterior
- SONK: spontaneous osteonecrosis of the knee
- FTCL : full thickness cartilage loss
- RIO : Robotic Arm Interactive Orthopaedic System
- CT: Computed tomography
- PF : Patellofemoral
- ROM: Range of Motion

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1. ABSTRACT

Key words: knee osteoarthritis, compartment, partial knee replacement, unicompartmental arthroplasty.

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Osteoarthritis is a degenerative joint disease that results in a cartilage erosion process. This medical condition serves as a burden for the elderly population, particularly amongst people over the age of 75. Osteoarthritis of the tibiofemoral joint of the knee could be divided into either medial or lateral compartment of the joint where either result in debilitating symptoms. If other means of treatment have failed or have not provided satisfactory results surgical intervention is prompted. The current gold standard choice of surgical treatment is the procedure of unicondylar knee arthroplasty, where the main goal is to relieve osteoarthritis in the degenerative compartment in which the damaged parts of the knee are replaced. The main unicondylar knee arthroplasty procedure was designed as a means to cause less trauma compared to total knee arthroplasty by removing less bone and maintaining most of the patient’s inaugural anatomy. Moreover, it is designed in a manner of using smaller incisions with smaller implants. Therefore, reducing post-operative pain, reducing time of recovery and preserving the joint’s natural mechanism of movement.

SAZETAK

Osteoartritis je degenerativna bolest zglobova koja dovodi do erozije hrskavice.

Ovo medicinsko stanje predstavlja teret za stariju populaciju, pogotovo za starije od 75 godina. Osteoartritis femorotibijalnog dijela koljena se može podijeliti na dva dijela, medijalni i lateralni dio zgloba, a u oba slučaja simptomi su bolni i onemogućavaju normalan svakodnevni život.

Ukoliko su ostali načini liječenja neuspješni, ili rezultati nisu zadovoljavajući, potrebna je kirurška intervencija.

Trenutni zlatni standard kirurškog tretmana je procedura unikondilarne artroplastike koljena, gdje je glavni cilj smanjiti osteoartritis u pogođenom području, i zamijeniti oštećene dijelove koljena.

Unikondilarna artroplastika koljena je kreirana kao manje invazivna procedura, u usporedbi s totalnom artroplastikom koljena, na način da se odstranjuje manji dio kosti i čuva pacijentova originalna anatomija.

Koriste se manji rezovi i implantati, što dovodi do manje post-operativne boli, kraćeg vremena oporavka i očuvanja prirodnog mehanizma kretanja zgloba.

2. Introduction:

Knee replacement is a surgical procedure that decreases pain and improves the quality of life of many patients with severe knee osteoarthritis. Knee arthroplasty is the most common form of lower limb OA [42]. It is estimated that 6% of people age 30 years and older as well as 15% of people age 45 years and older experience the condition of knee OA [43], with a lifetime risk of 45% [44]. In most of the cases the patients undergo this surgery after a non-surgical treatment (such as: knee injection or activity modification) have failed to provide alleviation of the symptoms. So far surgeons performed knee replacements for over 4 decades, with excellent results and favorable outcomes with a reported 10 years survival of greater than 90% [45-48]. Over the years, minimal invasive PKA has replaced the TKA in cases of osteoarthritic knee that is isolated to a single compartment. This surgical technique allows an insertion of prostheses through a small incision (3-10 cm) with very minimal damage to muscles and tendons around the knee. Therefore, the UKR has rather many advantages (Table 1) over the TKA. But it also seems to possess disadvantages in terms of revision rate. Hence selection of either UKA or TKA is a matter of debate.

Advantages	Disadvantages
Faster Recovery	Strict patients selection
Preservation of bone and ligaments	High failure and revision rates
Increased ROM	Disease progression
Better knee kinematics	Potential increased wear

Table 1: advantages vs disadvantages of UKR

2.1 Knee Anatomy:

The knee is the largest and most superficial synovial joint in the human body. It is classified primarily as a pivotal-hinge joint, a special type of mobile trochoginglymus, allowing flexion and extension. But this type of joint is combined with gliding and rolling as well as rotation about a vertical axis. The knee plays an essential role in movement related to carrying the body weight in horizontal (running and walking) and vertical (jumping) directions.

The articular bodies of the knee joint consist of the femoral condyles and the tibial condyles. The knee joint is relatively weak mechanically because of the incongruence of its articular surfaces, which has been compared to 2 balls sitting on a warped tabletop. As a result of this incongruence these joint surfaces are compensated by a relatively thick cartilaginous covering and by the menisci. In addition to the tibia and femur, the patella also forms part of the knee joint. The physicians also use the term femoro-patellar joint, meaning the region of the knee joint in which the patella is in contact with the femur. The femoral condyle diverges to some extent distally and posteriorly. The lateral condyle is wider in front than at the back, while the medial condyle is of more constant width. In the transverse plane the condyles are only slightly bent on a sagittal axis. In the sagittal plane, the curvature increases toward the back. In addition, the medial condyle curves about in a vertical axis (curvature of rotations). The superior tibial articular surface is formed by the condyles, which are separated by the intercondylar eminence and both intercondylar areas.

At various points the knee joint possesses ligaments, menisci and communicating bursa. Unlike some other joints in the human body due to the incongruence of the knee articular surfaces, the ligaments use to secure the joint. The four main ligaments are: anterior cruciate ligament (ACL) - the most commonly injured knee ligament [49] and the posterior cruciate ligament (PCL). The medial collateral ligament (MCL) and the lateral collateral ligament (LCL). The knee has 2 cartilage structures, the medial and lateral meniscus that are localized between the femur and tibia. The menisci are crescentic plates that consist of fibrocartilage as part of the articular surface. They play a role in shock absorption allowing greater effectiveness in the articulation between the rounded femoral condyles and flat tibial plateau. [22]

2.2 Biomechanics and stability of the knee:

The knee joint has mainly two types of movements: flexion and extension. When the knee is in flexed position, some rotation can occur. When the knee is completely in extended position (foot touches the ground), the knee passively locks due to the medial rotation of the femoral condyles on the tibial plateau – this is known as the screw-home mechanism [23]. This position makes the lower limb a solid column and more adapted for weight-bearing. When the knee is "locked", the thigh and leg muscles can relax for a short period of time without making the knee joint too unstable. In order to unlock the knee, the popliteus contracts, the femur rotates laterally about 5 degrees on the tibial plateau and thus this flexion of the knee can be performed. The cruciate ligaments can cause a rolling movement of the knee, in which during flexion of the knee the contact point between the tibia and femur moves posteriorly while in extension it returns anteriorly. Moreover, at the time of rotation of the knee one femoral condyle moves anteriorly on the corresponding tibial condyle while the other femoral condyle moves posteriorly, rotating about the cruciate ligaments. The menisci must be able to migrate on the tibial plateau as the point of contact between femur and tibia change.

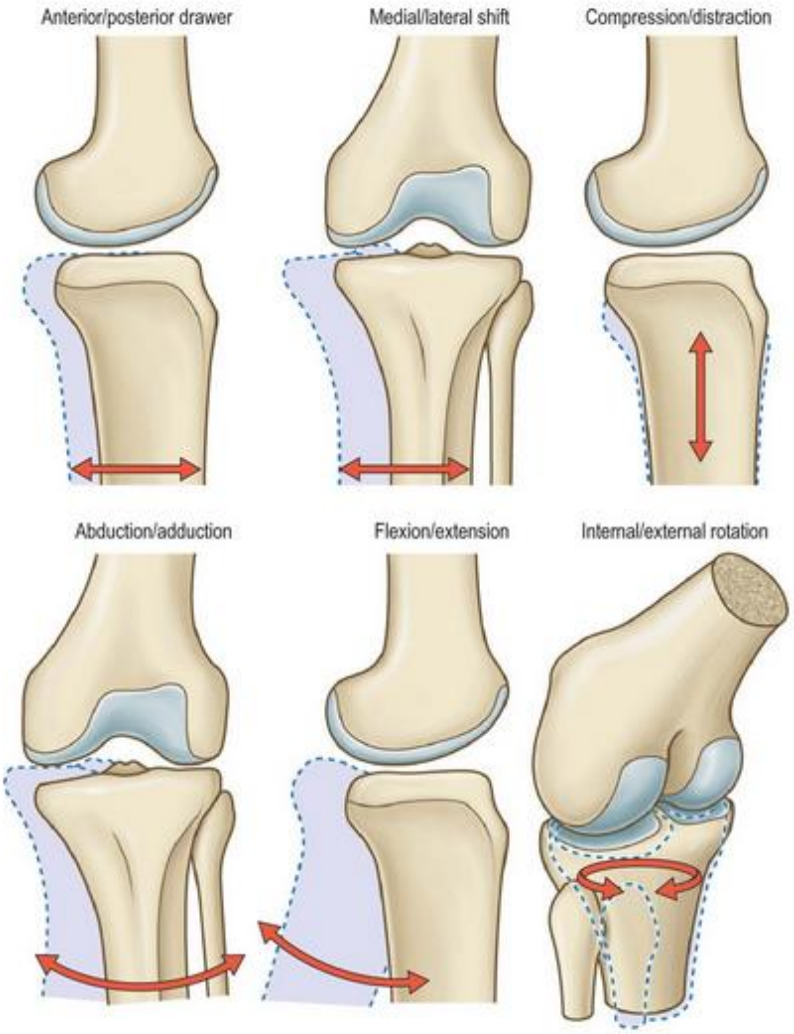


Figure 1: Biomechanics of the knee – 6 degrees of freedom: abduction, adduction, flexion, extension, internal and external rotation, anterior and superior draw, medial and lateral shift, compression and distraction [24]

3. Indications:

In 1989, Kozinn and Scott outlined the classic indications for unicompartmental knee replacement. According to their viewpoint they proposed that the ideal candidate for the procedure would be a patient that met 11 criteria [1-3]

1) Age < 60 years old
2) Weight <82 kg
3) Low or lack of physical activity
4) Isolated medial compartment disease
5) Cumulative angular deformity of less than 15 degrees
6) Anterior and posterior cruciate ligament are intact
7) Pre-operative range of flexion of 90 degrees
8) Flexion contracture of less than 5 degrees
9) Minimal pain at rest
10) No radiographic or intra-operative evidence of chondrocalcinosis or patella-femoral osteoarthritis
11) No evidence nor history of inflammatory arthropathy

To this date some physicians still follow these indications. However, the new Oxford Group offered a more liberal set of indications for unicompartmental knee arthroplasty. The oxford UKA has a freely mobile meniscal bearing that allows sliding freely as well as rotating between the congruent surfaces of the condyle femur and plateau tibia, and this congruency is maintained in each direction and position throughout the range of motion of the knee joint. Therefore, it helps in minimizing wear and makes the implant 'patella friendly'.

Thus, the criteria for medial Oxford Unicompartmental Knee Arthroplasty are avascular necrosis of the knee (also called SONK- spontaneous osteonecrosis of the knee) which is the most common indication for UKA, and AMOA- anteromedial osteoarthritis.

Figure 2: Before surgery, radiograph imaging of a patient with anteromedial osteoarthritis [4]

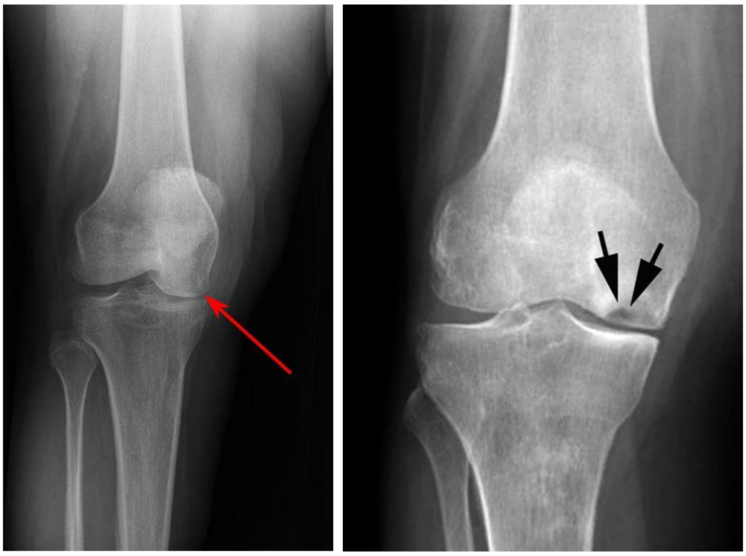


Figure 3: left: osteonecrosis of the knee, narrowing of the joint space can occur due to loss of articular cartilage [19]***;*** right: osteonecrosis of the lower end of the femur in the medial femoral condyle [20]

3.1 Principal physical signs:

The patient is admitted to the physician usually with pain in the knee which is noticeable especially during walking or standing. The knee might be associated with swelling but not necessarily. On physical examination the leg can be observed in varus alignment between 5 to 15 degrees without the ability to correct the deformity with leg extension. But this deformity can be corrected either with valgus stress when the knee is flexed to 20 degrees or more or either spontaneously when the knee is flexed to 90 degrees.

3.2 Principal anatomical feature:

In most cases, during the operation the anterior and posterior cruciate ligaments are functionally normal, but the ACL can have some surface damage. Additionally, on the tibia, the articular cartilage is eroded and exposes the eburnated bone, from the anteromedial margin towards the posterior margin. In a similar way the cartilage on the distal articular surface of the medial condyle is eroded and exposes the eburnated bone. On the femoral condyle, the posterior surface preserves the full thickness lesion of the cartilage. The MCL is of normal length and the posterior capsule is shortened.

3.3 Correlations:

An intact of the MCL, ACL and PCL can explain the signs and symptoms the patient has. The ACL and PCL maintain the physiological roll-back of the 2 bones, the femur on the tibia in sagittal plane. Thus it preserves the distinction between the damaged contact in extension (the medial femoral condyle and the anterior tibial plateu) and intact contact area in flexion (the posterior femoral condyle and the posterior tibial plateau). Due to the shortening of the posterior capsule, deformity appears during flexion and due to loss of cartilage and bone erosion, the varus deformity appears during extension of the leg. This varus deformity has an angle which is determined by the amount of bone loss. When the total thickness of the cartilage is lost (around 5mm), there is an explosion of the bone on both surfaces and this leads to 5 degrees angle of varus deformation.

In order to confirm and diagnose AMOA, the clinical findings which are described above are enough. However some radiography imaging is useful as well. On AP and lateral imaging of the knee, we can see the bone on bone appearance especially in the medial compartment as well as the varus deformation of the knee, which is presented in most of the cases. In case the radiographs will not show the bone on bone appearance in the medial compartment, it means there is FTCL (full thickness cartilage loss) over the femur and tibia in the affected compartment, and it is possible to confirm that by the varus stress view.

Figure 4: Varus and valgus stress x-rays, obtained with the patient supine using a dedicated knee stress system, are important in order to assess the presence of full-thickness articular cartilage in the uninvolved compartment and to confirm full correction of the deformity to neutral. [21]

After performing the varus stress it is required to take the valgus stress view before proceeding to UKA in order to confirm the lateral compartment has full thickness cartilage.

4. Contraindications:

Patient's age, weight, level of activity, patella-femoral osteoarthritis and chondrocalcinosis could be ignored for mobile bearing UKA [5-7]. Some new studies show that obesity has no adverse effect on the outcome of fixed bearing UKA [8-10]. Moreover, it has been reported that existing of lateral osteophytes in the varus leg is not associated with cartilage wear in the lateral compartment and therefore it should not be considered as a contraindication for medial UKA [11-13]

Inflammatory arthritis, active infection, ACL deficiency (which is absolute contraindication for mobile bearing UKR & lateral UKA), fixed varus deformity over 10 degrees, fixed valgus deformity over 5 degrees, decrease arch of motion less than 90 degrees, flexion contracture of 5 to 10 degrees and above, previous meniscectomy in other compartment, previous high tibial osteotomy, all of these remain contraindication for UKA.

According to the Kozinn and Scott indications for UKA, it is reported that about 6-12% of the patients can be a candidate for the procedure UKR [14-16]. Whereas up to 50% of the patients can be candidate for the oxford criteria for the procedure UKR. [17-18].

5. Techniques:

Today in the modern world there are several techniques for performing UKA, from mobile bearing, fixed bearing (onlay design) and robotically or computer guided method (Makoplasty). The main differences between mobile and fixed bearing techniques involve strict adhesiveness to equalization of the extension and flexion gaps to refrain bearing 'spit-out'. The computer-guided MAKOplasty method uses preoperative CT studies to record anatomical landmarks in the operation room. The computer-guided system then helps and assists with the preparation of the bone on the tibial and femoral sides for proper implant positioning for adjustment of the preoperative plan.

UKA for anteromedial osteoarthritis with a functional and normal ACL utilizing a mobile meniscal polyethylene bearing has clearly shown 92.3% [25] survivorship at 20 years. Clinical results have been excellent in 91% of patients at a minimum 10 year follow up utilizing Hospital for Special Surgery Knee Scores. [26].

At the beginning a tourniquet has to be placed on the proximal thigh of the involved leg and a hanging leg holder is used to have the involved leg flexed at 30 degrees at the hip with enough abduction to allow at least 135 degrees of knee flexion without impingement on the surgical table. Current UKA is done by MIS - minimal invasive surgery approach. The main technique involves a small incision about 4 to 10cm in length [36], it is basically depends on the patient's skin elasticity and short and small medial arthrotomy from above the upper pole of the patella to the tibial tuberosity.

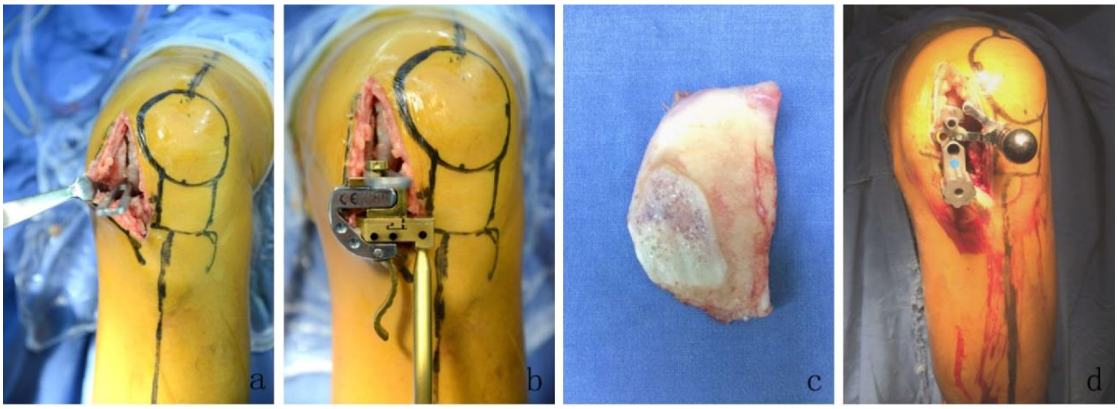


Figure 5: Sizing spoon was placed in the medial compartment restoring normal tension in flexion (a). The coupling clamp was used as a link between the tensioning spoon and the tibial resection guide (b). The resected tibial bone demonstrated anteromedial osteoarthritis with full-thickness loss of cartilage (c). An intramedullary rod was coupled to the flexion gap spacer by the linkage bar (d). Pilot holes of 4 and 6 mm [27]

Differences between Fixed and Mobile Bearing Design:

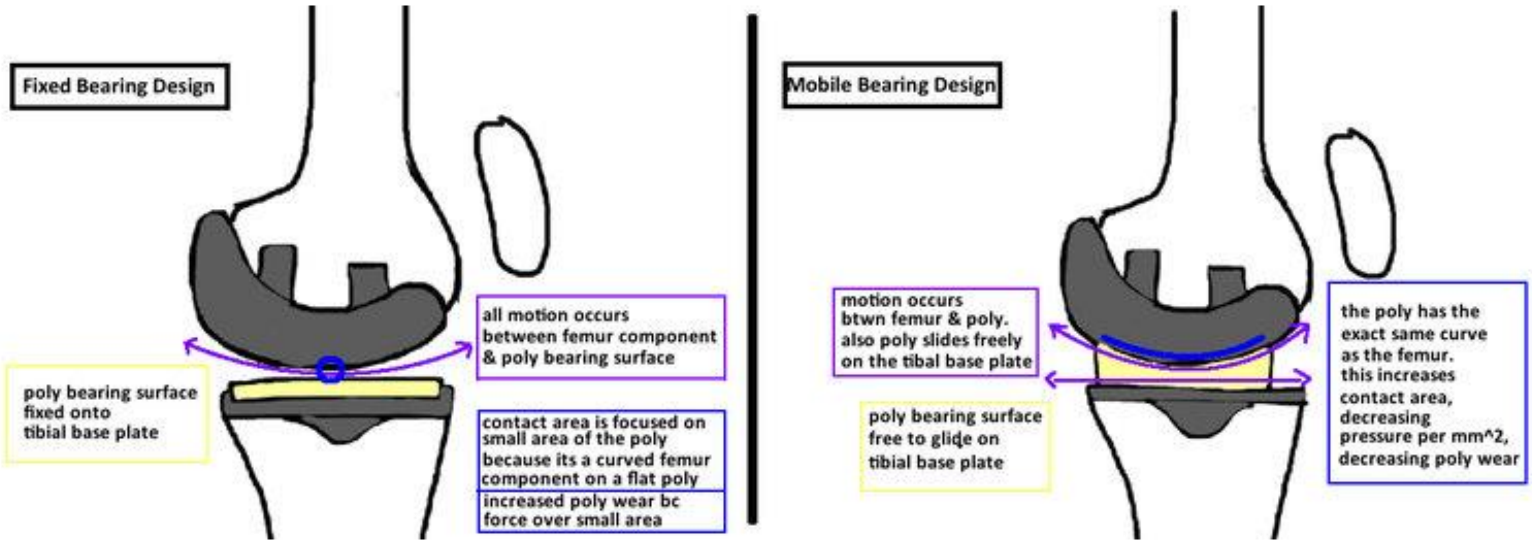


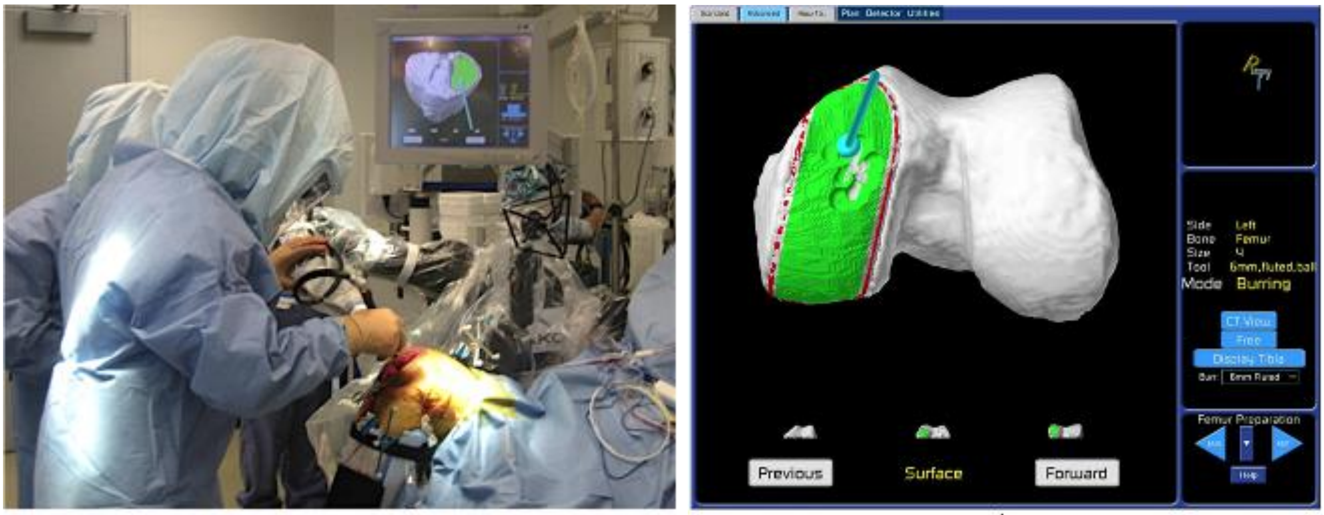
Figure 6: on the left side: Fixed bearing design. On the right side: mobile bearing design [28]

Figure 7: on the left side: Fixed bearing UKA. On the right side: Mobile bearing [28]

The fixed bearing design has to be fixed to the tibial plate. It has a flat surface thus the articular geometry offers no guided motion. Therefore, this kind of design can accelerate wear because the femoral condyle which is curved in shape is sitting on a flat poly. On the other hand, the mobile bearing design is a curved shape component which fits exactly on the femoral condyle component which means the contact area is increased compared to the fixed bearing design. Taking into consideration physical laws, the pressure on the poly is diminished which can reduce wears. Therefore, today many surgeons prefer the mobile bearing design which has an excellent survival rate.

Computer guided method:

Over the past decade, technology and regeneration have entered the medical world. With the creation of medical robots, it’s done in order to achieve better capabilities beyond the human hands. Resulting in an innovation that enhances the speed, accuracy and efficiency of many problems the medical world encounters. The RIO uses a moveable robotic arm that gives the surgeon tactile information and feedback of the cutting zone, which means that the bone cutting takes place only within the desired footprint area of the proposed implant and therefore eliminates the risk of some surgical mistakes and bone cutting error. The robot is navigated by the computer, and if it maneuvers outside the designated cutting area, the process shuts off. This technology is based on 3D CT images of the knee. Once it's done and it has entered into the robotic computer it starts performing segmentation. In this process each CT image is sketched with a computer probe and the shape of the bone finally being inputted into the computer. By this process accuracy is constructed.



a b

Figure 8: Illustration of the intraoperative setting for a unicompartmental knee replacement robotic surgery (a) view from behind the surgeon (center) showing him machining the condyle with support from the semi active robot arm based on the screen plan ;(b) computer screen showing the bone upper tibial bone model (white), the contour of the condylar implant cavity to be machined (red), and the machining progress (green) [30]

5.1 Unicompartmental Knee Implants:

The UKR requires from the surgeons to choose an implant fixation type which is used to connect the implant to the bone. The implant's material which most of the UKR consist of are metal on plastic. This means that the metal implants are mostly made of titanium or cobalt chromium, sometimes even ceramic caps for the femur and tibia. And between these metal implants, the surgeon places a spacer which is made of polyethylene and this plastic spacer can be either mobile or fixed. The implants material must be bio-compatible, in order to prevent the body to create any rejection reaction. Additionally, they should duplicate the knee structures and be able to preserve their shape and strength for an extended period of time. The implant fixation can be divided into 3 options: Cemented fixation, using polymethylmethacrylate. Cementless fixation which is based on growing new bone into the implant surface, thus attracting growth of new bone. And finally by the Hybrid fixation method where one component (femoral) is placed as cementless while the other component (tibia) is placed as cemented fixation.

In 1969 Engelbrecht developed the sled prosthesis (figure 9), which has metal-backed component. And in 1972 the first UKR was introduced by Marmor (figure 10), later the Oxford Group developed the mobile bearing prosthesis (figure 11) which now it has more than 20 years of follow up data worldwide.

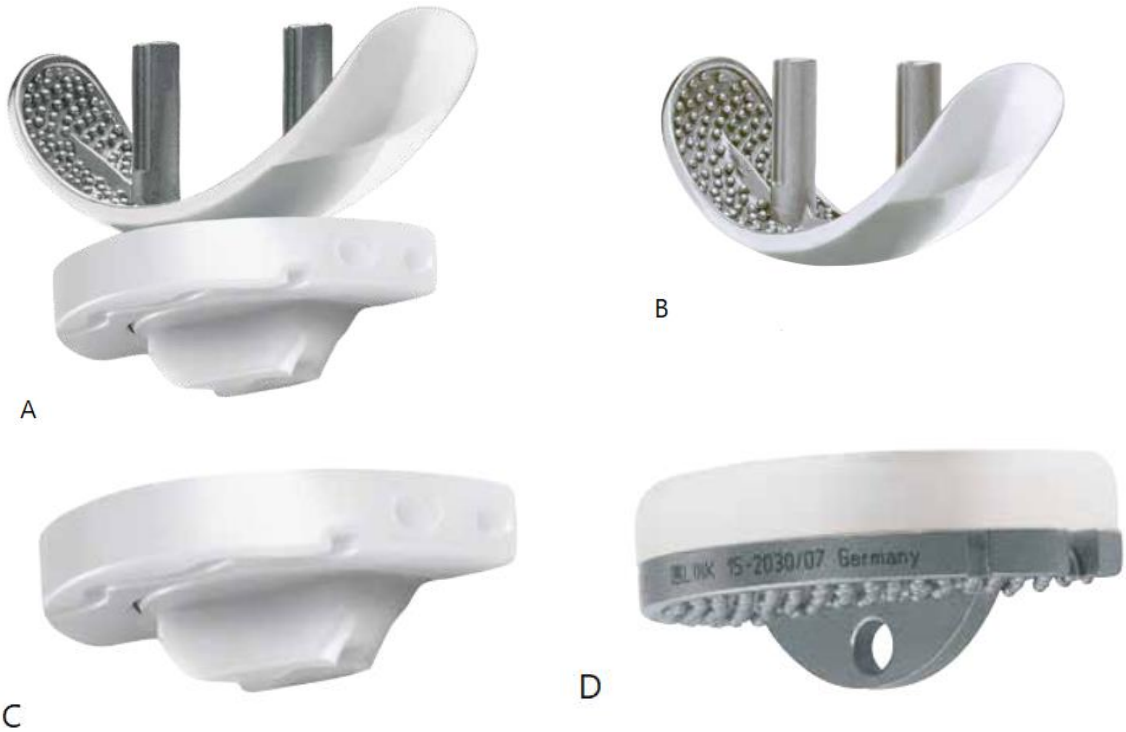


Figure 9: A: sled prosthesis B: femoral component C: tibial component (all-poly design), D: tibial component (metal-backed design) [31]

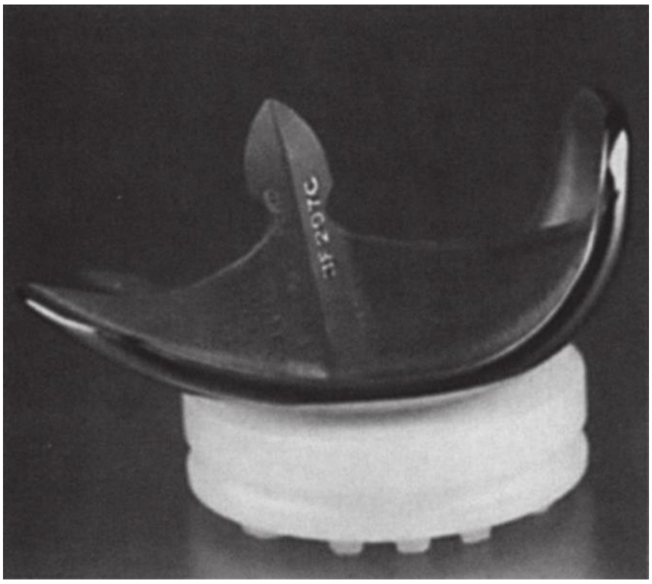


Figure 10: Marmor prosthesis [32]

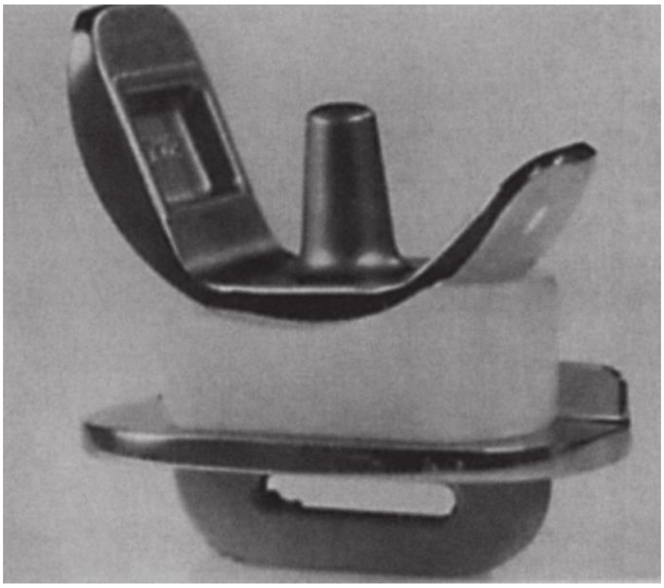


Figure 11: meniscal bearing Oxford prosthesis [32]

Today there are 20 and more companies that produce these unicompartmental prosthesis around the world (Figure 12)

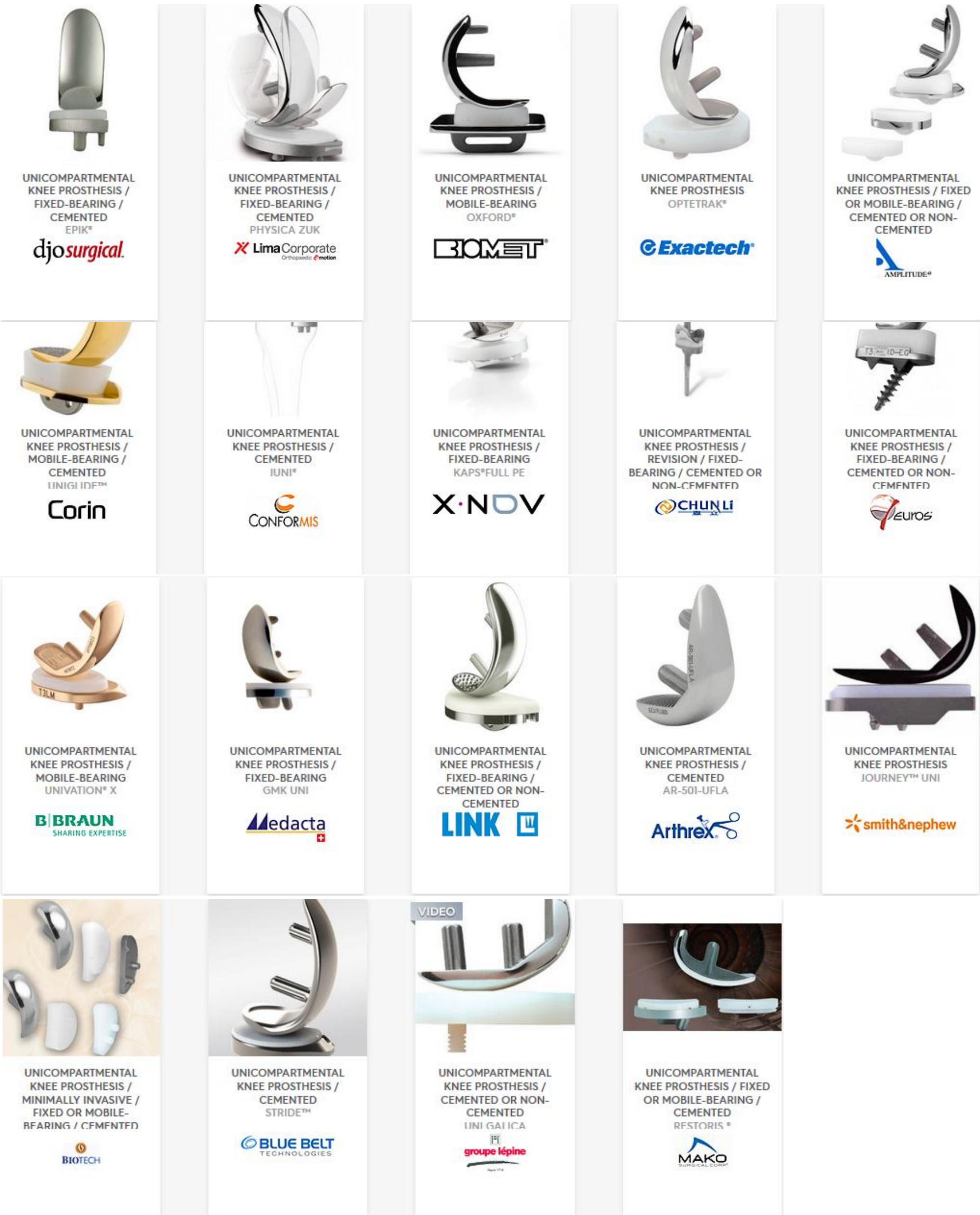


Figure 12 : unicompartmental knee prosthesis [33]

6. Failure and Complications:

Aseptic mechanical loosening with isolated tibial component and polyethylene wear[37,38] remain the leading cause of early failure (5 years) that is reported in fixed UKR (between 25%-45% of the cases) while sepsis is the less frequent failure in UKA compared to TKA (less than 1%) [37]. Even though the incidence rate of these complications are significantly diminished from the past until today with the use of the new implants and design [34, 35]. At the same time cautious patient's selection as well as novel instrumentation has significantly reduced the progression of osteoarthritis in contemporary UKR, and left the polyethylene wear the main mechanism and cause of failure of fixed implants. Following the aseptic mechanical loosening, the other common causes of complications are: progression of arthritis (15%), technical errors (11.5%), progressive degeneration of the unresurfaced contralateral compartment of the knee (1%-10%), unexplained pain (5.5%), failure of supporting bone (3.6%), DVT (1%-5%) and infection (less than 1%)[39].

Fractures can arise either with post-operative high activity or intra-operative with forceful impacting or implant. These fractures almost always involve the tibia pin sites which can lead to difficult revision scenarios. Therefore, it is crucial that during the removal approach, to perform it cautiously and avoid removal of too much bone. A patient that suffers from stress fractures might feel pain in intervals especially spontaneous pain during activity.

Other failures of UKR can occur due to: inappropriate surgical and/or cement technique, inappropriate component design, component malalignment, component failure and preforming the surgery on patient's that do not meet the indications or exceeded the recommended indications.

Figure 13: Disease progression of the other compartment from overstuffing, over-correction or misbalance. A: early loosening B: and wrong component positioning may lead to UKA failure [40]

Figure 14: lateral OA progression after medial UKA [41]

7. Conclusion:

Unicompartmental knee replacement is a safe, cost effective and excellent surgical option for people who suffer from unicondylar knee degeneration. UKA is an alternative option for TKA in cases of end stage osteoarthritis which is limited to a single compartment with an excellent survivorship rates for up to 20 years. The UKA accounts for about 5-50% of surgeries where knee replacement is indicated. While the most common location is in the medial compartment. During this type of operation there is a need to use an implant, where there are 2 types of implants, the mobile bearing and the fixed bearing. Besides that, UKA offers to the patient faster rehabilitation and recovery, less morbidity and less blood loss. This procedure preserves the normal kinematics of the knee.

8. Acknowledgment:

I would like to acknowledge my mentor: Associated Professor Mislav Jelic, MD, PhD for mentoring me on my thesis paper. I am grateful for his support, guidance ,valuable comments and feedback on my thesis. I would like to thank to Professor Domagoj Delimar, MD, PhD and Professor Tomislav Dapic, MD, PhD for reading and examining my thesis.

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10. Biography:

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His hobbies included travelling, playing guitar music, and watching movies among others.