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Native Hip Anatomy Restore with Different Type of Hip Prosthesis

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Table of Content

I. Summary

This narrative review discusses the newest available clinical studies and data which are concerning the restoration of the native hip anatomy with prostheses. The three main arthroplasty styles of Total Hip Arthroplasty, unipolar and bipolar Hemiarthroplasty and lastly Hip Resurfacing Surgery are presented. These surgeries are very common and worldwide executed with increasing prevalences due to the more ageing population.

In this review, newest data for prostheses including indications for these arthroplasties like osteoarthritis and osteoporosis are presented, as well as the natural anatomic gait laboratories, surgical approaches, templating variations, new robotic technologies and fast-track surgeries. Additionally and importantly, numerous materials as well as fixation styles, stem lengths and various complications, including impingement, femoral neck fractures and dislocations are thoroughly displayed and discussed. More in depth matters like alignment styles and the reason behind them, as well as revision rates in various scenarios are displayed additionally.

Ultimately, it is important to note, that every new technique is based on the surgeons' abilities and moreover on the patients' comorbidities. This narrative review's ultimate goal is to differentiate various types and topics concerning prostheses and the restoration of the anatomy by comparing new available data, different opinions on new techniques and thus, display the most important key points to achieve the best possible outcome during these surgeries.

a. Key words

Total hip prosthesis, hemiarthroplasty, hip resurfacing arthroplasty, approach, cementless, materials, prosthetic stem, osteoarthritis, templating, femoral neck fractures, complications

II. Introduction

Restoring the correct hip anatomy remains a challenge in Total Hip Arthroplasty surgeries.

The possibilities arthroplasty surgery offers nowadays help millions of patients each year to minimize symptoms including pain and therefore offer the restoration of possibilities of increased range of motion and thus everyday tasks including walking, sitting, and climbing stairs symptomless. Different types of arthroplasties are total hip arthroplasty, Hemiarthroplasty, and hip resurfacing arthroplasty. These surgery variations are indicated in different scenarios, which will be discussed in this paper.

Still, there are topics that need further research and investigations to eventually be able to minimize or diminish complication risks and therefore offer the patient a guaranteed unproblematic pre-, intra-, and postoperative process. This includes faster and more accurate robotic technologies, correct prosthetic component selection, improved modular head-neck adapter systems, precisely accurate prosthesis positioning, alignment, and correct offset to therefore decrease the complication risks more. Those include limb-length differences, infection, prostheses failure and importantly dislocation.

In this narrative review, the newest literature, data, and clinical evidence concerning restoring the native hip with hip prosthesis, will be discussed. The ultimate goal of this review is to differentiate and claim the best type of prothesis for different possible situations for restoration of the native hip with different types of hip prosthesis. To get more into detail, the main objectives are different prosthesis including their materials, coatings, shapes, insertion, and fixation styles, but also general arthroplasty indications, surgical approaches, risks and clinical outcomes, new technologies in templating and robotic-assistant surgeries, revision surgeries and their risks, as well as possible complications and consequences.

Thus, this evaluation may offer a clearer perceptiveness into the question how the native hip may be restored with the newest available technologies in different scenarios with prostheses.

III. Literature selection strategy

For this narrative review, searches on Google Scholar and PubMed were conducted. Also added were relevant articles and journals, including MDPI, Elsevier and Springer Link. All articles were published and read in English. The search was done between August 2023 and April 2024. All the used data and studies correlated to Hip Arthroplasty, especially concerning the three different Arthroplasty types, their diagnoses, indications like osteoarthritis, surgical approaches, and their differences each. Additionally, new studies and meta-analyses on templating and new robotic technologies, advantages of cementless over cemented implantation, different fixation styles and in what age group these are indicated, were conducted. Assessment of data various materials and new classifications were included. Moreover, various complications, their risks assessment and possible prevention methods, which were proven in various studies, were evaluated and integrated. The cut-off point was 2015 to exclude older data, whereby it is important to mention that these were an exception as nearly all sources were younger than 2020. Further exclusion criteria incorporated studies not directly related with arthroplasty, case reports, single conductive studies, or studies with under 30 participants. Also, publications incorporating indications different than osteoarthritis, osteonecrosis, and fractures, studies which only focus on non-prosthetic or conservative anatomy restoration and lastly, articles not accessible in full text were excluded.

VI. Clinical description

Hip protheses are designed to restore the hip anatomy and thus its function by replacing different parts of the hip joint, depending on the type of prothesis.

The main indication for hip arthroplasty is symptomatic osteoarthritis, osteonecrosis, and hip fractures. (1) Additionally, osteoporosis may alter the bone quality and therefore play a role during arthroplasty surgery. (2) Osteoarthritis and fractures will be the main focus on this narrative review. After explaining different styles of hip arthroplasties, to understand the underlying conditions which lead to the necessity of repairing and restoring the native hip anatomy with hip protheses, next explained will be the damages to the joint by osteoarthritis and shortly. This will be followed by descriptions of the hip anatomy to underline which structures need to be replaced in order to achieve a good functional outcome.

During a total hip arthroplasty, the hip joint is replaced with a femoral head, stem, and acetabular cup. As there are different implant styles, a polyethylene liner or different compartments may be included as well, which will be thoroughly explained in this paper.

Hemiarthroplasties (HA) are partial hip replacements, with an exchange of the femoral head and neck. They are divided into unipolar and bipolar. HA are often the first choice of surgery in elderly patients in cases of Femoral neck fractures (FNF) according and depending on the AO classification of the fracture. Therefore, indications of THAs and HAs differ, as THAs are mostly performed due to OA (about 85%). The differences in unipolar and bipolar HAs, as well as its comparison to THAs will be discussed in this paper. (3) The third hip arthroplasty surgery is hip resurfacing surgery (HRS). Here, the femurs head is covered with a prosthetic cap and thus less native bone is removed in comparison to THA and HA. (4)

VII. Osteoarthritis and Osteonecrosis

The hip joint is an enarthrosis and one of the most weight holding joints of the human body. The highest indication rate for hip arthroplasty is symptomatic osteoarthritis (OA). These symptoms mostly include pain during internal rotation, morning stiffness of <60 minutes, reduced walking distance and daily living disability due to reduced hip rotation range of motion (ROM) by pain. (5) In OA, there is a characteristic progressive loss of structural integrity of articular cartilage and underlying muscle, ligament, joint margins, and subchondral bone structure. In Europe, >40 million citizens are affected. Females are more prone to OA. They have a higher prevalence of inflammation rates, pain, physical difficulties, decreased cartilage quantity, and smaller joint spaces in comparison to males. OA is differentiated into primary and secondary advanced types. About 10-15% of adults > 60 years suffer from it worldwide. OA is more prevalent among the elderly. These prevalences are described in a study done in Germany in 2015 by the Robert Koch Institute, the prevalence of OA in 45-64-year-olds is 23,2% in women and 16,6% in men, rising to 48,1% in women and 31,2% in men among people above the age of 65. (6)

One of the reasons for progressive loss of the cartilage in OA is the forces that are wearing the joints down chronically by everyday tasks like walking or standing, especially in cases of obesity or overuse. Genetic factors and chondrocytes age related changes are further risk factors. The cartilage damage occurs predominantly due to an imbalance between the time of joint tissue repair and damage. Irreparable damage of the cartilage is inevitable in case of a decreased matrix synthesis but increased degeneration within the hyaline cartilage that is lining the articular surface, as well as the daily deterioration of the joint. Softening, ulceration, facilitating fracturing, eburnation, and swelling lead to typical symptoms of joint deformity, pain, and stiffness. After cartilage loss started, cysts and osteophytes may form. (7) Generally, if symptoms are progressed too far, conservative OA treatment is not sufficient, and arthroplasty is the ultimate choice.

Next to OA, Osteonecrosis (ON) is an indication for THA. The prevalence of avascular necrosis or ON is rising among younger patients worldwide, with a current incidence rate of about 15-20.000 new cases annually in the United States. ON of the femoral head (ONFH) describes a condition of necrotic femoral head lesion due to disrupted blood supply. As lesions vary in sizes, exact location and risk of progression, different treatment options including bone grafts, resurfacing arthroplasty and especially THA are available. Still, more research in treatment outcomes with these surgeries and additionally medication therapy is needed. (8) As about 10% of THAs are indicated by ON, it is an important factor in terms of revising to the native hip. (9) Interestingly, OA and ON are both states of disruptive bone, especially of the femoral head. While comparing them in terms of THA outcomes, a study by Salman et al. from 2023 proved, that OAs revision rates were statistically significantly lower, while dislocation and HHS rates were about equal after THA. The Harris Hip Score (HHS) is a measurement scale of joint functionality and thus possible dysfunction of the hip implant on a scale of 0-100 – low scores meaning poorer joint function and a level of above 70 is set as good result. (10) This may be due to the still intact blood supply OA offers and different confounding factors. (11) Concludingly, concrete knowledge about not only OA but ON is essential in establishing THA treatment options due to its rising prevalence.

VIII. Natural anatomic gait laboratories

To be able to reconstruct the natural hip anatomy, the development of natural anatomic gait laboratories with the increased knowledge of hip biomechanics are from great importance.

The hip joint is a ball-and-socket joint and moving in three planes: frontal, sagittal and transverse. The entirety of its stability offering structures will be explained in the following part for better understanding of what the prostheses need to replace.

For ensuring stability, mobility, and balance of the hip joint, the capsular ischiofemoral, iliofemoral and pubofemoral ligaments play a major role. For capsular strengthening during extension and external rotation of the hip joint, the iliofemoral ligament is attached from the anterior inferior iliac spine to the femoral intertrochanteric line with its two branches.

The ischiofemoral ligament strengthens the capsule during internal rotation, flexion, and adduction movements. It extends from the ischium to the acetabular rim posteroinferiorly and reaches the posterior intertrochanteric line. For excessive abduction and external rotation restriction during hip extension, the pubofemoral ligament has its insertion at the superior pubic ramus and together with the other two ligaments reaches down onto the femur.

Important for the structural stability and proprioception is the ligamentum teres. With its small vessels within, it innervates the femoral head while placed between the fovea of the femoral head and the inferior acetabular notch. Its ability decreases with ageing.

A stability providing collar enclosing around the femoral neck is formed by circular fibers from the zona orbicularis. Thus, during deep hip flexion, it secures the femoral head posteriorly, while during hip extensions, the zona orbicularis stabilizes the femoral head anteriorly.

(12) Releasing the iliofemoral ligament in THA is performed during capsulotomy, to gain better access to the femoral head and neck. As this ligament limits the hips external rotation and extension, instantly after releasing it, a significant increase in movement is achieved, as described in several studies.(13) Some studies claim, that preserving the iliofemoral and pubofemoral ligament support restoration of the hip's offset and the even leg length. Thus, not only the native anatomy is restored but the patients' functional ability is ensured. (14) Nevertheless, it needs to be stated that as the releasing of the ligament increases movement, in case the arthritic hip joint is too instable, releasing the iliofemoral ligament may be leading to extreme instability. Thus, the mobility increase is not worth the stability concerns in these cases. Therefore, while planning the operation, the patients individual state of intracapsular conditions, how tight or stiff the patient's joint may be, and the joint stability need to be evaluated before deciding how to eventually restore the hips physiological anatomic functions. (13)

IX. Diagnoses

To diagnose OA and thus to indicate arthroplasties, radiograph review is the most fundamental tool. (15) It can show nonuniform joint space loss, subchondral cysts and sclerosis as well as marginal osteophyte formation. (16) As in any radiographic diagnostics, a minimum of two planes are essential for being able to get a clear view of the structure's dynamics. Here, a radiograph of the pelvis in antero-posterior (AP) and in lateral perspective is necessary. In the

AP radiograph of the entire hip, a possibility of comparison of both hip joints is given. Thus, joint deformities and abnormalities are easier identified, as well as detection of bilateral OA and different grades of disease progression. (17)

X. Comparison of arthroplasty surgeries

After discussing the natural anatomic gait structures and diagnosing, the three arthroplasty types can be compared and explained in detail. In comparison to THA, in HRS a lesser amount of material is used. Thus, the surgery is less invasive and faster recovery time is achieved. Hence, HRS is mostly performed in young and active patients with osteonecrosis to offer them a possibility to return to a high-level active lifestyle faster. (18) Additionally, wear and tear risks and dislocation risks are lower. Possible revision surgeries are not as frequent and not as invasive due to previous bone preservation. Moreover, material induced complication risks like increased metal ion levels, are reduced. (19) Commonly used are titanium, cobalt blood concentrations and chromium. (18) Metals will be explained in detail at a later point.

As explained above, the main indication for HA is Femoral Neck Fractures (FNFs). Generally, in FNFs, the surgeon decides whether a fix of the fracture or a HA is needed. (3) Internal fixations are considered with later mobility, more reoperations and decreased functional outcome one year postoperatively. (20) To be able to discuss HAs thoroughly, FNFs will be discussed before continuing the comparison of arthroplasty styles.

FNFs are frequently induced by OP and a challenge in terms of complications. Its incidence is increasing due to the fact of generations getting older and thus, increasing numbers of osteoporosis occur. Additionally, with the older ageing population, bone quality and other risk factors increase, which then again lead to higher risks of FNF as well as a general increased complication risk for any surgery. In the United States, statistics predicted that 6,26 million cases of FNF by 2050 will occur. This number is crucial, as a statistic has shown, that there is a 15% chance of mortality due to FNF despite surgical treatment. Of course the need for treatment and surgery therefore also plays a big role financially for health institutes and hospitals. Surgery following FNF does not only include THA but also internal fixation and bipolar and bipolar HA. An American meta-analysis has shown better patient outcome and lower cost in THA without Dual mobility cups (DMC) in comparison to internal fixation and HA in these fractures. Still, postoperative dislocations, especially in THAs, must be considered. HAs are differentiated into unipolar and bipolar. Unipolar HAs compared to bipolar HAs consists of fewer components and material, it costs less and is simpler in inserting. Bipolar HAs on the other hand are more modular due to the inlay, thus, arguably offer a greater range of motion and have a lower risk for dislocations. Additionally, bipolar HAs have less acetabular

wear, protrusion and is associated with less pain postoperatively. In terms of the question on which patient group to do a bipolar HA on, many studies have been performed.
Khan et al. compared cemented unipolar and bipolar HAs to show differences in clinical outcome in 120 patients >60 years of age with traumatic FNF. Remarkably, initial assessments at the 3-months follow-up revealed a discrepancy in the mean HHS, with the bipolar group achieving a score of about 75,8, two points higher than unipolar. Nonetheless, no substantial disparities were observed between the two groups over the progression of the follow-ups to 6, 12 and 24 months. Additionally concerning mean operating times, the modular bipolar approach requiring an average of about 10 minutes longer. Both groups showed a similar incidence of acetabular erosion, affecting 4.5% of patients in each group. This percentage is considerably lower than that of previous, comparable studies.
Furthermore, mild coronal plane misalignments, stem varus and valgus were observed in a few patients in the unipolar group contrary to the bipolar group, in which no such misalignments occurred. Supporting the corresponding existing literature, the presence of coronal plane misalignment in the unipolar group did not significantly affect functional outcomes.
In conclusion, there was no substantial difference of unipolar and bipolar HAs in the functional outcome looking at the long term follow ups, although the operation time was statistically significantly longer in the bipolar group.(3)

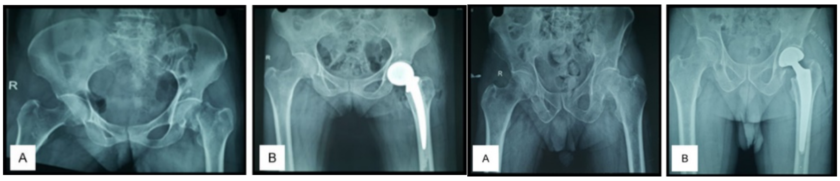

Figure 1: Pre-and postoperative AP X-Rays, unipolar HA (left) and bipolar HA (right). (3)

For comparing this data to another age group of patients, Moon et al. performed bipolar HAs on patients under the age of 60. They concluded that the 114 participating patients showed a quite high conversion rate to a THA after 10-year follow-up. BMI of the patients played a large role as well as age. As long-term survival thus cannot be ensured for young and active patients, before deciding on implanting a bipolar HA, careful consideration is advised.
Concluding, bipolar HA are a good choice in traumatic FNFs in elderly patients, while in young and active patients, especially with a higher BMI, the extend of risk factors that are affecting long-term survival need to be established. (21)
According to the AO classification, in young adults, internal fixation is mostly advised, and arthroplasty should be avoided if possible. This is to ensure a union of structures in FNF, as well as maximize the potential of reestablishing prefracture mobility. While this is also the goal

in elderly patients, their treatment goal additionally consists of avoiding long bed rests and offer instant weight bearing postoperatively. (22) When comparing HAs to THAs, it is noticeable that HA is associated with higher rates of surgical site infections (SSI) and mortality when set in comparison with THA. A French study by Grammatico-Guillon et al. underlines this statement. Here, SSI risks in THA and HA were compared by including individual patient confounding factors. Their results showed a significantly increased SSI rate in HAs. Mortality rates were higher in HA as well as in THA with 7% and 4%, respectively. Thus, while indications are different in these surgeries, THA has lower risk and complication rates even though more native anatomy, especially bone, is replaced. (23) Thus, next to tranexamic acid to reduce blood loss, in many hospitals, cephalosporin is given to the patients prophylactically thirty minutes preoperatively to reduce infections, which may be set as prevention as well. (24)

XI. Templating and Robotic Technologies

Templating is used to plan procedures like THA preoperatively. Implant sizes, restoration of the center of rotation, alignment, positioning, and limb lengths are predicted precisely. Thus, it increases the surgical process efficacy and decreasing postoperative complications. Also, it helps to avoid limb length differences, periprosthetic fractures and implant failures due to instability including dislocation, component loosening, insufficient offset reconstructions. Also, it shows reduced operation time and therefore costs.

While templating was previously done analogue by measuring and outlining on transparencies, nowadays digital templating offers more precise and dependable plans. Planning the implants size has a success rate of about 98%, this will be discussed in detail later. (25) For templating, anatomical bone landmarks are the greater and lesser trochanter, the medullary canal in the diaphysis or the acetabular roof, which need to be identified. Especially good for planning is a low AP pelvic radiograph because the beam center is put on the pubic bone and the proximal femur is visible well, which is important for measuring the pelvic tilt. Even though AP X-ray is most helpful in templating, axial and in some clinics lateral, like Dunn lateral, is used. Here, different rotation angles are seen. (17)

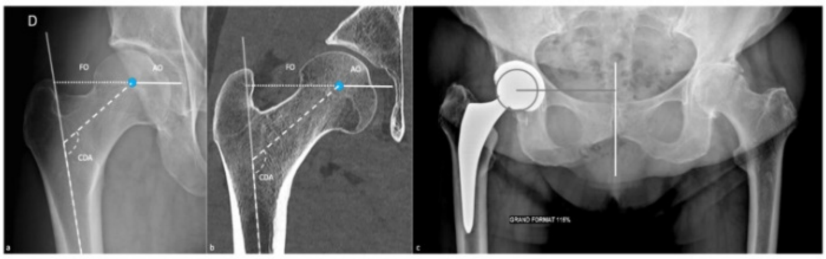

Figure 2: Images for templating including X-Ray and CT (1)

An example of preoperative planning is shown in Figure 2: an AP radiograph (a) and coronal CT (b). The white line of the acetabular offset (AO) is measured in between the acetabular floor and the femoral head center (blue circle). It can also be measure between the center of rotation and the abductor musculature The femoral offset (FO) is drawn as a dotted line in-between the femoral midshaft axis and the femoral head center. Cervicodiaphyseal angle (CDA) is seen as large, dotted line. It is important to measure AO from the pelvic midline instead of the pelvic floor (seen in image (c)) to ensure correct measurement especially in

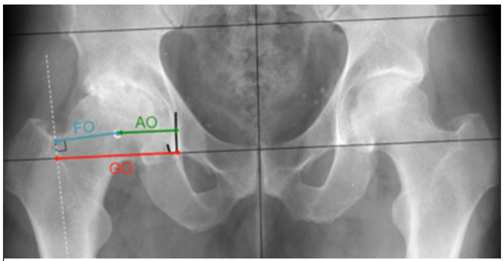

Figure 3: Globular Offset as sum of Femoral Offset and Acetabular Offset (28)

cases of cup protrusion. (26) As seen in the Figure 3 above, Global offset is described as the sum of AO and FO. (27) The mean FO is 41-44 mm, and most studies show that it is influenced by the neck-shaft angle as it decreases in valgus and increases in varus position. Additionally, it decreases with anteversion. Concludingly, to be able to evaluate FO, accurate measurements of femoral anteversion are essential. As anteversion plays a large role in FO, it will be discussed thoroughly at a later point.

As mentioned above, the Lower limb length discrepancy (LLLD) is an important factor in templating THA, as it is the most frequent litigation after THA. Even though cut-off point has not been established yet, it is known that above 10mm difference affects the clinical outcome by gait disorders, instability, back pain, and sciatica. Moreover, it can lead to pelvic obliquity, need for shoe rises and is associated with an increased risk of osteoarthritis in the operated leg and increase aseptic loosening. Its prevalence can range from one to 50%, though when taking careful consideration, it can be minimized below 10mm in 97% of cases. To reduce this risk, anatomical landmarks, computer – or robotic assisted devices and therefore thorough templating and intraoperative controls are essential. (27)

It is important to discuss the natural pelvic tilt more, as it is important for templating. It is measured by the distance between the upper border of the symphysis to the projection of the

Figure 4: pelvic tilt (red), sacral slope (green), pelvic incidence (blue) (15)

sacrococcygeal joint in the sagittal plane. In women it is about 32mm and in men 47mm long. To not miscalculate FO and neck lengths and therefore miscalculate the needed prosthetic shafts length, both femora need to be rotated internally with 15 to 20° on the X-ray. If measurements like size, position shape and type of implant are prepared via digital X-ray planning, they can be done more precisely and are easily accessible during the operation. (15) To be able to restore the native hip anatomy, during templating, the patients' individual spine-hip relations need to be defined. It describes the relation from the hip joint to the lumbo-pelvic complex and include three parameters: the pelvic tilt, pelvic incidence, and the sacral slope. These relations are visible in a lumbo-pelvic lateral radiograph and offer a kinematic alignment technique. Thus, as Riviere et al. says, the acetabular anteversion, as well as the center of the rotation as directed by the spine modification, equals in restoring the native anatomy. As this is an important topic in THA, it will be discussed thoroughly below. While pelvic incidence is constant in everyone, during different body positions, pelvic tilt and sacral slope vary. To adapt the cup position, the transverse acetabular ligament (TAL) is used as a reference. TAL is a load-bearing structure inferiorly to the bony part of the acetabulum, which, together with the labrum, supports the femoral head.

In Primary prosthesis implantation, mostly X-Ray is used and sufficient. For revision THA for example, CT is advised to use additionally to be able to see possible damaged structures more clearly, including bone, prosthesis compartments and surrounding tissue. CT is a good image for templating, but not yet introduced as routine, due to its cost and time consumption. Though, as beams are not as harmful in new CT technologies as they were years ago, this argument for not using CT is not as strong anymore. (1) 3D view offers a great possibility in templating, but it remains costly and with more side effects than x-ray. Thus, primarily used in templating remains x-ray over CT imaging in many hospitals, while CTs accuracy remains undisputed. (1) Generally, robotic assisting and therefore 3D planning is the best technology for templating there is on the market, but which has some complexities, as it remains costly and unavailable in many hospitals. (1) Robotic technologies are used more frequently in assisting templating and intraoperatively. They decrease malpositioning and achieve a more accurate intraoperative execution and preoperative planning of implant sizes and positioning for in respect of e.g. global offset, leg length discrepancies and implant alignment to overall ensure a more accurate restoration of the native hip anatomy. Additionally, companies like Stryker promise next to reducing the likelihood of dislocation, to replicate the feeling of a natural joint. (28) A CT scan on the patient's hip is used to create a 3D model. Bone structure, native joint alignment, disease severity and surrounding tissue is evaluated by the surgeon, as well as implant size, placement and alignment are measured and planned. During the operation, the MAKOs robotic arm creates a virtual movement boundary, assesses the surgeons' tension, movement and guides the implants to the anticipated angle for insertion. (29) In the last years, semi-autonomous robot assisted devices used for templating THAs were invented and developed. Their goal is to ensure an even more precise and accurate placement of the prosthetic cup, therefore improve the implants stability and decrease intraoperative complications to ensure an improved long-term result. In a Canadian retrospective cohort analysis published in January 2024 with patient data from 2021-2022, a new fluoroscopy-based robotically optimized total hip arthroplasty planning technique (RA-THA) was tested for accuracy. These outcomes and numbers are compared to outcomes of the existing unassisted manual THA (mTHA) technique. 199 patients were analyzed. The goal was to establish the difference in accuracy of templated and implanted component sizes for the femoral head and stem sizes with these two techniques. All 199 cases were templated with mTHA technique, 93 cases additionally were templated with the new fluoroscopy-based RA-THA and therefore had two preoperative planning techniques done. In all cases, a direct anterior approach for a first-time unilateral hip prothesis due to osteoarthritis, inflammatory arthritis or avascular necrosis was performed excluding patients under the age of 18 and cases of femoral neck fractures. Demographic values like BMI, gender and age at the time were considered. The surgical methods and perioperative care and management remained the same, with the sole exception being the use of robotic assistance in one group. While during the mTHA anatomic landmarks need to be identified manually on uploaded AP radiographs in order to generate an operative plan, the RA-THA automatically detects landmarks and auto-generates all templating information including leg length differences, offset, implant positioning and sizes etc. The templating then may be adjusted further by the surgeon. The study's result show that the new RA-THA planner is highly accurate for evaluating implant sizes, as they were >90% identical with the later implanted sizes including the acetabular cup and femoral head. The matching of templated and eventually implanted femoral stem size was improved by 11%. (29) The outcomes of this study show that nowadays, using robotic-assisted increases the ability of restoring the native hip anatomy with protheses and can be advised to use. In comparison to the previous study, a British study published in April 2023, patient-reported outcomes measures (PROMs) of robotic-arm assisted arthroplasty (RO THA) were compared to conventional THA (CO THA) with a follow-up range of three years. One surgeon performed 100 THAs on patients who had symptomatic osteoarthritis and a primary THA performed between 2016 and 2018 with the at the time invented robotic technology, respectively. There were 50 patients in each group. Measures included the Oxford Hip Score (30), which is a patient focused tool for measuring functional disability (31), University of California at Los Angeles score, a questionnaire which assesses possible physical activity levels (32) and lastly the Forgotten Joint Score (FJS). This score evaluates the patient's awareness of the artificial hip joint. (33) The results showed higher FJS scores for the RO THA group, which, nevertheless, did not reach statistical significance. Nonetheless, cup positioning was more accurate in the RO THA group, as well as the restoring of native joint mechanics and thus, better long-term functionating. Also, this study reported about a matched cohort study including a five-year follow-up, which additionally showed a reduced risk of placing the acetabular component outside of the established safe zone. Though, overall, the difference in accuracy of cup positioning did not show impact in evaluating the PROMs, as both groups were seen with excellent long-term functioning and satisfaction. By that, this study showed, that the RA THA technology was slightly more accurate in a sense of restoring the native anatomy but without a statistically significant difference in patient-focused scores. Concluding this study, it needs to be noted, that for these patient groups, trials with a longer period of observation are essential for thoroughly understanding any potential functional advantages for RA THA patients. (30) In comparison to these studies, a French propensity score study published in February 2023 made a similar comparison by evaluating one-year postoperative outcomes of acetabular RA THAs in comparison to manual implanted THAs. Each group consisted of 98 patients. For RA THA the MAKO robotic arm was used. Here, comparable values were met, as this study concentrated on comparing functional results by also including FJS scores. In this study, postoperative complications, and the influence of symmetry in radiographs on postoperative function were compared additionally. While no cases of material loosening or need for revision were stated in the previous described study from Britain, in this study, the revision rate was higher in the non-robotic assisted group with 5,1%. Additionally, FJS scores showed higher values, as well as the rate of abarticular pathologies, e.g. greater trochanteric bursitis, were statistically higher for RA THA patients by a difference of 8,8% total. Furthermore, robotic acetabular assistance for positioning showed a higher success rate for exact implant placement to reduce the Global offset, which states the femoral lateralization and offset for rotation. Though, neither robotic femur navigation, nor lower limb length showed an improvement in RA THA in comparison. Concluding, this study showed a statistically difference for restoring the hip joints native anatomy in some terms of implant placement, especially including minimizing global offset, improving FJS score results, as well as reducing abarticular pathologies, leading to reduced short-term complications. (34) The comparison of these studies outline that RA THA is leading to a better outcome of restoration of the physiological anatomy, as the implant placing intraoperatively as well as the accuracy in planning the right sized implants is assured. At the same time, these comparisons lead to the conclusion that more data for patient related outcome, for example measured in scores, need to be done. A reason for the difference in these FJS score results may be the number of participants, the periods of time between the operation and the questionnaire, or differences in outcomes of articular leg lengths discrepancies, as well as limited expertise in the British one-surgeon study.

XII. Surgical Approaches

In THA, there are three main surgical approaches. Firstly described are lateral, posterior, and direct anterior approach (DAA). The lateral approach (LA) includes splitting musculus gluteus medius and reveals access to the hip joint anterolaterally. During posterior approach (PA), to access the hip joint posteriorly, musculus gluteus maximus is split, while avoiding splitting the hip abductors. This approach provides a very good exposure of the femur and acetabulum. Compared to the other approaches, it is linked to an increased risk for dislocations, which may be reduced by careful posterior soft tissue repair and cautious implant positioning. The DAA describes opening the hip through intermuscular and inter-nervous planes between tensor fascia latae and musculus sartorius. The advantages of this direct approach include faster recovery, lower dislocation risk due to minimal invasiveness and thus, shortened hospital visits. (35) In comparison to the conventional anterior approach (AP), it is more minimally invasive as its incision is smaller. (36) Which approach is the most profitable in general is widely discussed. Generally, DAA has gained popularity during the last years due its many benefits. For example, in a study from June 2023, DAA HAs after femoral neck fractures showed many benefits on geriatric patients. Here, 50 patients with DAA had reduced blood loss intraoperatively and a shorter recovery. Significantly more patients walked with walking aids quicker compared to 50 patients with LA. Thus, DAA is recommended in patients for bipolar HAs by displaced femoral neck fractures. Generally, DAA is viewed as the approach with fewest complications and thus as the best approach not only for HA but for THA as well. (37) A study from 2024 compared newest meta-analysis and newest data to compare approaches benefits and complication risks. Here, techniques called direct superior approach (DSA) and supercapsular percutaneously-assisted total hip (SuperPath) were integrated as well. These two techniques are sparing the musculus quadratus femoris, musculus obturatorius externus and the iliotibial band. In comparison to LA, DSA show results of decreased blood loss, increased muscle strength and postoperative gait. SuperPath showed shorter incision length, which ultimately leads to decreased infection rates, and faster mobilization. DAA showed beneficial results in many aspects, but especially in reduced pain, faster recovery, and mobilization time. Still, nerve injuries were seen quite frequently.

Concludingly, significantly higher long-term HHS in DAA was seen, which underlines that DAA is the most beneficial and highly advised approach. It was directly followed by DSA/ SuperPath, which also showed better outcomes in patients compared to lateral approaches. (38)

Generally, most available studies and data conclude with DAA being one of the best approaches. Older studies comparing anterior approaches to LA and PA showed significantly higher complication rates. (39) The reason could be, that the anterior approach is more invasive than LA and PA. This underlines again the benefits of DAA. Secondly, due to the different patient comorbidities and other individual patient and surgeon factors, results may differ in each study. Concluding, these findings may support a surgeon's decision for choosing an approach in hip arthroplasty. Though, the surgeon's choice needs to be guided and supported by justifications, but most of the current available data does recommend DAA above others. Further studies are needed to evaluate the new techniques further. Nevertheless, the chosen approach is in some cases still based on the surgeon's experience, knowledge, and individual parameters. (37)

During surgery, it is advised to reveal the acetabulum entirely and use an instrument as the Hohmann to expose the TAL by placing it inferiorly. The TALs position is independent from the patients' position. According to Beverland, to achieve the correct anteversion and therefore center of rotation, the prosthesis cup is to be installed parallel to the TAL. (15) To check for

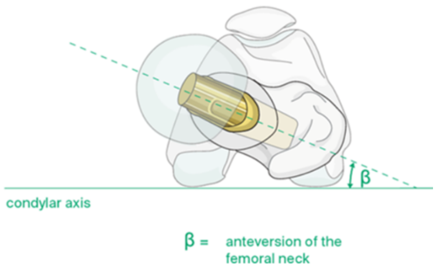

Figure 5: Anteversion of the femoral neck (41)

correct alignment, visualizing a line along the center of the mediolateral dimension of the femoral neck to guide placement is advised. Based on this line, the slot for the stem should be placed slightly posterior or exactly in the center of this line.

For optimal positioning, it is necessary that the medial edge of the femoral stem is exactly aligned with the center of the concavity of the medial femoral neck (40) as illustrated as angle β for the anteversion in the Figure 5. Excessive anteversion and retroversion need to be avoided, as they may lead to anterior or posterior dislocation respectively. (41) Additionally, as

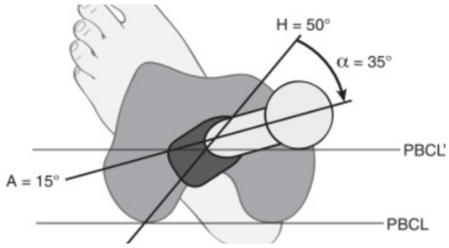

Figure 6: Anteversion: posterior bicondylar line (PBCL), neck (PBCL'), anteversion angle (A), Helitorsion (H) (28)

mentioned before, extensive anteversion leads to decreasing of FO. Nevertheless, internal rotation of 20° can minimize the decreases angle. To measure FO, Computed Tomography (CT) can be used.

Femoral anteversion is measured by helical torsion (angle between helical torsion axis and posterior bicondylar line) and alpha angle (angle between anteversion axis and helical torsion axis) as seen in Figure 6. Used for measurements are the posterior bicondylar line (PBCL) and its neck. As seen in the Figure 6, the anteversion angle equals approximately 15°. Here, the helical torsion angle (HTA) is about 50°, which means that, to achieve an anteversion angle of 15°, alpha angle and thus the prosthetic neck needs to be adjusted between -35° and 35°. As the correct offset influences implant survival, patients satisfaction and functional outcome, it is very important to accurately template and pay attention to it intraoperatively as well. (27)

XIII. Options of Materials and Implants

To get more into detail of differences of prosthesis, their styles and materials will be discussed next. Materials such as Titanium alloy or cobalt-chromium alloy in hip stem, femoral head, and acetabular liner, are most broadly used. Titanium alloy has shown to have lower elastic modules than other materials and thus, many benefits in long-term functioning. Additionally, reinforced polymers can be manufactured more accurately and thus, are better functioning additionally. Greater flexibility, minimum wear rate, as well as improved function is also seen in fiber-reinforced composite materials, like the collagen fiber reinforced polymer matrix composites as shown and proven in an Indian study from 2022 by Hermanth et al. Here, a process wear test of the material was done, which has shown these results. (42) Generally, it should be noted that a serious amount of stress shielding is being experienced in Titanium alloy. A corresponding reduction is necessary and can be achieved by reducing the effective stiffness of the implant as close as possible to the cortical bone elastic modulus.

a. Stem implants

250 cemented femoral stem prostheses that were based on titanium alloy were implanted for about 13 years, conducted by Eingartner et al. Here, at the follow-up time, the average HHS was 77.3 points. Thus, good results were shown. Additionally, the prothesis showed a promising outcome in long-term follow-up controls. It was comparable to those of other cemented femoral protheses in primary THAs. Furthermore, the risk of aseptic loosening was not enhanced by the combination of titanium and cement at the femoral stem.

In a different study by Cubillos et al., chemical composition and microstructure of austenitic stainless steel (ISO 5832-9) femoral stems made in different productions were tested for differences in tests for hardness, placement, as well as other tests including scanning electron microscopy. Results showed variations of those implanted stems in grain size, hardness, and precipitates. Thus, a correlation to corrosion resistance and material fatigue is set which makes these results clinically relevant and therefore result in the need of further investigations. (43)

Additionally to varying materials, prosthesis may also differ in stem lengths. Implant sizes and their impact on the surrounding tissue play a broad role for restoring the native anatomy as far as possible. When these differences in stem lengths were firstly broad up, studies were made to determine the impact shorter or longer stems had in comparison based on stress distribution. Revision rates were seen as very similar in all sizes, with a difference of 0,7% in short stems and 1,5% revision rate in longer stems. This result was published in a meta-analysis by Panichkul et al. Thus, based on revision rates, the minimal difference of risk may not be the only determing factor for choosing an implant size for the general recommendations. (44)

In a study published in 2009, Gong compared outcomes of four types of stems after THA with lengths of 137, 140, 143 as well as 146 mm. Besides length, these implants were all constructed out of titanium alloy, so that results can be based on their different sizes. As seen on this study's' outcome, long femur stems should rather be avoided to preserve as much native bone as possible and thus, be able to eventually restore as much native anatomy as possible, since stress on the prosthesis was only decreased slightly on larger implants with no significant difference. (43)

Moreover, Small et al. demonstrated with a femoral loading apparatus, that short stem implants, without reducing needed stability, showed off cortical strain responses. These responses were more similar to the native bone compared to longer and medium stem sized implants. Concluding, in terms of restoring the native anatomy, short stems may show the best solution.

However, a new classification system for femoral stems was proposed and published in 2023 by Radaelli et al. from New York. This classification is the first of its kind as it was based on

Figure 7: Stem variations (45)

three factors including geometry, location of modularity and stem length. Its' goal was to specifically compare newer studies on stem variations, as well as to set comparison with clinically significant characteristics. Most available studies are limited to specific prosthesis component or compare large groupings, rather than comparing all attributes concerning the implantation. There are six key stem geometrics described, which are seen on the figure below. They consist of flat taper (type A), quadrangular tapers (types B1-B2-B3), as well as short stems including fit-and-fill (types C1-C2-C3), conical (type D), cylindrical (type E) and lastly calcar-guided short stems (type F). They generally differ in their shape in means of thickness throughout the inferior part of the stem and their head thickness. Their benefits include correcting a valgus formed femoral neck, focus on rotational stability or contribution to a more homogenous load distribution. Further investigation about their individual benefits are needed to evaluate need for newer classifications. (45)

b. Modular head-neck stems

Modular neck stems (MNS) were designed to ease the restoration of the hip by giving the possibility to choose between neck lengths and degree to increase stability. Thus, their usage offers not only increased HHS outcomes, but additionally increase ROM. MNS are mainly designed to be used in cases of proximal femur anatomical abnormalities and especially severely deformed femurs. It is important to add, that offset and leg-length restoration, as well as joint stability can be restored with these implants. A meta-analysis showed not only that, but also HHS improvement, as lowest improvement scores were about 31 points. There were many concerns among surgeons, because first designs showed high rates of neck fractures among other complications. Newest designs analyzed in the meta-analysis showed, that titanium-titanium metal combination have significantly lower revision rates than modular stems with a titanium and cobalt chromium combination. This may be important for further research in specific material combination for this type of implant. Even though newest MNS decreased risks of the first designs, very long stem necks need to be considered carefully and MNS should be avoided in men with a BMI >30 to minimize fracture risk. (46) The newest variation of modular head-neck system composed of ceramic heads was investigated in a study from 2023. In this study, fixed stems were set in comparison. Therefore, they were not implanted into severely damaged anatomic states, but general OA indicated cases. The study concluded with excellent results not inferior to results of standard implants at all. As generally, these implants offer a great variability, more studies and improved designs are desired to study longer-term clinical and radiographic outcomes to evaluate instability, mechanical failure rates and non-fitting patients for these systems further. (47)

c. Head implants

As for implant heads, different variants which can be connected with various stems are well-established and used due to the practicality in individual needs and anatomy.

Generally and as described in the previously mentioned classification by Radaelli et al., there are four types of attachment possible on stems: the head only type, neck and head modularity, head and subtrochanteric and head modularity with modular metaphyseal sleeves for fixation.

Reasons for the importance of right size choice for head components include hip range of motion (ROM) especially concerning external rotation (ER), hip stability and reduce risk for impingement in order for the patient to return to good functionality of the joint.

In a north American study by Jang et al., the impact of head circumcise on the ROM was evaluated on 32 patients who underwent primary posterior approach THAs. Femoral head trial with intraoperative imageless goniometer were done with fitted head size, 3,0-3,5mm shorter and 3,0-4,0mm longer heads to find out ER differences. The result clearly showed a decreased ER range of about 10,8° in bigger heads with a mean of 3,4mm. Shorter heads increased ROM. Thus, this result emphasizes the importance on the right head size as even a few millimeters in difference impacts the ability of motion very much. (48)

Additionally, smaller head sizes are associated with higher rates of dislocation which is the most common reason for early revision operation in THA. Dislocations happen in 10-35% cases of primary and revision THA. These results are commonly known nowadays and proven in many studies, such as in a Dutch study with 166.231 patients with primary THA and 3.754 revision operations including risk assessment for different approaches and a six-year follow-up. Here, posterolateral approaches showed the highest revision rates in comparison to anterior, anterolateral and lateral approaches. The risk for implant loosening was higher in anterolateral and anterior approached surgeries. Independently to the approaches, in comparison to 22-

28mm, a 32mm sized head reduced the dislocation risk the most. The risk of dislocation can be further reduced in anterolateral approach with a 36mm sized head. While minding the previous explained study, minimizing ROM needs to be considered at this point. (49)

d. Locking mechanisms

Different types of acetabular locking systems are designed to reduce the motion between liner and metal shell. This motion leads to reduced wear debris and thus decrease inflammatory reactions by polyethylene (PE), as this remains a complication of aseptic loosening complications. The firm connection these locking systems offer, therefore can reduce aseptic

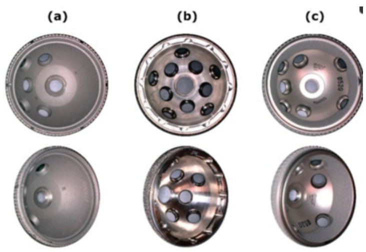

Figure 8: Titanium cup implants: (a) Zimmer Biomet; (b) DePuy Synthes; (c) Aesculap (50)

loosening and revision surgery risks. Three of these locking hip titanium components are shown in the Figure 6. (a) is fixed by a press fit circular mechanism with two spikes on which the smooth PE liner is attached to for rotational stability. On (b), a central dome region with a taper locking and twelve grooves on the rim offer rotational stability as well. In comparison to that, in (c), the PE is fixated through a conical locking with a rough PE liner. A study comparing these three specifically showed, that the locking restraints influence the relative motion of the hip and non-conforming implants have a more than 60% higher motion range. The highest dislocation risk was shown in mechanism (c). Nevertheless, (c) showed a higher ROM and disassembly forces, which may be contributed to rough surfaces for once. Concluding this study, many different variations of locking mechanisms bring different benefits which have to be matched with individual needs of the patient and surgeons' preferences. (50) Other new studies to this subject show, that highly porous titanium acetabular components show similar short- and medium-long outcomes than other materials. (51) Moreover, 3D printing of porous trabecular titanium metal cups for THA show very promising results for short- to midterm outcomes in terms of survival rates, outstanding fixation, and cup-survival rate of 100%. As these techniques are new and there are no long-term outcomes (52), new studies are desirable to evaluate the ultimate best locking system. Comparison of locking mechanisms and conventional standard stems in hip arthroplasty was done in a study by Guo et al. Used was the locking mechanism was the Tri-Lock Bone preservation Stem (BPS) and a Corail conventional stem in primary THA. Conclusions showed that BPS ha lower postoperative thigh pain rates, decreased intra-operative fractures and decreased stress-shielding. Blood loss rates were decreased in BPS. In other clinical outcomes, they showed similar results. (53) Therefore, the BPS may be advised to use in future patients, with consideration of revision risks and patients bone quality. Generally, it may be further evaluated in future long-term studies, whether conventional stems need to be replaced with new locking systems when seeing these promising results.

XIV. Femoral preparation and fixation

The femoral preparation is a very important operation step as it plays a significant role in fixating and placing a well fitted stem implant. By paying exact attention to expanding the contact of cortical bone and the stem, implant loosening risk soon after the operation can be minimized. Optimizing the fit increases stability, decreases risks for periprosthetic fractures while improving the press-fit strength of the implant. Special attention hereby is on cementless application, as risks of periprosthetic fractures rises as explained earlier. (41)

To ensure the fit and thereby decrease risks and complications, generally, three different ways of femoral preparation are available. They include ream only, broach and ream and broach only.

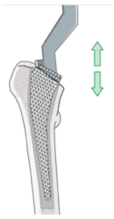

Figure 9: Illustration of broaching (54)

These techniques are used to prepare the femur for insertion of the implant and are especially important for cementless implantation, as the roughness of the bone has to align with the implants coating well adjusted. Firstly the “canal finder” starter is used and moved as a hand rasp motion laterally to the greater trochanter. Afterwards, a trial implantation of prosthesis is performed to check for equal leg length and stability. Hereby, the stem later sits in a neutral or in a valgus position, therefore not leaving the femur in a varus position and thus prevent dislocation or deflection, as well as ensure a closer restoration of the native hip with the prosthesis. Eventually, the broaches or reamers used are increasing in sizes, until the right fit size is achieved. They are moved carefully in consistent brisk blows with steady force. It is important to handle and especially remove them carefully, to not damage the femur. Axial and rotational stability are seeked while finding the right size. To ensure a femoral stem insertions’ success, a correct alignment is crucial. Thus, the medial compartment of the instrument should be aligned with the endosteal cortical bone and no cancellous bone in between and the leg-length difference needs to be looked after. (40)(54)

a. Cemented and cementless fixation

Implants may be either implanted and fixated with cement or cementless. The basis for a cementless implant to hold into place are the principles of mid-term biologic fixation, also described as osseointegration, long-term equal femoral stress distribution and lastly direct contact between implant and bone leading to rigid stability. (45) Which of these fixation methods may be more profitable, is discussed broadly since many years. However, cementless stem implantation has become more usual e.g. in the USA, as recent numbers have shown. There, 86% of THAs are performed uncemented as of 2022 with a tendency of rising numbers. Benefits of uncemented THA implantation include less blood loss, shorter operation time, fewer complications in comparison to cemented as decreased risk of periprosthetic osteolysis from cement particles and bone cement implantation syndrome.

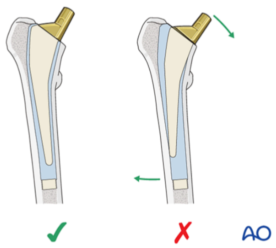

Figure 10: Angle of Stem insertion (41)

A cement restrictor is used in cemented stem surgeries to pressurize the cement to fill into the cancellous bone instead of moving distally further into the femur. It is inserted after cleaning the broached femur, during which a temporary dry sponge is placed at the same position the cement restrictor will be set. (41)

In case of needed revision after many years, changing the prosthesis is less invasive and more sparing for the native bone in uncemented THAs. In the contrary, when implanting cemented THAs, revision surgery risk is decreased in elderly patients. Moreover, intraoperative fractures occur 14 times more frequently in uncemented THAs with a prevalence difference of 3,0% to 0,23% in cemented prostheses. Thus, the question of preference arises. (45) It needs to be stated, that the gold standard in many countries for elderly patients, which only need an intact hip for not more than 10-15 years, is the cemented fixation to minimize the risk of additional need for surgery. (55) Moreover, in cemented THAs, risks of postoperative but also intraoperative periprosthetic fractures decreases. Still, both fixation styles have shown excellent survivorship outcomes. (45) A Danish study from 2020 by Pedersen et al. showed no clinically relevant difference in risk of mortality of 90 days postoperative outcome when comparing cement and cementless THA implantation. (55) Additionally to that, an American meta-analysis from 2022 concluded that based on the available data, a general clear preference for all patients may not be named, as more investigation in terms of long-term clinical outcomes is needed. A study from 2024 by Hameed et al. compared fixation outcomes in cemented and uncemented THAs after FNFs of nearly 3000 >65-year-old patients. The results showed lower rates of periprosthetic fractures but higher Venous thromboembolism rates in short-term outcomes of about 90 days. In longer-term outcomes of about two years, the cementless group showed higher results of aseptic revision surgeries. (56) As stated here, it cannot be determined ultimately which way would be the most beneficial for restoring the native hip. Still, this decision needs to be done individually and may depend on patients age, health and bone status and reason for the THA, as well as preference of the clinic and operating surgeon. (57)

b. Surface coating

In terms of how to lower the revision risk in cementless stems, since they were new on the market, research was performed on seizing the best material for surface coating. The goal of them was to optimize adhesion without the use and need of cement. One of the most important factors is the accurate osseointegration. Ceramic surface coated implants are used to enhance this osseointegration of surrounding structures and to thus intensify the implant to bone border interference.

Shown in a study by Harboe et al., integrating hydroxyapatite (HA) and deposing calcium phosphate onto the titan stems increases bone alignment and increased need of strength for extracting it. Thus, integrating this may help decreasing numbers of implant loosening and increase the restoration of the native hip. While this study was performed on goats, another study by Xu et al. performed HA coated titan implant THAs on 81 patients. This study showed similar results with a good clinical outcome and an average HHS score of 92.3±5,6. Thus, long-term clinical outcomes would need to be monitored in the future, with a promising direction of achieving lasting biological fixation while preserving native bone movement surrounding the titanic implant. A study by Barakat et al. published in 2020 offered further information about survival rate, radiological long-term results of these hydroxyapatite coated stems in revision THA, as well as its function. 30 patients were examined after about 3,5 years postoperatively. Good outcomes were seen concerning radiological implant loosening, pain, functional outcome and survival rate. Thereby, the results were very promising, as there was no case of loosening and a survival rate of 100%. (43) Functionally gradient materials (FGMs) are a relatively new material class, which distribute the stress which is put on the inserted stem naturally to prevent its breaking or loosening, as well as reduce the stress at the bone/cement/prosthesis interfaces. The reduction of shear stress at the artificial joint decreases bone loss and increases the patients' life span. Repetitive and continuous application of stress, forces and tensions on material which ultimately leads to wear, material degradation and fatigue is described as cyclic loading. (58) In order to for the implants material to not suffer from cyclic loading, the fatigue resistance needs to be greater than that of the femoral bone.

For better understanding of correct implant insertion, next, impingement and angle of insertion will be explained before continuing with different cup variations.

XV. Impingement and alignment

Impingement occurs in case of component on component, like acetabular liner to the femoral neck or component on host contact, like implant on osteophytes and lastly, host on host contact, like greater trochanter to acetabular wall. (59)

A large study for impingement geometry predicted that impingement of anterior-superior components is mostly connected to movements leading to posterior dislocation. Also, movements leading to anterior dislocation are associated with posterior-inferior impingement. With an acetabular cup position range of 25° anteversion - 35° inclination up until 15-20° anteversion- 70° inclination, an impingement free-zone was established as the risk was minimized. Thus, impingement prevalence can be reduced by aligning the acetabular cup rather in anteversion position and by more declination. This supports the statement of importance for anteversion rotation in acetabular cup positioning further. (60)

To slightly increase the anteversion of the stem, it is advisable to align the stem slot on the lateral side slightly posterior to the midline. It is crucial for both the medial side of the slot and with this, for the femoral stem, that the deviation from the central position within the cortex of the femoral neck is as small as possible. The modularity of the femoral prosthesis consists of the head and neck modularity, modular metaphyseal fixation sleeves and subtrochanteric modularity. Its limited junction spaces are important to minimize opportunity of implant failure and thus severe complications, including fatigue fractures and particle-generated tissue damage. It is composed to offer an impingement-free motion range, improve femoral offset, soft tissue tension and leg-length difference. Ultimately by that, restoring the native joint is carefully thought after. (59)

XVI. Constrained acetabular liners and Dual mobility cups

Constrained acetabular liners (CALs) are used for patients with recurrent dislocations or high-risk for dislocation, as well low stability concerns. Reasons for these risks include inadequate stability by the surrounding soft tissue (abductor deficiencies, especially of musculus gluteus medius), cognitive deficits or low functional status. CALs consist of an acetabular cup, outer polyethylene liner, locking ring, bipolar liner, and prosthetic head. They act similar to the tissue envelope stabilizing function and are secured by screws. CALs secure the head and thus reduce the primary movement arc and thus, the risk for impingement arises. Though it has many benefits, failures in mechanism include disengagement of liner, component failure and dislocation. (59)

Dual mobility cups (DMCs) have Similar benefits in terms of fixation. They have been firstly published in 1979 and consist out of two articulating surfaces with a prosthetic head. A polyethylene liner is mobile inside the acetabular metal cup. Similar to CALs, they reduce the ROM. There are different opinions on DMCs, as rates of aseptic loosening and costs due to its complicated construction increase. (61) As seen in a study by Mohaddes et al., 984 primary revisions were performed because of dislocation. About half of them were revised with DMCs in comparison with cemented conventional cups. Results showed that re-dislocation rates in DMCs, as well as other complications were lower in DMC implanted patients. Other studies show, that although dislocation rates decrease, infection rates or other material-based complications may rise in long-term outcomes of DMCs. (62)

The meta-analysis by Mufarrih et al. showed, that the dislocation rate of FNF treated with THA including DMC is at 1,87% and therefore is knowingly lower than the dislocation rate of THA using single cups with 8-11%. Additionally, with a risk of dislocation of 2% and 3% respectively are unipolar and bipolar HAs. Moreover, THA with DMC in comparison to bipolar HA have a clinically significant lower rate for reoperation, dislocation, as well as mortality. Concluding, by lowering these risks, THA and DMC can be used as an effective way to lower risk of further damaging of the native anatomy. Furthermore, as seen in a review from 2020, DMCs have more benefits and are therefore more recommended to use in comparison to constrained acetabular components. The reasons include lower dislocation rates, loosening and re-revision rates in long- but and in short-term outcomes. Concluding comparing these studies and their disadvantages and advantages, CALs are recommended to use for elderly patients, whose bone quality is already very poor and whose primary attempts in restoring the anatomy and function did not work due to complications. (61) Still it needs to be said, that there is not much evidence on how DMC performs on younger and very active patients. Thus, more data for comparison is needed in the future.

XVII. Bone Grafting and Osteoporosis

While discussing insertion of the stem, impaction bone grafting is a proven good way of bone preservation in cases of acetabular osteolysis and bone loss on either the acetabulum or femur. These bone chips fill the voids to restore the bone stuck ultimately. The latter is especially important in case of need for a possible future revision. It is often used in revision surgeries for reconstructing the proximal femur after arthroplasties by using it with morselized allografts. It can be used in cemented and uncemented cups. (63) One of its greatest benefits next to immediate stabilization is the ability of repairing bone defects and its 20-year survival rate is at 87% for the acetabulum and at 98,8% for the femur. (64) If applied correctly and firmly, morselized grafts increase implant stability and can be inserted together with antibiotics to reduce infection risks further. (63) In cases of Osteoporosis (OP), bone grafts are often essential. (65) OP is characterized by decreased bone mineral density due to altered bone microstructure. Thus, especially in elderly patients, it poses a challenge in fixation. Decreased bone quality is caused by an imbalance of bone resorption and its remodeling. In histology, decreased osteon sizes, thinned trabeculae, distended marrow spaces and Haversian canals are seen. OP may be differentiated into primary and secondary. In primary, the aging process and the contribution of the decreased sex hormones are the main cause. Mentioning OP is important, as the prevalence of this condition is quite high and still rising. About 50% of Caucasian post-menopausal women experience it. OP increases mortality, disability and mortality rates and thus lead to an impactful decrease in the quality of life. (2) Hence, usage of CALs or DMCs, as well as bone grafting and cementation are important alternatives to discuss for ensuring osseointegration in the low bone quality.

XVIII. Additional complications and postoperative recommendations

As numbers for THAs are rising, so do the numbers of aseptic loosening**.** They occur either due to intraoperatively insufficient fixation, biological loss, mechanical loss of prosthesis in long-time outcomes, or a mixture of these factors without an infection. More specifically, inadequate cementation technique, inadequate press-fit fixation with lacking osseointegration, bioincompatibility of prosthesis and additional insufficient bone quality lead to aseptic loosening eventually. Diagnostics are based of image evaluation as in X-rays, MRIs etc., clinical physical tests and thorough history taking. Continuous pain additionally to fitting imaging results mostly support the diagnosis sufficiently. (66) To be aware of this complication is important, as for revision THA, about 66,6% are caused by aseptic loosening, as a study from 2022 estimated. (67)

To avoid Venous Thromboembolism (VTE), every patient with treated fractures in the lower extremities, including FNF, needs a VTE prophylaxis. Its prolongation is dependent on the severity of fracture. This prophylaxis can consist of Aspirin, Apixaban or Rivaroxaban, to name a few. (68)

Fat embolism Syndrome (FES) describes a fat-emboli entering blood circulation and is associated with a prevalence of about 0,9-2,2% in long bone fractures. To avoid FES, early immediate fracture fixation is discussed to be essential, as in some studies the extend of decreasing the risk rate is discussed. More long-term studies are needed here. While there is no laboratory test to identify FES, the risk of it needs to be acknowledged and discussed while planning the period of time between fracture and surgery. (69)

To reduce the dislocation risk postoperatively, the patient will be asked to limit certain leg positions and movements. Those include combined internal rotation, adduction over the midline and hip flexion over 80-90° to avoid dislocation after surgery with posterior approach. After anterior approach, the patient is educated to limit combined movement of external rotation, hyperextension, and adduction past the midline. Moreover, movements of crossing legs, flexion in the hips and squatting should be advised to avoid. Also, asking for help while rising up is counseled. These precautions may be eased after about six weeks postoperatively. In terms of mobilization, walking aids for a safe gait in terms of walking frame or crutches are recommended to ensure a safe gait and no complications, including dislocations during falls and fractures. Additionally, restricted weight bearing in uncemented prostheses may be advised for about six to twelve weeks postoperatively, depending on the surgeons' preferences. (41)

XIX. Fast-Track Surgery

A novelty to improve the system behind THAs is the fast-track surgery. Its goal is to shorten hospital stays and fasten patient mobilization. As a result, socioeconomic gains are achieved in terms of minimization of costs for the hospital, reducing mortality and morbidity as well as enhancing patient recovery by bettering functional outcome without increasing complication risks. It has become a significant part of European surgical procedures. (70)

A national French prospective observational study published in 2020 compared the fast-track system to conventional system. Here, 10% more patients from the fast-track group could be discharged without inpatient rehabilitation or to convalescent homes, readmission rates were 7% lower and decreased reoperating rates within the three-month period was observed.

Thus, the number of patients discharged straight to their homes was higher, while having a reduced readmission rate. The study concluded with the statement to set the fast-track system as standard for care in primary THA in France. Agreeing with these positive outcomes is a German study from 2022. Here, a similar comparison was done. Results showed that the fast-track group had an about 3 days shortened hospital stay. Similar to the French study, fewer complications were noted, and functional outcomes were significantly improved. (71) The native hip anatomy is safer to be restored with THA by proceeding with fast-track protocols due to its many benefits, like lowered risk for revision surgeries and thus, the need to remove even more native bone and structures. Moreover, the related psychological, social, and occupational gains for each patient should not be underestimated. Hence, it may be advised to recommend setting the fast-track protocol as standard protocol. The evidence-based acceptance would improvement broadly beforehand. This could be done by further studies and awareness. Staffs' habit and structures would need to change. With the benefits for all parties, changing the protocol seems inevitable. German not yet translated sources explain "Ultra-Fast-Track". It shortens hospital times even further and may be reviewed in the future until further notice.

XX. Conclusion

The ultimate goal of this review is to differentiate and claim the best type of prothesis for different possible situations for restoration of the native hip with different types of hip prosthesis. To get more into detail, the main objectives are different prosthesis including their materials, coatings, shapes, insertion, and fixation styles, but also general arthroplasty indications, surgical approaches, risks and clinical outcomes, new technologies in templating and robotic-assistant surgeries, revision surgeries and their risks, as well as possible complications and consequences.

Restoring the native anatomy with prostheses is an increasing topic worldwide with the ageing population. In both Total Hip Arthroplasty and Hemiarthroplasty, templating, component sizes, especially stem lengths, modular neck-head stems, locking mechanisms, as well as used approaches and fast-track systems are widely discussed according to patients individual needs, age and bone quality as primary base of decision making. The best counterplay of different materials and robotic-assistance is developing further. Thus, surgeries get more accurately and lower in complications. In terms of prostheses, a well aligned placement, fixation and choosing the right sized and formed implant components are key. Osteoarthritis, Osteoporosis, Osteonecrosis and Femoral neck fractures are the most common indications for hip arthroplasties and as their prevalence rises worldwide, concrete knowledge about their treatment decisions especially including different options in arthroplasties becomes essential. In most of the recent available clinical trials, direct anterior approaches have demonstrated good long-term results with low dislocation and pain rates, faster recovery and mobilization time while maintaining very good functional outcomes. Still, further data evaluation is desired. Amongst currently existing techniques for templating, fluoroscopy-based robotically optimized Total Hip Arthroplasty technique proposes the most successful option for better outcomes of restoring the native anatomy, especially by exact placement of correctly measured sizes intraoperatively. Still, with the ever-developing techniques in templating, more comparing clinical trials may be necessary for further evaluation.

The newest studies show many benefits of fast-track surgery and rehabilitation programs when comparing it to conventional programs due to decreased revision surgery rates. Thus, improved restoration of the native anatomy is assured because no more native bone and structures need to be removed by having to exchange implants. While many materials were reviewed, the best outcomes show titanium alloy or elastic moduli cobalt- chromium alloy in addition with reinforced polymers like collagen fiber reinforced polymer matrix composites, which adds flexibility and stability. The effectiveness of cementless fixation has been demonstrated in many studies and clinical trials. Revision and intraoperative fracture risks decrease when implanting cemented prostheses, which plays a major role in elderly patients. As data has shown, decisions need to be based on individual health status, age, and bone quality.

While discussing the importance of carefulness in implantation, broaching is especially important in cementless fixation due to the significance of correct alignment. Complications include aseptic loosening, which accounts for about two thirds of revision Total Hip Arthroplasties. New data evaluation indicated the benefits of short stem usage, as no clinically significant difference in stability outcomes or stress distributions were shown.

Generally, presented data has exposed the importance of right sized implants as even a few millimeters may impact stability and the range of motion very much.

Using stems with a decreased junction space while inserting them with anteversion in accurate alignment has shown to minimize postoperative impingement risk.

Dislocations due to various reasons like smaller cup sizes are a common risk. It leads to stability issues. Thus, bone grafts and Constrained acetabular liners and Dual mobility cups may be inserted to strengthen fixation as they have shown good outcomes. While discussing femoral neck fractures, constrained acetabular liners also showed lower reoperation, dislocation, and mortality rates, disadvantages included decreased range of motion and increased costs. Thus, Total Hip Arthroplasty with Dual mobility cups offer an effective way to prevent further damage on the native anatomy. To reduce postoperative risks including dislocations and revision surgery, newest recovery recommendations were displayed.

This narrative review offers and reports about newest and most important key points to achieve the best possible long-term clinical outcomes.

Concluding, the individual patient parameters as well as the surgeon’s individual ability and preferences play a large role in deciding on the variation of options throughout this process of restoring the hip. Future clinical trials will be interesting for exploring the here presented new techniques even more and additionally finding desirable new pathways on how to achieve better long-term outcomes and limit complication rates further, to eventually restore the native hip anatomy with prostheses in an even more advanced way.

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