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Review Article

Total Knee Replacement in Valgus Knee

Mohammad Triadi Wijaya[1], Ismail Hadisoebroto Dilogo[1]

[1]*Department of Orthopaedic & Traumatology Universitas Indonesia, DR. Cipto Mangunkusumo Hospital, Jakarta, Indonesia*

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Corresponding Author :
Mohammad Triadi Wijaya, MD
E-mail: m.triadi@gmail.com

Abstract

Total knee replacement (TKR) in valgus knee patients presents unique challenges and requires careful consideration of various factors to ensure optimal outcomes. Valgus knee deformity can be associated with various underlying conditions, including autoimmune diseases like rheumatoid arthritis. Nearly 10% of patients undergoing total knee replacement have valgus knee deformity, which is associated with poorer functional outcomes than varus knees. When planning TKR procedures for patients with valgus knee deformity, it is crucial to identify the underlying reason, as the surgical strategy and implant selection may vary according to the individual etiology and patient factor. Proper alignment and stability of the knee joint need precise bone cuts, soft tissue balance, and implant design. Soft tissue balance ensures optimal joint function and range of motion. A comprehensive pre-operative planning process that takes into account these factors is essential for achieving the best possible outcomes and patient satisfaction in TKR for valgus knee patients. Different surgical approaches, such as the medial parapatellar and lateral parapatellar approaches, offer distinct advantages and disadvantages in treating valgus knee patients, and the choice of approach should be based on the surgeon's expertise and the patient's specific anatomy and deformity. For a successful output, the coronal, sagittal, and rotational alignment must be in proper proportion. Therefore, before performing a total knee replacement on a valgus knee, it is necessary to have a thorough understanding of the problem and the treatment options available.

Introduction

A valgus knee is a type of knee deformity characterized by an outward angulation of the lower leg about the thigh.[1] Osseus malalignment in the valgus knee is defined by medial proximal tibial angle (MPTA) >90º, lateral distal femur angle (LDFA) <85º, or a combination of them.[2] Valgus knee deformity can result from various causes, including osteoarthritis, rheumatoid arthritis, rickets, and renal osteodystrophy. Valgus deformity with total knee replacement is less prevalent than varus deformity. Nearly 10 percent of individuals receiving total knee replacement (TKR) exhibit valgus knee deformity and are associated with less favorable functional results than varus knees.

Anatomical Differences

There are anatomical differences to consider while performing total knee replacement on a valgus knee that can be caused by a bony or ligamentous pathology. Bone abnormalities such as hypoplastic lateral condyle, lateral tibial plateau bone loss, external rotation deformity of the tibia, femoral and tibial metaphyseal valgus remodeling, and patellar malalignment often add difficulties to doing TKR. In contrast, soft tissue pathologies such as a tight iliotibial band (ITB), lateral collateral ligament (LCL), lateral retinaculum and capsule tightness, posterior cruciate ligament tightness, and the laxity the of medial ligament may also worsen the valgus deformity.[4] The anatconsiderationseration and clinical implications are presented in Table 1.

No	Anatomical considerations	Clinical Implications
1	Lateral femoral condyle hypoplasia	The posterior femoral condyle is often deficient and may result in malrotation of the femoral component. Therefore, the anteroposterior (AP) axis and the trans epicondylar axis should be used as reference to achieve correct femoral component rotation.[5]
2	Tibial plateau remodeling	This may lead to under-correction of the deformity if the distal tibia valgus there is unrecognized. Lateral side tibial components augments may be necessary.[5]
3	Tightness of the ITB	The pie crusting technique is conducted to lengthen the ITB and maintain its continuity.[5]
4	Tightness of the LCL	Released in the case of tightness in flexion.[6]
5	Lateral retinaculum and capsule tightness	Released in the case of tightness in extension.[6]
6	Tightness of the PCL	Released in the case of pathological laxity of the medial compartment with the release of the lateral side, followed by PCL balancing.[6]
7	Medial ligament laxity	Advancement of the medial structure.[6]

Table 1. Anatomical consideration and clinical implication for TKR in valgus knee

The diagnostic procedure for total knee replacement (TKR) in valgus knees is similar to that of normal knees, with some additional considerations such as evaluating the valgus deformity using CT-Scan or MRI to measure joint anatomy and alignment. Soft tissue evaluation such as medial and lateral collateral ligaments, the posterolateral capsule, the popliteus tendon, the hamstring tendons, the lateral head of the gastrocnemius, and the iliotibial band also need to be carefully evaluated to determine whether soft tissue releases are necessary to perform.[4] The surgical procedure for total knee replacement in valgus knees also has some different considerations compared to normal knees such as approaches, soft tissue release, bone resection, and implant selection since there are changes in the anatomy of the landmark that is usually used for bony cut in total knee replacement. This condition can lead to malalignment of the implant and may cause instability or post-operative pain. To manage bone abnormalities or soft tissue disease or both in valgus deformity, thorough pre-operative planning, clinical assessment, implant backup, and good operation skill are needed.[7]

Classification

Several classifications of the valgus malaligned knee have been recorded, with the severity of the deformity and the extent of soft-tissue involvement often being considered. Ranawat classifies valgus knee into three types, Type I: Valgus <10°; Type II: 10°< Valgus <20°; Type III: Valgus >20°. (Figure 1).

Mullaji and Shetty[8] amended the initial Ranawat classification[9] to incorporate multi-planar and/or extra-articular abnormalities, and they categorized valgus deformity as follows:

- Type I: correctible valgus deformity with no fixed deformity and an intact MCL
- Type II: fixed valgus deformity with an intact MCL
- Type III: valgus and hyperextension deformity with an intact MCL
- Type IV: valgus and a fixed flexion deformity with an intact MCL
- Type V: severe valgus deformity with an incompetent MCL
- Type VI: valgus secondary to extra-articular deformity

Pre-operative Planning

Total knee replacement (TKR) is an elective surgery that is not typically considered an emergency procedure. It is essential to carefully evaluate the degree of valgus deformity, the underlying cause, and the extent of bone and soft tissue abnormalities before proceeding with surgery. Pre-operative planning, alignment assessment, soft tissue balancing, and implant selection are crucial for achieving optimal outcomes in TKR for valgus knees. Rushing into surgery without proper evaluation and planning can increase the risk of complications and lead to suboptimal outcomes. Pre-operative planning is crucial when performing total knee replacement in a valgus knee. Obtaining an accurate axis restoration, component orientation, and joint stability in a valgus knee with combined bony and ligamentous pathology may be challenging. Therefore, it is vital to take the time to carefully evaluate the patient's condition and plan the surgery accordingly.[5]

An important aspect of pre-operative planning for valgus knee deformity patients undergoing total knee replacement is determining the patency of the ligament via physical examination (TKA). To discover dynamic instabilities, the general alignment should be evaluated both in the supine and weight-bearing position, and the gait should be watched. The knee must be assessed for anteroposterior laxity, range of motion (ROM), coronal and sagittal deformities, and mediolateral instability. The surgeon must evaluate the medial and lateral collateral ligaments, along with the posterolateral capsule, popliteus tendon, hamstring tendons, lateral head of the gastrocnemius, and iliotibial band. The integrity of these ligaments is essential for excellent outcomes in TKA procedures for valgus knees. In fixed valgus deformity, the lateral collateral ligament is contracted and added varus force in physical

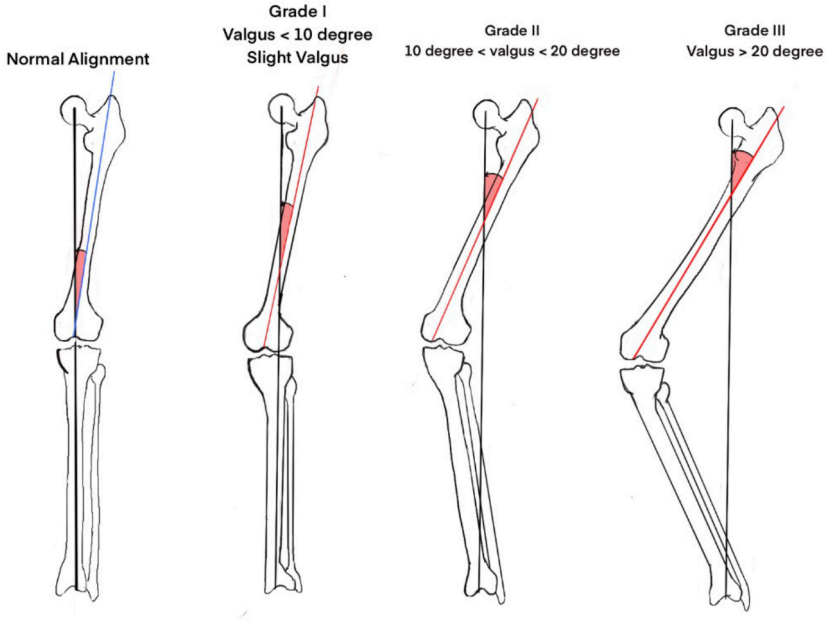

Figure 1. Ranawat classification based onthe degree of valgus deformity

examination will not correct the deformity. In dynamic valgus deformity, the deformity will be corrected if the varus force is added in physical examination. It is easier to do TKR in Dynamic valgus deformity because lateral soft tissue is not contracted and only a little release is needed to balance the medial and lateral soft tissue. The surgeon can prepare for suitable soft tissue releases or changes during TKA to promote optimal joint stability and range of motion by carefully analyzing the integrity of the ligaments during pre-operative planning.[10]

When performing total knee replacement in a valgus knee, pre-operative planning such as radiographic planning, templating, component positioning, balancing, and implant selection should be considered carefully. Radiographic planning is essential to determine the degree of valgus deformity and the extent of bone defects. A template of bone cuts must be performed in the anteroposterior radiographic view of the knee. On the tibial anatomical axis, a line is drawn, followed by a perpendicular line at the level of the tibial plateau. The femoral anatomical axis is drawn, followed by a second line at the level of the intercondylar notch with the desired amount of valgus. Metaphyseal remodeling at the distal femur often makes the entry point of the intramedullary guide for distal femoral resection more medial than normal. The anatomical femoral axis have to be drawn with the center of the shaft as the guidance and the point where anatomical axis at the most distal part of the femur should be marked as the entry the point of intramedullary guide for distal femoral resection.[9] Incorrect entry point of intramedullary guide will make the distal resection inaccurate and usually will lead to more valgus resection of distal femur.[11]

The distal femoral resection angle is a crucial aspect of pre-operative planning for total knee replacement (TKR) in valgus knee patients. It refers to the angle at which the distal femur is cut during the surgery to accommodate the implant. This angle is determined based on the degree of valgus deformity and the degree of tibia and femur bowing. Proper evaluation of the distal femoral resection angle is essential for achieving optimal alignment and stability of the knee joint during TKR. Precise distal femoral resection with an accurate valgus cutting angle (VCA) is important while correcting valgus deformity in total knee replacement. SA study by Song et al[12] showed that a fixed distal femoral resection with a valgus cutting angle of 3° is more appropriate in intra-articular valgus deformity than exta-articular valgus deformity in TKA. By carefully evaluating the distal femoral resection angle during pre-operative planning, surgeons can develop a comprehensive surgical strategy to address the deformity and optimize the results of TKR in valgus knee patients.[13]

In valgus knee patients, pre-operative planning for total knee replacement (TKR) should include an examination of the tibia and femur bowing condition. In valgus knee, lateral femoral bowing refers to a deformity where the femur bone curves outward on the lateral side, which can pose challenges in achieving optimal outcomes and longevity of total knee replacement. In addition, the tibia bone may bow medially in the valgus knee, which can lead to misplacement of the tibial component during TKA. This misplacement can result in instability, pain, and premature wear of the implant. Therefore, these are important to be considered in the pre-operative phase to plan the corrective techniques to address the tibia

and femur bowing during the surgery. This may involve adjusting the bone cuts and implant positioning to achieve proper alignment and stability.[14]

Approach

When approaching total knee replacement in a valgus knee, several considerations should be taken into account including the approaches, soft tissue release, osteotomy, implant selection, and balancing. The medial parapatellar approach is the most commonly used approach for total knee replacement (TKR), including in patients with valgus knee deformity. However, in valgus knee patients, the medial parapatellar approach may present some challenges in achieving proper soft tissue balance and joint alignment. One advantage of the medial parapatellar approach is its familiarity with most surgeons, providing satisfactory exposure for the procedure. On the other hand, this approach has a disadvantage in that it requires additional release of lateral soft tissue structures, which can jeopardize patellar blood supply and compromise patellar tracking. When a medial approach is employed to treat a valgus knee, the surgeon must be highly cautious when detaching the MCL. In valgus abnormalities, the release of the medial structures should be limited to the overhanging osteophytes.[15]

Alternative methods, such as the lateral parapatellar approach, can provide direct access to the tight lateral ligamentous structures, allowing for easier release and proper knee balancing while preserving the medial structures. This approach also optimizes patellar tracking and maintains the medial blood supply to the patella.[16] Study by Cheng et al[17] also showed that the lateral parapatellar approach improved pain and function post-operative significantly without deviation of the lower limb mechanical axis of the prosthesis position, good knee stability, and simplifying the complex soft tissue balance technique of the valgus deformity. However, the lateral parapatellar technique may bring certain disadvantages, such as technical issues with patella eversion and surgeon unfamiliarity.[18] In addition, there is a possibility of soft tissue closure and wound healing difficulties. Despite these obstacles, the lateral parapatellar approach is a viable option for treating patients with valgus knee deformity, as it has been demonstrated to result in higher post-operative Knee Society Scores, shorter surgery times, and comparable complication rates compared to the medial parapatellar approach.[19]

Technical Consideration

When performing total knee replacement in a valgus knee, achieving proper balance and correction of limb alignment by utilizing appropriate sizing and type of implant is crucial for long-term success. Accurate bone cuts are crucial for achieving proper alignment and stability of the knee joint, while soft tissue balance ensures optimal joint function and range of motion.

Tibial Resection

When performing a total knee replacement on a valgus knee, a shallower resection of the tibia is preferred. A significant correlation exists between the needed tibial resection and the pre-operative leg axis. In valgus deformities, the required resection depth-averaged 5.1 mm and was significantly reduced compared to knees with a neutral leg axis (6.8 mm) and varus deformities (8.0 mm). Manufacturers recommend undercutting the high side of the tibial plateau to the depth of the thinnest insert available. However, the study demonstrates that in valgus deformities, unnecessary bone loss can be avoided by reducing the tibial resection depth. The optimal tibial

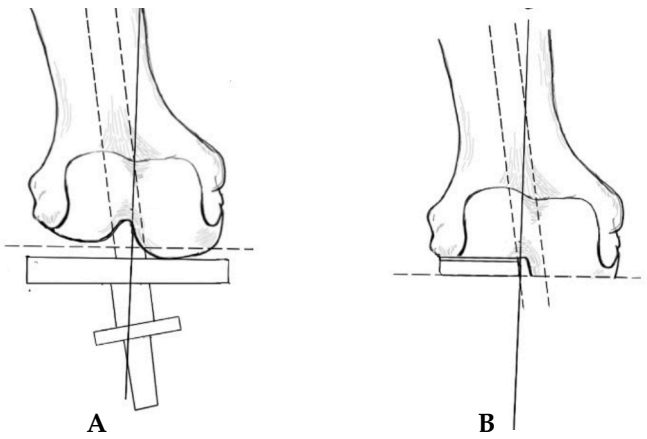

Figure 2. Lateral condyle hypoplasia; 2.a note the resection doesn't involve lateral condyle that is smaller than usual; 2.b block augment can be used to compensate for lack of bone stock in lateral condyle

resection depth in valgus deformities corresponded to the smallest insert thickness minus 3 mm.[20] The tibial cut should be performed perpendicular to the anatomical axis, removing the smallest possible bone amount, especially from the lateral side. In cases of severe bony deformities of the tibial plateau, it may be necessary to remove nearly no bone from the lateral side to prevent medial over-resection or mal-aligned cuts.

Distal Femoral Resection

Distal femoral excision in total knee replacement (TKR) for valgus knees requires alignment correction, joint line restoration, anatomical considerations, and surgical technique. The objective of distal femoral excision for the valgus knee is to achieve appropriate alignment and restore the joint line. When the distal femoral cut is performed, the surgeon should pay attention to the distal femoral angle of the cut and also how much bony cut will be performed.

The amount of bone resected during distal femoral resection should be based on the medial condyle. With lateral femoral condyle hypoplasia, sometimes there is no lateral femoral condyle bone that was resected in severe valgus deformity of the distal femur (Figure 2). It is not recommended to add more distal femoral resection to compensate for lateral condyle hypoplasia as it will alter the joint line and make balancing more difficult. The unresected lateral condyle should be managed with a distal femoral augment device or with a screw to fill the gap between the unresected bone and the implant.[10,12]

Femoral Rotation

Achieving proper femoral rotation is essential for restoring natural joint mechanics, patellar tracking, optimizing implant longevity, and ensuring functional outcomes. However, the complexity of femoral rotation in valgus knees poses unique challenges that necessitate a thorough understanding and precise surgical techniques. Due to lateral condylar hypoplasia and lateral cartilage erosion, it is difficult to achieve correct rotational alignment of the femoral component during total knee replacement (TKR) for the valgus knee. An available landmark that is usually used in TKR to determine the rotation is the posterior condyle, but in the valgus knee, the lateral condyle is often hypoplastic making the posterior condyle axis more internal rotation (more than 3 degrees) about trans epicondylar and anteroposterior axis (Figure 3).

The gap technique involves resecting the tibia in advance and performing anterior and posterior cuts of the femur parallel to the tibial cut when the knee is at 90° of flexion. This permits free rotation of the femoral component while limiting soft tissue release. The gap technique-based navigation system allows surgeons to quantify femoral component rotation based on the

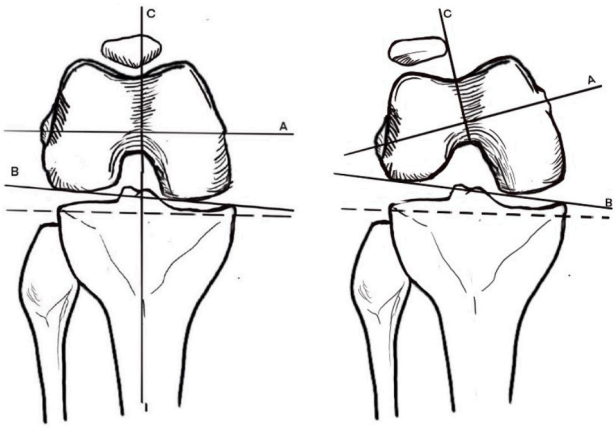

Figure 3. The left is a normal knee and the right is a valgus knee with lateral femoral condyle hypoplasia. Note that in the valgus knee, the posterior condyle axis is often unreliable due to hypoplasia. A = trans epicondylar axis, B = posterior condyle axis, C = Anteroposterior axis (whiteside line)

posterior condylar axis, which can help achieve proper rotational alignment of the femoral component in TKR for valgus knee deformity.[21]

Arime et al.[22] identified the anteroposterior axis, the posterior condylar axis, and the trans epicondylar axis in thirty cadaveric femora to determine the reliability of using each axis in the operative setting to achieve correct rotational alignment of the femoral component in total knee replacement in a valgus knee. In addition to obtaining radiographs of the distal side of each femur, creating the axes, and calculating the angles to compare with the visual measurements, radiographs were also taken for this investigation. The article demonstrates that the anteroposterior axis is a reliable reference point for rotational alignment of the femoral component in a valgus knee. Utilizing the anteroposterior axis as a trustworthy landmark, surgeons can lessen the likelihood of malalignment and enhance the knee joint's overall performance.

All landmarks available such as the trans epicondylar axis, anteroposterior axis, medial and lateral flexion gap balance, and posterior condyle axis should be considered to determine the correct rotation of the femoral component.

Soft Tissue Balancing

The soft tissue balance in the valgus knee is more difficult due to the specific collection of bone and soft tissue anomalies that must be addressed during the procedure.[7] Proper soft tissue balance can help in the optimization of alignment, stability, and functional outcomes. In valgus knees, lateral soft tissue release is frequently performed during TKR. To correct the valgus deformity and achieve normal alignment, tight lateral collateral ligaments (LCL), posterolateral capsule (PLC), popliteus tendon (POP), hamstring tendons, the lateral head of the gastrocnemius (LHG),

and iliotibial band (ITB) are released. Gap balancing is a technique used in TKR to improve soft tissue balance and joint stability. This involves correcting the bone cuts and soft tissue releases so that the gaps in flexion and extension are equal and symmetric. Gap balance in valgus knees can be difficult due to the specific mix of bone and soft tissue anomalies that must be addressed after surgery.[23]

The sequence of lateral soft tissue release is still debated in the literature. The overall alignment should be assessed both in the supine and weight-bearing positions, and the gait should be observed to identify any dynamic instabilities. It is also very important to determine whether the valgus deformity is fixed or reducible, as this will determine the level of constraint needed for the prosthesis. If the deformity is fixed, a semi-constrained or higher-constrained prosthesis may be necessary.[9,24]

Although numerous soft tissue techniques and procedures have been promoted over the past three decades, there is no consensus regarding the structures that must be targeted during TKR and the order of their release.[1] However, a sufficient lateral soft tissue release must be undertaken to prevent residual valgus deformity and patellofemoral alignment issues, while avoiding excessive releases that may increase the risk of complications.[25] In a lateral parapatellar approach, the lateral retinaculum and vastus lateralis muscle are separated to expose the lateral portion of the knee joint. It permits improved sight and access to the lateral components of the knee joint, which can be advantageous in cases of severe valgus deformity.[26] In addition, selective soft tissue release involves releasing particular soft tissues, such as the iliotibial band, lateral capsule, and lateral collateral ligament, to equalize the stress on both sides of the knee joint. It has been determined to be effective without restricting prosthetic mobility. Importantly, poor soft tissue balancing can result in consequences such as late-onset joint instability, and the choice of approach should be determined by the degree of deformity and joint instability. It is essential to highlight that the literature lacks sufficient information to determine the best strategy for lateral soft tissue release.[1]

Ranawat introduced an inside-out technique to release lateral soft tissue in the valgus knee. The technique has several steps: (1) Remove peripheral osteophytes. (2) Extend the knee and distract with a lamina spreader. (3) Irrigate and dry the joint. (4) Palpate the posterior cruciate ligament, posterolateral corner, and iliotibial band to determine tight structures. (5) Release any remnant of the posterior cruciate ligament. (6) Release the posterolateral capsule intra-articularly with the use of electrocautery at the level of the tibial cut surface from the posterior cruciate ligament to the posterior border of the iliotibial band. (7) Preserve the popliteus if possible, unless it is too tight. (8) The iliotibial band is lengthened as necessary from the inside with multiple transverse stab incisions a few centimeters proximal to the joint line with the use of the so-called pie-crusting technique. (9) Repeat these steps after manual stress testing if necessary.

Implant Design

When considering implant design for total knee replacement (TKR) in valgus knees, posteriorly stabilized (PS) implants are commonly used. In valgus knees, PS implants are favored over cruciate-retaining (CR) implants due to the greater risk of instability associated with CR implants.[27] The size of the implant should be carefully selected based on the individual patient's anatomy and the degree of valgus deformity. Undersizing the femoral component can lead to increased rates of aseptic loosening and revision surgery.[4] It is important to avoid overcorrecting the Hip-Knee-Ankle (HKA) angle, particularly the tibial mechanical angle, in the event of a fixed severe valgus knee. Maintaining a severe valgus knee in a mild residual valgus to use a less limited implant or to avoid substantial ligament releasing should not hurt the 5-10-year implant survival and the functional scores.[28]

In valgus knee replacement, there is still no consensus on the degree of implant restraint that should be applied. With satisfactory clinical outcomes, both cruciate-retaining (CR) and cruciate-sacrificing (CS) TKR implants have been utilized.[1] On the other hand, a previous study by Lombardi et al[29] proposes PCL-substituting implant designs to circumvent PCL balancing problems and deal with a potentially abnormal native ligament. Other studies, on the other hand, argue that cruciate-retaining designs should be preferred to protect condylar bone in the event of additional revision surgery, particularly in younger patients. In addition, some authors used primary constrained components with and without stem extensions.[30–32]

Varus Valgus Constraint or Constrained condylar knee (CCK) prosthesis is commonly used for revision surgery, but it can also help surgeons improve implant stability in primary knee replacement, particularly in cases of severe knee arthrosis with severe deformity and significant instability where a more constrained articulation is required.[33]

This technique is intended to give a more confined articulation, hence decreasing the chance of implant dislocation and enhancing knee function overall. The device consists of a semi-restricted prosthesis designed to offer stability in the coronal and sagittal planes while allowing for some rotational movement. Ren et al.[34] studied the midterm results of CCK implants in primary total knee replacement for severe valgus deformity involving 47 patients who received primary TKR. According to the findings, in primary TKR for severe valgus deformity, CCK implants can yield satisfactory midterm outcomes.

Mancino et al.[35] evaluated the clinical and radiological results of CCK with posterior stabilized (PS) implants in 52 patients who had undergone primary TKR for valgus knee. The study concluded that there were no significant differences between the two groups in terms of clinical and radiological outcomes, and both groups had good outcomes. The constrained condylar knee (CCK) prosthesis can be utilized in primary total knee replacement (TKR) to increase implant stability, particularly in cases of severe knee arthrosis with severe deformity and considerable instability. There were no significant differences in clinical and radiological outcomes between CCK and posterior stabilized (PS) implants in primary TKR for valgus knee, as demonstrated by research.[34,35]

Other Techniques

The stability of the knee following a complete knee replacement is essential for implant survival over the long term. Extreme axial abnormalities pose a difficulty in total knee replacement (TKR) because it is technically challenging to create a satisfactory soft tissue balance. In severe valgus deformity, soft tissue release alone cannot address the imbalance of medial and lateral gap especially in extension. Several authors use sliding osteotomy of the lateral condyle to lengthen the lateral contracted soft tissue. The lateral epicondyle along with LCL and popliteus is osteotomized and moves to the distal to open the lateral gap. Shifted lateral epicondyle fixated with screw or staples after correct tension was achieved. Mullaji et al.[36] suggested using computer navigation to aid in shifting the lateral epicondyle to prevent over-release and imprecise correction of the lateral structure.

The elongated medial collateral ligament in severe valgus deformity gives severe laxity and difficulty in balance. Some authors tighten the medial collateral ligament by osteotomy of the medial femoral condyle and shift the medial femoral condyle along with the medial collateral ligament to a superior position.[37,38] This technique may help avoid excessive release, the descent of the joint line, and peroneal nerve palsy due to over-release on the lateral side of the knee.

Conclusion

Total Knee Replacement in a valgus knee is a challenging procedure that requires careful pre-operative planning and clinical examination to manage bone deformities and soft tissue contractions/ elongations. Finding the correct balance of the coronal, sagittal, and rotational alignment is necessary for a good outcome. Understanding what happens in the valgus knee and options to overcome the conditions are mandatory before performing total knee replacement in the valgus knee.

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