

Total Knee Arthroplasty in the Valgus Knee – A Surgical Challenge (Part 1)

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Abstract— The valgus knee presents a unique set of problems that must be addressed during total knee arthroplasty. Both bone and soft-tissue deformities complicate restoration of proper alignment, positioning of components, and attainment of joint stability. The variables that may need to be addressed include lateral femoral condyle or tibial plateau deficiencies secondary to developmental abnormalities, and/or wear; primary or acquired contracture of the lateral capsular and ligamentous structures; and, occasionally, laxity of the medial collateral ligament. Understanding the specific pathologic anatomy associated with the valgus knee is a prerequisite to selecting the proper surgical method to optimize component position and restore soft-tissue balance. The aim of this article is to review the anatomical variations underlying a valgus knee, to assess the best pre-operative planning and to evaluate how to choose the grade of constraint of the implant. We will also review the main approaches and surgical techniques both for bone cuts and soft tissue management.

Keywords— review, valgus knee, total knee arthroplasty, alignment.

1. Introduction

Approximately 10% of patients requiring total knee arthroplasty have a valgus deformity (defined as an anatomic valgus of more than 10°)¹. Correction of the valgus deformity has posed technical challenges and has produced variable clinical results in terms of correction of the deformity, instability, and the overall results. The valgus deformity may be caused by rheumatoid arthritis, posttraumatic arthritis, osteoarthritis, or metabolic bone disease and overcorrection consequent to valgus osteotomy². It is important to correct the deformity during surgery even if it does not completely eliminate the increased risk of failure (1.9 vs 0.5 %)³. The valgus deformity consists of two components: an element of bone loss with metaphyseal remodeling, primarily from the lateral femoral condyle and lateral tibial plateau, and a soft-tissue contracture consisting of tight lateral structures, such as the iliotibial band, lateral collateral ligament, popliteus tendon, posterolateral capsule, and hamstring muscles. The described changes can lead to a tibial external rotation and to a patellar lateral subluxation tendency⁴. Multiple surgical techniques have been described to balance the soft tissues after correction of a severe valgus deformity during total knee replacement. Because of the length of

the review it would be divided into two parts. In part 1 we will fix our attention at alignment, classification, physical examination, radiographic evaluation and component selection.

2. Alignment

During total knee replacement (TKR) the surgeon aims to achieve good alignment of the femoral, tibial and patellar components. This can reduce both the mechanical stress placed on the bearing surfaces and the shear stress on the bone/implant or bone/cement/prosthesis interfaces. Good alignment also helps to balance the forces transmitted to the soft-tissue envelope, which is crucial for proper function of the joint.

Under normal circumstances, in the standing position, a vertical line drawn downwards from the symphysis pubis is known as the vertical axis. Meanwhile, the mechanical axis of the lower limb is a line drawn from the center of the femoral head to the center of the ankle joint, and passes through the knee just medial to the tibial spine⁶. The mechanical axis does not correspond to the vertical axis (a common cause of confusion), but generally makes an angle of 3° with the vertical axis; however, this can vary subtly depending on the height of an individual and the width of the pelvis.

The anatomical axis refers to a line drawn along the length of the intramedullary canal of either the femur or the tibia. In general, looking from the front, the anatomical axis of the tibia corresponds to the mechanical axis of the lower limb, while the anatomical axis of the femur makes an angle of 5° to 7° with the mechanical axis. The anatomical axis of the tibia thus subtends an angle of 3° with the vertical axis, while for the anatomical axis of the femur this subtended angle is from 8° to 10° .

In contemporary knee replacement systems, the intramedullary rod, which may be surprisingly flexible, determines the anatomical axis of the femur. It is passed retrograde through a drilled entry point in the distal femur; a distal femoral cutting block is then applied over it. When performing this simple step, it is possible to select an entry point that may lead to errors in alignment. In the coronal plane, a more valgus distal femoral cut can be made if the intramedullary entry hole is too lateral, while a more varus distal femoral cut can occur if the hole is too medial. This has implications for soft-tissue balancing and subsequent polyethylene wear^{7,8}. In the sagittal plane, a posterior entry point may cause the distal femoral cut to be relatively flexed, while for an anterior entry point the end result may be a distal femoral cut that is relatively extended. This has implications for component size. When the block is applied for anterior and posterior femoral cuts, the femur can be relatively oversized or can be notched anteriorly. This can later be a risk factor for periprosthetic fracture⁹⁻¹¹.

The anatomical axis of the tibia can be determined by intramedullary or extramedullary alignment jigs. With intramedullary methods attention has to be carried out on the presence of a very bowed tibia and, as with the femur, the selected entry point is critical. Alternatively, extramedullary alignment methods rely on an estimation of the anatomical axis and hence, mechanical axis of the tibia, by aiming to be parallel to the coronal and sagittal axes of the bone. The extramedullary technique can be technically more demanding; defining the tibia is more difficult with large or obese patients, where it may be hard to identify the subcutaneous border of the bone and the center of the ankle

joint. A varus tibial cut may cause tightness on the lateral aspect of the knee in both extension and flexion. If the tibia is cut with an excessive posterior slope there may be instability in flexion. If the cut fails to recreate the normal posterior slope, or is too extended, this may result in a knee that is too tight in flexion and the range of movement is compromised.

Accurate alignment of the patellofemoral joint is also crucial to the performance of a TKR. A key determining factor is rotation of the implanted femoral and tibial component¹². For the tibia, rotation is referenced to the anteroposterior axis, which is a line that runs perpendicular to the plane, passing medial to lateral through the widest point of the tibia. In practice, the tibial component is aligned to the medial third of the insertion of the patellar tendon. In a normal knee the tibial tuberosity is offset laterally from the trochlear groove by approximately 1 cm; the same must be recreated during TKR in order to ensure similar forces are passed through the patellar tendon¹³. Excessive internal rotation of the tibial component will result in relative external rotation of the tibial tuberosity, increasing the chance of subluxation or dislocation of the patella. Excessive external rotation of the tibial component may lead to posterolateral overhang of the prosthesis with softtissue impingement and relative internal rotation of the tibial tuberosity. This can lead to pain and poor function¹⁴.

For accurate rotation of the femoral component, the key reference is the transepicondylar axis, which lies in the coronal plane with the knee extended and flexed; it is perpendicular to the mechanical axis. The transepicondylar axis is determined by drawing an imaginary line between the lateral epicondyle and the origin of the medial collateral ligament, which is found at the bottom of a sulcus in the medial epicondyle. The axis is perpendicular to 'Whiteside's line', a line drawn along the deepest part of the trochlear groove¹⁵.

The transepicondylar axis can be difficult to reliably define in up to 50% of cases, whereas Whiteside's line is more reliably found. The exception can be in cases where there has been significant patellofemoral wear, which can alter the normal anatomy of the trochlear groove. Identifying these landmarks is the key to determining rotation of the femoral component, which is controlled by the anterior and posterior cuts made to the distal femur after application of the femoral cutting block. In most knee systems a sizing jig is first applied to the distal femur, which can be referenced from the anterior or posterior aspects of the femoral condyle. There are advantages and disadvantages of both methods, but in each case pins are used to define the rotation of the femoral cutting block. A line connecting the pinholes should be perpendicular to Whiteside's line and parallel to the transepicondylar axis.

If a posterior condylar referencing system is used for a valgus knee with a relatively hypoplastic lateral femoral condyle, it may be necessary to keep the paddle of the sizing jig away from the posterior aspect of lateral condyle. This permits less lateral bone resection, compared with the more common situation seen with a varus knee. It is more important to ensure correct alignment of the anatomical landmarks for rotation, rather than attempting to equalise bone resection from both posterior condyles. The latter would result in an internally rotated femoral component, which has clear implications for patellar tracking. In addition, there will be relative laxity in flexion on the lateral side, but with tightness on the medial side. This can be difficult to balance by soft-tissue

release. In contrast, excessive external rotation may make the lateral side tight in flexion and the medial side relatively lax, which can cause a medial lift-off as the knee is flexed. In both situations, because of ligament tightness, there will be restriction in the range of flexion. The force through the extensor mechanism in both situations will be altered, causing abnormal loading of any patellar component and contributing to early wear and loosening.

The technology of computer navigation has developed further in recent years. There is evidence that the accuracy of placing components in the coronal plane within 3° of ideal alignment may improve¹⁶. However, there is little evidence to confirm a long-term effect on function or survivorship and no evidence to confirm increased accuracy of patellofemoral tracking and soft-tissue balance¹⁷. Computer navigation relies on accurate data input in order to calculate the mechanical axis from the center of hip rotation, through the center of the knee, to the center of the ankle. It will not take into account variations in anatomy, such as a very bowed tibia or a pronounced femoral bow in the sagittal plane. In the latter situation, it is possible to cause femoral notching. A direct evolution from computer navigation has been the use of bespoke jigs, manufactured by taking measurements from pre-operative MRI or CT scans. To perform this, the mechanical axis has to be determined and numerous points registered on three-dimensional reconstructions. The benefits of this technique include more accurate component placement in coronal, sagittal and transverse planes and better rotational alignment of the components. Performing a TKR requires the accurate execution of key bone cuts in the correct orientation to the appropriate axes. There is huge potential for cumulative errors to occur, which may have significant and dramatic effects on function and longevity.

3. Classification

The **Kellgren and Lawrence system** is a common method of classifying the severity of knee osteoarthritis using five grades. This classification was proposed by Kellgren et al. in 1957¹⁸ and later accepted by WHO in 1961. Grade I, demonstrates doubtful narrowing of the joint space with possible osteophyte formation. Grade II, demonstrates possible narrowing of the joint space with definite osteophyte formation. Grade III, demonstrates definite narrowing of joint space, moderate osteophyte formation, some sclerosis, and possible deformity of bony ends. Grade IV, which demonstrates large osteophyte formation, severe narrowing of the joint space with marked sclerosis, and definite deformity of bone ends.

In 2005, Ranawat *et al*¹ described three grades of valgus deformity. More specifically, Grade-I occurs in 80% of the patients, whereas the mechanical axis deviation is less than 10° and it is passively correctable. In Grade-I the medial collateral ligament (MCL) is intact. Grade-II accounts for 15%; is characterized by a range of axis deviation 10° to 20°, whereas the MCL is functional though elongated. Grade-III is seen in the remaining 5% of the patients having axis deviation more than 20°. The medial stabilizing elements are typically not functional so a constrained implant is often required^{1,5}.

Mullaji and Shetty¹⁹ modified the Ranawat classification to include multi-planar and/or extra-articular deformities. Type I is defined as correctible valgus deformity with no fixed deformity and an intact MCL; type II is a fixed valgus deformity with an intact MCL; type III - a 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 and type VI - valgus secondary to extra-articular deformity. For each type, the authors describe the surgical management to correct both the bone and soft-tissue components of the deformity.

4. Knee physical examination

During standard physical examination for endstage degenerative knee disease the orthopaedic physician should observe the patient's gait, in order to identify other dynamic instabilities and assess the lower limb alignment both in the supine and weight-bearing positions. Any sagittal deformity, such as fixed flexion contracture or recurvatum, as well as any rotational deformity, should be attended. It should also be measured the range of motion; and further evaluated the status of the extensor mechanism and the patellofemoral articulation^{2,4,20,23}. Furthermore, clinical examination plays a major role for the surgeon so as to determine even if the deformity is correctable or fixed, and whether the knee is stable or unstable. The knee should be further evaluated for antero-posterior laxity, coronal and sagittal deformity, and mediolateral instability²¹. It is very crucial to assess if valgus deformity is fixed (Ranawat Grade III) or still reducible (Ranawat Grade II or I). In a fixed deformity, the lateral structures are tight and require release. In cases with nonfunctional MCL and when the release of the lateral structures has fulfilled, the use of a constrained prosthesis may be necessary. If the deformity is reducible, soft tissue release will be less invasive, and a standard unconstrained prosthesis could be sufficient. The orthopaedic surgeon would lastly perform a neurovascular examination to differentiate a possible lumbosacral or vascular disease^{4,5,20,22}.

5. Radiographic evaluation

After the clinical assessment, the mandatory preoperative planning radiographs that should be included are: (1) a weightbearing knee anteroposterior view; (2) a lateral; and (3) a patella Merchant view. Furthermore, the limb axis deviation measurement with long standing film or CT-scan with anterior orientation of the patella is also often required²¹. It has been shown that rotation up to 20° has little effect on the measurement of the femorotibial axis deviation²⁴. Based to our experience, in cases of serious bone stock deficiency a knee computer tomography will be helpful. Attention should be focused on the hypoplastic lateral femoral condyle, the eroded posterior femoral condyle and the remodeled femoral or tibial metaphysis that can lead to malaligned or malrotated position of the femoral component. The patellofemoral joint may also be partially dislocated. A precise profile X-ray of the knee will help to assess the tibial slope, and the patellar height (alta or baja) according to the ratio. Besides, the patellofemoral view at 45° will add to the evaluation of patellar centering by classifying three states (centered, subluxation, luxation)^{4,20,25}. A weight bearing long leg view is fundamental for

the evaluation of lower limb alignment (mechanical and anatomical axis), measure the valgus deformity level and plan the amount of correction (templating). In order to determine the amount of valgus deformity knee medial instability stress radiographs could be also used²⁰. An electromyogram should be made in any case of lower limb dysesthesias that may be attributed to lumbosacral disease^{4,20}.

6. Component selection

Most orthopaedic supply companies manufacture a range of implant designs, from cruciate ligament retaining (CR) and posterior stabilized (PS) implants that usually provide sufficient stability in the primary setting, through to mega prostheses for replacing tumor or expanded bone loss. The level of built-in constraint, or stability, required by a knee prosthesis depends upon whether the posterior cruciate and collateral ligaments are intact. If the posterior cruciate ligament is compromised, as it is in most rheumatoid knees, or there is fixed coronal plane or significant flexion deformity, then the PCL is replaced by a cam and post, the design of which controls sagittal plane kinematics. A larger post can provide additional side-to-side/coronal plane stability. In some cases it may be more difficult to obtain the deformity correction with an intact PCL, since the PCL presence contributes to the deformity on frontal level^{26,27}. If the medial collateral ligament is compromised, a hinged prosthesis is chosen to further improve coronal plane stability. Inevitably, this puts greater strain upon the hinge itself and produces increased shear stresses at the implant interface with the bone. Favorito et al² proposed that the surgeon should resist the temptation, when possible, to move to a more highly constrained prosthesis, such as a totally stabilized prosthesis, to compensate for shortcomings in achievable soft-tissue balancing. A rotating hinge allows movement in the axial plane between the polyethylene and tibial surface, decreasing these stresses but producing a secondary surface for the generation of wear debris. Modular femoral and tibial stems are added to the resurfacing implants in this scenario to increase the area of fixation, spreading load and decreasing stresses at the implant bone interface.

Femoral or tibial stems of varying lengths may also be added if there are significant uncontained bone defects. Generally, a contained bony defect with an intact cortical rim or an uncontained defect of less than 5 mm can be filled with cement upon implantation. Contained defects greater than 5 mm with an intact cortical rim can be treated with morcelized impaction bone allografting. Uncontained defects require shaping to accommodate the metal wedges that are added to the implant. Larger defects are not commonly encountered in the primary setting, but when present may require bulk bone allograft. The addition of a femoral or tibial stem provides additional stability and protects supplemented defects, minimizing the risk of long-term implant subsidence.

In 2013 Pang et al.²⁸ reported a retrospective review of patients with a type II valgus knee who underwent primary TKR. There were 50 patients in whom a constrained TKR was performed and another 50 cases who received a PS or CR prosthesis. They concluded that there were no statistically significant differences in anteroposterior and mediolateral stability between the two groups. Constrained TKR were associated with more significant joint line changes compared with the unconstrained ones.

On the other hand, in grade III valgus deformity, in which the medial soft tissue is no longer functional with certainty, a higher constrained prosthesis is mandatory to achieve a stable knee¹.

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