Chapter

Total Knee Arthroplasty in Valgus Knee

Alessandro Rozim Zorzi, Wander Edney de Brito, Gustavo Constantino de Campos and João Batista de Miranda

Abstract

Total knee arthroplasty in valgus knee deformities continues to be a challenge. It comprises only 10% of patients who undergo total knee arthroplasty. The surgeon should be aware of the technical aspects that differentiate it from the varus deformity: surgical exposure, bone cuts, ligament balancing, gap balancing, joint line obliquity, patellar tracking, preserving fibular nerve function, and selection of the implant. The aim of this chapter is to provide step-by-step comprehensive knowledge about different surgical techniques for the correction of severe valgus deformity in total knee arthroplasty.

Keywords: knee, arthroplasty, deformity, valgus, prosthesis

1. Introduction

Valgus deformity of the knee occurs in the presence of a valgus alignment of the anatomical axes of the femur and tibia in the frontal plane greater than 10° [1]. Although osteoarthritis is the most common pathology related to this deformity in adults, other events and diseases, such as post-traumatic deformities, rickets, renal osteodystrophy, inflammatory pathologies such as rheumatoid arthritis, systemic lupus erythematous, psoriatic arthritis, or even hemophilic arthropathy are commonly associated [2].

Valgus deformity accounts for approximately 20% of the patients undergoing total knee arthroplasty (TKA) and can impose some challenges for the knee surgeon [1]. Proper coronal deformity correction is widely accepted as crucial for the success of a TKA [3]. It is recognized that the correction of a valgus deformity has technical particularities that need to be recognized by the knee surgeon when performing a TKA. It comprises surgical approach, bone cuts, and mostly ligament balance [1, 2, 4].

2. Preoperative evaluation

Patients diagnosed with end-stage primary or secondary osteoarthritis or other inflammatory arthritis, with refractory pain and loss of function that impair daily live activities, having failed conservative therapy, are elected to undergo TKA. It is important to emphasize that only a bad radiograph does not constitute an indication for arthroplasty.

A complete medical history, associated with a general medical examination, should be performed to rule out conditions and comorbidities that may contraindicate the procedure.

Every candidate should be clinically evaluated for weight-bearing alignment, flexion contracture, and ligamentous instability. Preoperative radiological assessment includes:

- weight-bearing anteroposterior view;
- stress radiographs in valgus and varus;
- lateral view;
- axial patellar view;
- limb axis deviation with long-standing views of the knee for overall coronal mechanical axis alignment;
- Nowadays, with the increase in the number of robotic surgeries and customized prostheses, especially in the knee, CT scans of the hip, knee, and ankle are also needed.

3. Classification

Many authors have proposed ways of classifying valgus deformities of the knee for the purpose of surgical correction with TKA. The idea is to stratify the patients in order to improve the surgical planning and the choice of the degree of constriction of the implants.

The Krakow classification [5] proposed in 1991 is one of the most famous classifications. It categorizes valgus knees based on the integrity of the medial soft tissues and on prior surgeries. Type 1 deformity has an intact medial collateral ligament (MCL). Type 2 has an insufficiency of the MCL with positive valgus stress test. Type 3 is a secondary valgus deformity created by an overcorrected high tibial osteotomy (HTO) in a previously varus-aligned limb.

The SOO classification, presented in 2003 (Societe d'Orthopedie de l'Ouest - Western France Orthopedics Society), recognizes four types of valgus knee, with increasing surgical difficulty. Type I can be completely reduced, without medial laxity. Type II is totally or partially irreducible, but without medial laxity. Lateral release is required, whereas Type III is reducible, but with medial distension laxity, and may require management of the medial laxity. Lastly, Type IV is irreducible, with medial distension laxity, combining the problems of types II and III [6].

Lombardi et al. in 2004 [7] proposed a slight modification of the Krakow classification, taking into account the degree of deformity, the status of the MCL, and the amount of release that must be performed. Variant I is characterized by mild deficiencies of the lateral femoral condyle and tibial plateau, with stable MCL and correction of the deformity with varus stress. In variant-II, the MCLs are intact, but they do not correct to neutral alignment with varus stress. Variant-III is distinguished by attenuation of the medial capsular ligament complex with opening of the medial joint line on valgus stress test.

Ranawat et al. in 2005 [1] added one more small modification, merging the previous classifications, adding the measure of the magnitude of the deformity to the Krakow classification. A type-I deformity has minimal valgus and medial soft-tissue stretching. A typical type-II fixed valgus deformity has a more substantial deformity (>10°) with medial soft-tissue stretching. A type-III deformity is a severe osseous deformity after a prior osteotomy with an incompetent medial soft-tissue sleeve.

Despite being widely used, the Krakow and the Ranawat classifications were designed with patients from developed countries, where most cases have minor deformities. In poorer countries, where the population has greater difficulty in accessing surgical treatment, there is a greater prevalence of severe cases and complex deformities. Therefore, new classifications have been proposed to better stratify severe cases.

In 2014, Mulaji et al. [8] proposed a classification into six types: type 1 reducible valgus, type 2 irreducible valgus, type 3 valgus associated with recurvatum, type 4 valgus associated with flexion contracture, type 5 valgus with MCL insufficiency, and type 6 extra-articular valgus.

Based on full-leg weight-bearing radiographs of 233 knees, the study of Mulaji et al. [9] identified four broad groups of valgus arthritic knees with nine phenotypes based on coronal plane variations in femoral and tibial morphology. Type 1 Neutral knees (12.5%) had almost normal values. Type 2 "Intra-articular valgus" (22.7%) showed lateral compartment bone loss. Type 3 "Extra-articular valgus" (35.2%) had extra-articular deformity: 3a showed valgus femoral bowing; 3b showed tibial valgus bowing; 3c showed tibial valgus bowing with lateral femoral condyle wear. Type 4 "Varus" type (29.6%) had features of varus knees: 4a had varus femoral bowing; distal femur in 4b was akin to varus knees with lateral tibial bone loss. 4c had varus tibial bowing and deficient lateral femoral condyle. 4d had varus tibial bowing and lateral tibial bone loss.

Yang et al. in 2021 [10] made deformity analysis on standing long-film radiographs and computed tomography (CT). Valgus deformities could be classified into five subtypes: the distal lateral femoral condyle (F1a), both distal and posterior lateral femoral condyle (F1b), the supracondylar region of the femur (F2), the tibial plateau (T1), or the metaphyseal segment of the tibia (T2). F2 and T1 (40.0% and 28.6%, respectively) were the most common two subtypes.

4. Surgical technique

4.1 Surgical approach

4.1.1 Anteromedial approach

As 90% of knee arthroplasties are associated with varus deformity, the anteromedial approach is more frequently practiced by surgeons. Therefore, even in valgus deformities, most surgeons opt for the anteromedial approach.

The advantage of this approach is that it allows a wide view of the joint cavity and does not require any additional training by the surgeon.

The disadvantage of this approach is that it does not directly address the lateral contracture structures. In cases of mild deformity, Ranawat grade 1, small surgical gestures such as releasing the iliotibial band (ITB) and pie crusting the lateral capsule may be sufficient. In developed countries in Europe and North America, this is perhaps the majority of cases. But in Latin American, African, and Asian countries, severe cases classified as Ranawat grade 2 or 3 are frequent. To correct these major deformities, the medial approach can cause problems not only with ligament balance, but mainly with patellar tracking.

To compare the clinical and radiological outcomes of anteromedial and anterolateral approaches for valgus TKA, a pilot randomized clinical trial evaluated the radiographic patellar tilt, the visual analog scale of pain, postoperative levels of hemoglobin, and clinical aspect of the operative wound. Mean lateral tilt of the patella was 3.1° (SD ± 5.3) in the lateral approach group and 18° (SD ± 10.2) in the medial approach group ($p = 0.02$). There were no differences regarding other outcomes [4].

In severe deformities, release of lateral patellar retinaclum is necessary in most cases in order to prevent patellar instability. Lateral release in combination with medial capsulotomy results in significant impairment of the extensor mechanism blood supply and could cause avascular necrosis of the patela [11].

4.1.2 Anterolateral approach

The anterolateral approach proposed by Keblish in 1991 allows for a better exposure of the lateral and posterolateral structures, which are contracted in valgus deformities and should be released for proper ligament balance; it also has the advantage of including the release of lateral patellar retinaculum, which is necessary in most cases with valgus deformity [12].

After proper preparation and placement of drapes and with the knee positioned at 90°, the technique begins with the skin incision, which must follow the direction of the deformity (so that at the end of the procedure and consequent correction of the deformity, the incision is straight). An incision between 15 and 20 centimeters is usually sufficient, starting over the superior pole of the patella, going to the anterior tibial tuberosity (ATT) (laterally). Skin and subcutaneous tissue should be detached together and to a sufficient extent just to access the lateral border of the patella, avoiding unnecessary tissue damage. The arthrotomy is performed starting at the center of the quadriceps tendon, going down the lateral border of the patella, to the lateral border of the ATT. It is essential to maintain Hoffa's fat connected by its pedicle to the lateral portion of the capsule, as this tissue will be necessary for its closure. Nikolopoulos et al. in 2015 provided a detailed description of the lateral approach technique, along with its advantages and disadvantages [6].

As in the classic medial arthrotomy, in which the deep medial collateral is released as part of the approach, we recommend, in the lateral approach, desperiostization of the lateral portion of the tibia, thus detaching the distal insertion of the iliotibial tract from the tubercle of Gerdy. This step already releases one of the three major soft tissue structures involved in valgus deformity (the other two being the lateral collateral ligament and the popliteal tendon). In cases of mild and reducible deformity, this already resolves the ligament balance. For this reason, we strongly believe that the indication of the lateral approach is advantageous even in milder cases, solving at the same time the ligament balance and patellar tracking.

Exposing the tibia is actually a little more difficult with this access. This is mainly due to the fact that the TAT is lateralized, which opens a smaller window of vision (the space between the TAT and the lateral collateral is much smaller than the space between the TAT and the medial collateral). For the same reason, patellar eversion is a more difficult maneuver to perform, which makes the exposure of the tibia more difficult. We recommend spending a little more time on this step for adequate exposure of the tibia and consequent correct understanding of the structures and their relationships.

Keblish's original description includes an anterior tibial tubercle osteotomy (ATT) for further exposure. We do not believe it to be necessary in the vast majority of cases. However, in certain situations such as in severe valgus knees or after a previous tibial osteotomy, patella's eversion may be compromised and the patellar ligament may be particularly prone to spontaneous avulsion by forceful retraction, especially if patella cannot be everted with the knee flexed at 90°. In these situations, the surgeon should not hesitate to perform an ATT. This is a safe and effective procedure. It also may simplify proper positioning of the tibial component in severe valgus knees, avoiding internal rotation of the tibial component. However, careful fixation of the tuberosity is mandatory [11].

4.2 Soft tissue balancing

The goal of ligament balance is to achieve symmetrical rectangular extension and flexion gaps. This can be achieved through several techniques, summarized in just two main philosophies: "Mesaured ressection" and "Gap balancing." Gap balancing relies on ligament releases prior to bone cuts. There are basically two gap balancing sequences. One relies on balancing the flex gap first, and the other technique initially balances the knee in extension. On the other hand, bony landmarks such as the transepicondylar axis and the posterior condylar axis are used to set femoral component rotation when using a measured resection technique. Bone cuts are initially made independent of soft tissue tension.

Regardless of the philosophy used, gap balancing, or measured resection or a combination of both, in general we can say that the ligament balance of valgus deformity depends on the release of tense lateral structures and the tensioning of attenuated medial structures. Unfortunately, many authors have described several sequences for the serial release of these structures, and there is still no consensus on the best technique.

4.2.1 Release of lateral structures

Ligaments can be released through pie-crusting, subperiosteal release, transverse section, or osteotomy. Unfortunately, there is no consensus among the authors on a sequence for carrying out the releases. The releases should be performed in full extension, by using spreaders to check the tension of the medial and lateral compartments. After each release, the surgeon should evaluate the alignment and the stability of the knee, in order to achieve a symmetrical rectangular extension and flexion gaps [6].

Krackow et al. [5] advocate the release of the ilio tibial band (ITB), followed by the lateral colateral ligament (LCL), next by the posterolateral corner structures (PLC) and the gastrocnemius muscle lateral head (LHG).

Buechel [13] presented a sequential three-step lateral release, which included elevation: (1) the ITB from Gerdy's tubercle; (2) the LCL and popliteous tendon (POP); and (3) the entire periosteum of the fibular head.

Ranawat et al. [1] described a stepwise technique in which the first structure to be released is the posterior cruciate ligament (PCL). When necessary, the ITB and the LCL are released with multiple stab incisions, the so-called "pie-crusting" technique. The POP is normally preserved.

Favorito et al. [14] proposed that LCL is the first structure to be released. The next sequential release follows the POP (an important structure for rotational and valgus stability in flexion), the PLC, the femoral insertion of the LHG, and finally, the ITB.

Whiteside [15] described a release sequence based on the tension of ligaments in flexion and extension: For tight knees both in flexion and extension, the LCL and POP tendon are released. For those knees, tightness remains in extension and only ITB is released. Posterior capsular release is performed only when necessary for persistent lateral tightness.

An alternative technique for lateral structure release was described by Brilhault et al. [16]. A sliding osteotomy of the lateral epicondyle contains LCL and POP insertions.

4.2.2 Tensioning of medial structures

As described by Krackow et al. [17], when the MCL is attenuated and there is a residual medial laxity, the authors suggest tightening of the medial structures. The advancement of the MCL from the epicondyle or a division and imbrication in order to tighten, it can be performed.

4.2.3 The fibular nerve dilemma

Fibular nerve palsy (FNP) is a feared complication after valgus TKA. The reported incidence of FNP after valgus TKA in the literature ranges between 0.3% and 9.5%. Injury of the Fibular nerve can be caused by indirect damage due to stretch or ischemia after correction, or by direct injury due to laceration during lateral soft tissue release. As FNP has serious consequences, some orthopedic surgeons advocate to prevent this complication by a concomitant fibular nerve release (FNR). Due to the limited number of studies investigating FNR, no consensus has yet been reached on the value and indication of the procedure. A systematic review demonstrated no significant differences in FNP rate between valgus TKA with and without FNR (2.4% vs 2.1%) [18]. Therefore, the authors of this chapter do not recommend the routine use of FNR.

4.3 Bone resection

Valgus deformity has particularities that need to be recognized so that bone cuts can be made properly. In most cases, the origin of the deformity is located in the distal femur, as opposed to the varus deformity. Lateral condyle hypoplasia is frequently present and needs to be recognized, as it directly interferes with several parameters of femoral bone cuts. A smaller number of cases may have lateral tibial plateau sinking, either due to fracture sequelae or in very advanced cases with deformity > 20° and MCL insufficiency.

Extra-articular deformities such as external torsion of the tibia and remodeling with valgus deviation of the femoral and tibial shafts may also coexist [19].

4.3.1 Tibial resection

We recommend that the first bone cut is the tibial one, parallel to the ground. The main reason is that we can use the tibia as a parameter for the posterior cut of the femur through the gap balancing technique, in which the cut is performed parallel to the tibial cut with the knee at 90° under symmetrical soft tissue tension. This is important because, due to hypoplasia of the lateral condyle, we cannot rely on the classic parameter of 3° of external rotation in relation to the posterior condyles, which will be discussed later.

A marked valgus deformity of the tibial diaphysis is frequently observed in valgus knee, which makes it impossible to use an intramedullary guide for the tibia in most cases. Therefore, we recommend the use of the extramedullary guide for all cases. In addition, tibial cutting guides are usually sided (left or right). In these cases, it will be necessary to use the guide on the opposite side. Another important detail of this step is the amount of bone to be cut. Traditionally, in varus knee prosthesis, 9–10 mm of bone can be removed using the healthy plateau as a parameter. However, the healthy tibial plateau in valgus knee is the medial plateau. It turns out that the medial plateau is 3 mm more distal than the lateral plateau. Therefore, we must discount this 3 mm when making the cut, otherwise we will inadvertenltly cut more tibia than ideal. Therefore, make the tibial cut 6 or 7 mm from the medial plateau.

4.3.2 Femural resection

Next, we will make the distal cut of the femur. Instead of the 7° of valgus traditionally used in varus knees, we used 5° in the distal cut of the femur, in order not to under-correct the deformity. The surgeon may also choose to use the exact difference

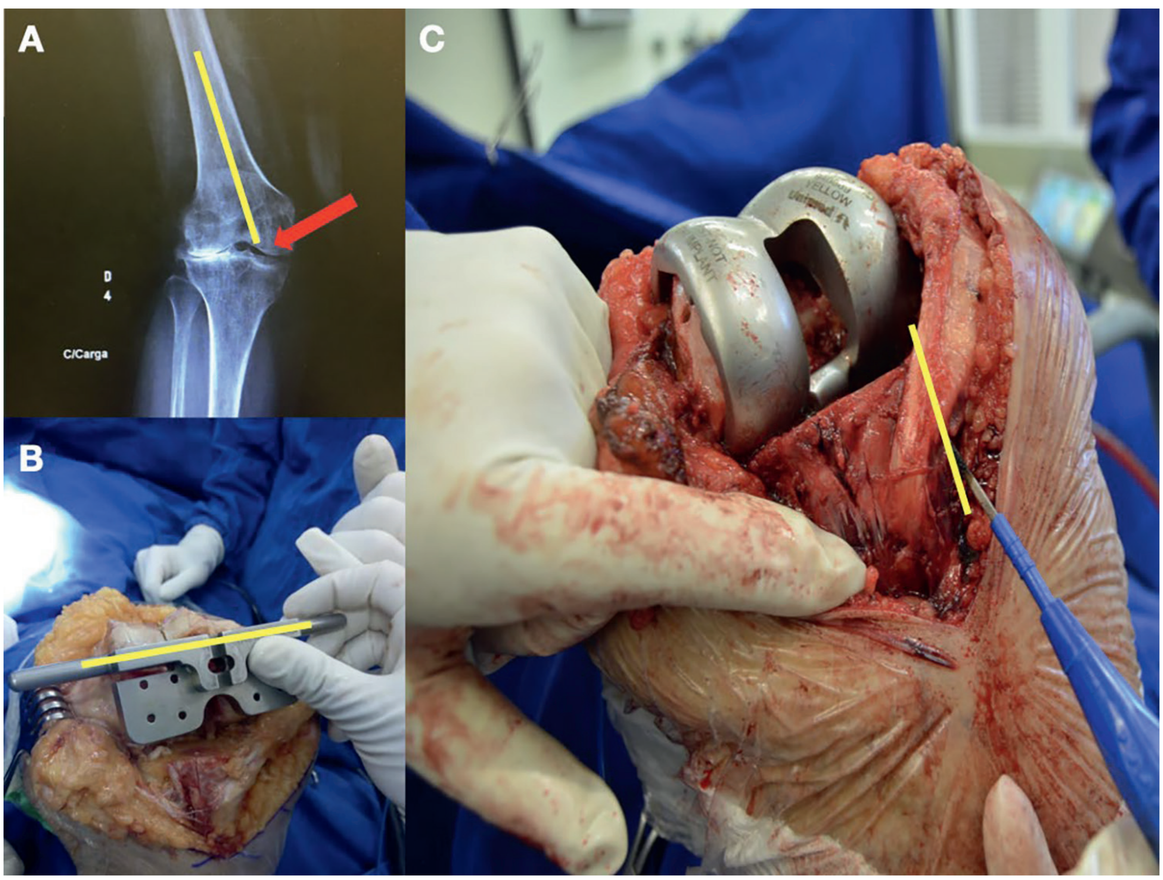

Figure 1.
Tips and tricks for appropriate bone resection in valgus TKA. (A) Weight-bearing knee radiography demonstrating lateral condyle hypoplasia and the adjusted entry point for IM guide at the medial condyle (red arrow), in the prolongation of the anatomical axis of the femur; (B) determination of the rotation of the femoral component by the Whiteside line (yellow), parallel to the transepicondylar axis. Do not use the support guide on the posterior condyles; (C) When determining the rotation of the tibial component, 1 centimeter medial to the TTA, the less experienced surgeon with the Keblish approach must be careful because the tibia is being viewed "in a mirror."

measured between the anatomical and mechanical axis of the femur in the preoperative panoramic X-ray. Caution should be taken with the entry point of the intramedullar guide. Because of hypoplasia of the lateral femoral condyle, the entry point must be medialized, sometimes not above the intercondylar notch as usually done in varus cases, but in the medial femural condyle.

Regarding the adjustment of the femoral rotation, one more point of attention: The existence of hypoplasia of the lateral femoral condyle is very common. Therefore, the use of a guide based on the posterior condylar line will incur in excessive internal rotation of the femoral component. If the technique used is measured resection that considers the anatomical points, the correct way is to base it on the trans-epicondylar axis or on the Whiteside line. An alternative, as already described, is to use the gap balancing technique in this step.

Figure 1 brings some tips and tricks to keep in mind as they are common causes of errors.

4.4 Implant choice

Some surgeons consider it inappropriate or almost impossible to preserve the posterior cruciate ligament (PCL) in severe valgus deformities. The use of intramedullary nails and implants with revision concepts is also frequently indicated by some surgeons whenever they are faced with a severe valgus deformity [19]. But what is the logical reasoning that should guide the choice of implant? **Figure 2** shows the algorithm for implant choice in valgus TKAs.

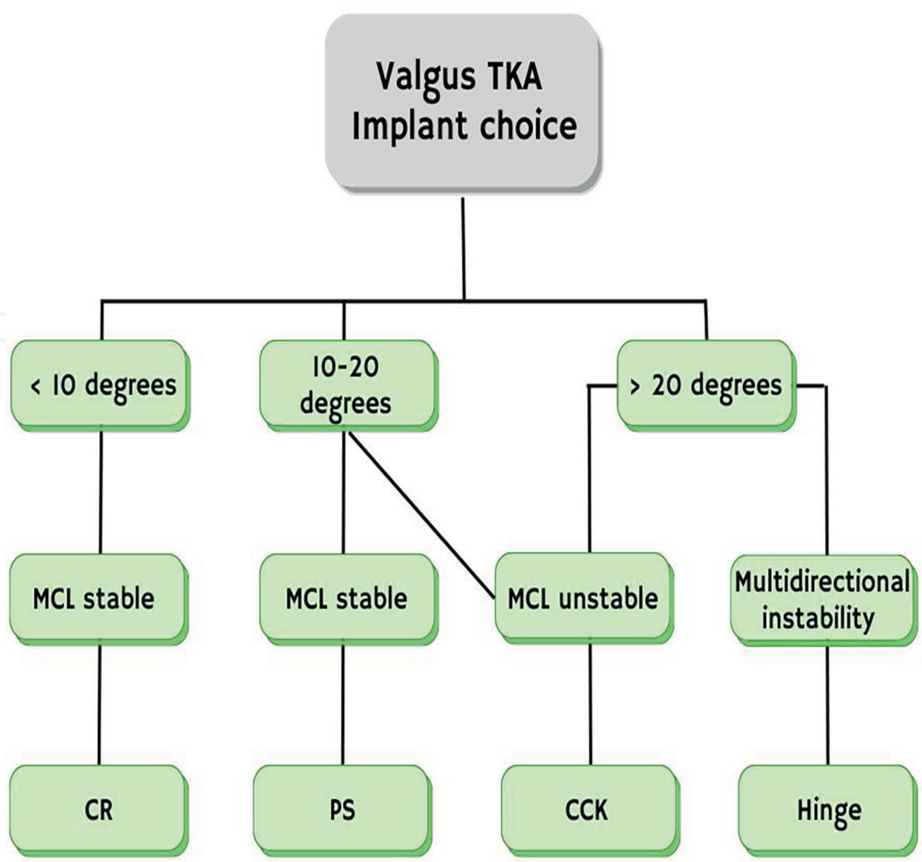

Figure 2.
Algorithm for implant choice in valgus TKAs.

The choice of implant must be based on the degree of joint instability and the presence of bone defects. Taking into account the Ranawat classification, for Grade I valgus knees (<10° deformity and intact MCL), Cruciate Retaining (CR) implants can be used, with proper bony resections and adequate soft tissue balancing for TKA long-term survival. The advantage of CR implants is the preservation of bone stock and improvement in knee proprioception [5, 6, 20–22].

For grade I or II valgus knees, mild-to-moderate coronal deformity is mild (<20°), and the MCL tension is inadequate, posterior stabilized (PS) implant can be used. In young patients, it is possible to preserve bone stock through the use of ultracongruent polyethylene insert, thus avoiding the resection of a box in the distal femur [7, 23–25].

In the presence of MCL insufficiency or >20° deformity (grade III), a greater constraint implant such as condylar constrained knee (CCK) or hinged implants should be used. CCK implants show good results at 10 years of follow-up, with a survival rate of around 97% [23, 26, 27]. Caution should be taken in younger patients, because it is necessary to remove a larger portion of distal femoral bone to accommodate the femoral box, which decreases the remaining bone stock available for revisions. In the case of elderly patients with severe ligamentous insufficiency and multiplanar instability or major bone defects, a hinged implant should be the choice [19].

5. New technologies

5.1 Computer-assisted navigation in valgus knee

Computer-assisted navigation (CAN) was developed to improve the position of the implants, achieving more accurate postoperative alignment through more precise and reproducible bony resection and ligament balancing [28].

Regarding the use of CAN in valgus TKAs, there are some published case series. Hadjicostas et al. [29] described the results of 15 knees with a mean valgus deformity of 21° (17–27°) and a mean follow-up of 28 months (24–60). All the knees were corrected to a mean of 0.5° of valgus (0–2 degrees).

Shao et al. [30] presented the results of six cases of CAN-assisted valgus TKA, in which ideal mechanical and prosthetic alignment was achieved with an image-free, computer-assisted navigation system. A primary, posterior-stabilized prosthesis was utilized in all cases. The average preoperative overall mechanical axis of the seven knees was 19.6° ± 4.6° of valgus, and the average postoperative mechanical axis was 0.4° ± 0.7°.

Between 2002 and 2009, Huang et al. [31] reported in a retrospective study, the results of 62 patients (70 knees) with Ranawat type-II valgus deformity who underwent primary TKA with or without CAN. At a mean follow-up of 6.2 years, both groups had significant postoperative improvements in clinical performance.

Unfortunately, there are still no good-quality randomized clinical trials that demonstrate evidence for the routine use of CAN in valgus TKAs. The decision remains based on the surgeon's common sense and experience.

5.2 Robotics and 3D printed implants in valgus knee

In recent years, the launch of new robotic platforms has caused great interest on the part of orthopedic surgeons. The use of robotic surgery in TKA improves the accuracy of knee alignment, implant positioning, and ligament balance, although it does not demonstrate superiority in clinical-functional outcome [32]. However, surgeons new to the robotics technique have been advised by more experienced ones to avoid valgus deformities at the beginning of the learning curve. The opinion of experts is that this is a challenge that requires more experience with the technique.

Marchant et al. [33] analyzed a series of cases with complex deformities undergoing knee arthroplasties and noted that robotic devices can help correct severe deformities, both in valgus with varus and in cases of flexion contracture. New studies should be carried out to analyze the clinical superiority of the use of robots in cases of valgus deformity. It was observed in another study that in seven knees with valgus deformity, all were corrected for alignment in neutral and without overcorrection [34].

Another recent technology is the manufacture of personalized implants. The use of 3D modeling techniques based on computed tomography in challenging cases of valgus deformity allows components to be placed in positioning according to the patient's anatomy in the coronal, sagittal, and transverse planes. This type of technology allows surgeons to make intraoperative adjustments and can place components outside of preoperative planning guidelines based on each patient's clinical need [35].

6. Rehabilitation

Rehabilitation of patients undergoing total valgus knee arthroplasty should follow common rehabilitation protocols. They should be focused on strength recovery, proprioception, and range of motion. Exercise therapy techniques, balance training, aquatic therapy, cryopneumatic therapy, and neuromuscular and transcutaneous electrical stimulation can be used [36].

The contact of the surgical and physical therapy team should be close. Consideration should be given to the surgical technique, implant design and constriction, release technique (osteotomy or soft tissue), and care in the possible neurological injury of the peroneal nerve.

7. Conclusion

Surgical treatment of the valgus arthritic knee presents a number of specific challenges. Multiple techniques have been described to treat this dysfunction with satisfactory clinical results. However, it is important for the surgeon to recognize the particularities and different techniques and practice a systematic approach to deformity correction.

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