U·P·O·J

A Systematic Approach to Soft-tissue Balancing in Primary Varus Total Knee Arthroplasty

[1]Russell N. Stitzlein, MD
[1]Alexander L. Neuwirth, MD
[1]Tyler R. Morris, MD
[1]Neil P. Sheth, MD

[1]Department of Orthopaedic Surgery, University of Pennsylvania Health System, Philadelphia, Pennsylvania

Introduction

More than 600,000 total knee arthroplasties (TKA) are currently performed annually in the United States and by 2030 the number is expected to reach 3.48 million per year.[1] Advances in implant design, materials and cement technique have contributed to increased survivorship. However, long-term outcomes are primarily predicated on overall alignment, component stability, and soft-tissue balancing. The degenerative process of osteoarthritis leads to altered joint mechanics and deformity in both the coronal and sagittal planes, frequently producing varus malalignment with or without an associated flexion contracture. More severe varus deformities typically require more complex surgical techniques in order to achieve appropriate soft-tissue balance. This article discusses a systematic approach to evaluate and address soft-tissue balancing in a varus primary TKA.

Background

Accurate bone resection and precise soft-tissue release of the medial side are critical in achieving a well-balanced total knee arthroplasty in the setting of varus deformity. Although still controversial, algorithms for sequential ligamentous, capsular, and tendinous releases have been described to restore alignment and optimize implant stability.[2-12]

Pre-operative Evaluation

Successful management of a degenerative varus knee requires careful pre-operative evaluation and planning. The surgeon should obtain a detailed history and perform a physical examination with a focus on overall knee/limb alignment, the quality of the soft-tissue sleeve surrounding the knee, the presence and location of previous incisions, the presence of a flexion contracture, stability to varus and valgus stress throughout the range of motion, and the ability to correct the varus deformity at 30° of flexion with a valgus directed force. Appropriate knee roentgenograms should be obtained. A complete set of X-rays includes a weight bearing anteroposterior (AP) view, a lateral view and a sunrise or merchant view (Figure 1). Radiographs should be carefully scrutinized for the presence of subchondral sclerosis and osteophytes, particularly medially and posteriorly where they may be impinging on capsular tissue, making the deformity worse. The lateral projection also provides information regarding the potential challenges of the exposure. In the setting of a short patellar tendon (patella baja) or a large inferior patellar nose or prominent tibial tuberosity (relative patella baja), surgical exposure of the knee is typically more challenging due to difficulty with subluxation or eversion of the patella. Full length weight bearing films also assist in determining the distal valgus resection angle (the difference between the mechanical axis and the anatomic axis of the femur), the correct point for cannulation of the femoral canal with intramedullary instrumentation and the level of bone resection both at the distal femur and at the proximal tibia (Figure 2). Based on physical exam and radiographic evaluation, the surgeon should determine the appropriate implant for planned TKA and determine whether a more constrained device should be available for backup.

Relevant Anatomy

When performing a TKA on a varus knee, the medial soft-tissues are tight and balancing therefore relies on appropriate releases of medial soft-tissue structures (Figure 3). Relevant structures include both static stabilizers (superficial fibers of the medial collateral ligament, posterior oblique ligament, posterior cruciate ligament and posterior capsule) and dynamic stabilizers (pes anserine tendons and semimembranosus tendon). Release of anterior structures primarily affects the flexion gap, while release of posterior structures affects the extension gap.

Procedure

There are two different schools of thought regarding TKA balancing: measured resection and gap balancing. In general, measured resection requires soft-tissue balancing after the bony cuts have been made, while gap balancing uses

Corresponding author:
Russell Stitzlein MD
Penn Medicine University City
3737 Market Street, 6th Floor
Philadelphia, PA 19107
Phone: (215) 796-8974
russell.stitzlein@uphs.upenn.edu

Figure 1. Standard radiographic evaluation of the knee. (A) A weight bearing AP view is critical to evaluate the degree of tibiofemoral joint space narrowing. (B) The lateral view, taken at 30° of flexion, allows for radiographic assessment of the patellofemoral compartment and is also particularly helpful for assessing posterior tibiofemoral wear patterns that are not readily apparent on AP views. (C) A weight bearing 45° PA (Rosenberg) flexion view is an alternative view to assess posterior wear patterns. (D) The Merchant view allows for radiographic assessment of the patellofemoral compartment.

the tension of the native soft-tissues/ligaments to determine the appropriate level of bone resection. Most surgeons use a combination of both techniques to achieve TKA balance. The authors prefer the use of gap balancing for the extension gap and then matching the flexion gap with the use of a measured resection technique.

As a part of the standard exposure for a TKA, the anterior capsule and deep MCL are released to aid in exposure. This release is more extensive (extends farther distal) in varus knees compared to valgus knees; however, it is equally important that this release be carried out medially around the tibia to the level of the posteromedial corner in both varus and valgus knees.

Following accurate femoral and tibial bony resections and removal of osteophytes, the surgeon should address soft-tissue balance with the goal of creating symmetric rectangular flexion and extension gaps. Soft-tissue balance can be assessed with spacer blocks, laminar spreaders, tensioning devices and/or trial implants and then applying a varus/valgus force in both flexion and extension. Generally, thorough removal of medial osteophytes in conjunction with a minimal soft-tissue medial sleeve release can result in a balanced knee; however, medial structures often enough remain tight, leading to unequal flexion and/or extension gap(s). When this happens, the surgeon must determine how to proceed.

After ensuring that the bony resections are accurate and the appropriate alignment has been obtained, attention should be given to additional medial soft-tissue release. We recommend addressing the extension space first. Initially, medial osteophytes will tether the medial soft-tissues; removal of any residual osteophytes will functionally lengthen the medial collateral ligament and result in further medial coronal

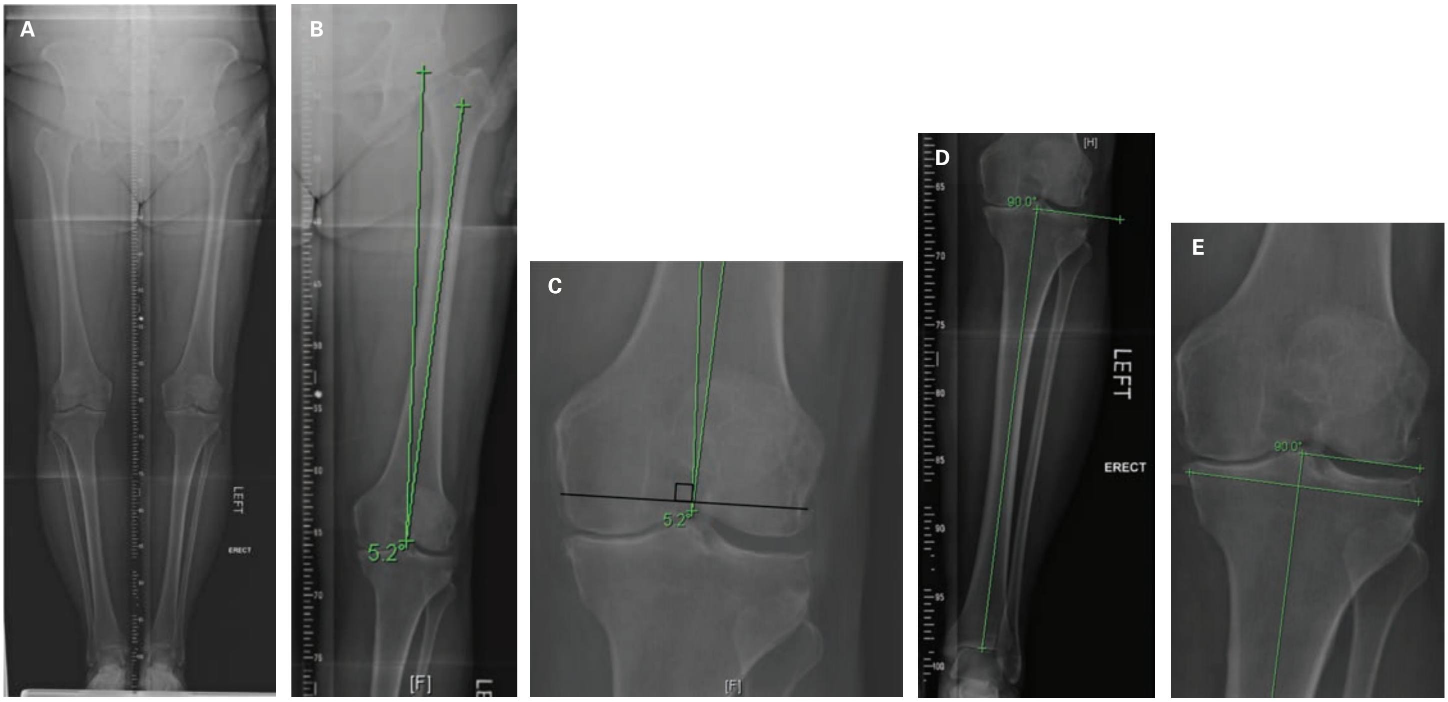

Figure 2. Templating the varus TKA. (A) Full-length standing AP radiograph of the lower extremities. (B) The distal femoral valgus resection angle is determined by calculating the angle between the mechanical axis (line connecting center of femoral head and center of the distal femur) and the anatomic axis (line connecting the center of the distal femur and bisecting the femoral shaft) of the femur. (C) A higher magnification view at the level of the knee shows the planned distal femoral resection (90° to the mechanical axis) as well as the entry site for the intramedullary femoral cutting guide (point where anatomic axis exits in the intercondylar notch on the AP view, which is generally just medial to the center of the notch). (D) The tibial resection for a TKA is performed at an angle 900 to the tibial mechanical axis (line connecting the midpoint between the medial and lateral tibial eminences and the center of the ankle. (E) A higher magnification view at the level of the knee demonstrates a templated tibial cut; in a varus TKA, generally 9 mm is resected from the uninvolved lateral tibial plateau and 2mm is resected from the medial side.

plane balancing. If additional soft tissue release is required, the next step is to continue around the posteromedial corner to include the deep MCL, the posterior oblique ligament, the posteromedial capsule and fibers of the semimembranosus insertion. A Cobb elevator should be utilized in the posteromedial corner to perform a distal release of the tight soft-tissues. If adequate coronal plane balance has not been achieved at this point, we recommend completing the remaining cuts of the femur and then re-assessing the coronal plane balance.

In flexion, the remaining femoral cuts are performed after appropriate sizing and femoral component rotation have been achieved. Resection of the medial posterior femoral condyle will result in additional medial release in extension—the posterior capsule, which plays a bigger role in extension stability will no longer be "tented" over posteromedial osteophytes and will thus be functionally lengthened. If, after femoral cuts have been made, the knee is still not balanced in extension on the medial side, there are a few more surgical decisions that can be made to achieve balance.

Total knee arthroplasty procedures that are being performed as a cruciate retaining (CR) procedure may benefit from release of the PCL to gain additional medial release and balancing. The PCL, which is a medial based structure based on its insertions may contribute to the overall varus deformity. If PCL release is not enough, then the only other options remaining are to downsize the tibial component (resect a portion of the medial tibia for further MCL functional lengthening) or to "pie crust" the superficial MCL. Pie crusting the MCL involves either making a small horizontal incision in the ligament or (author's preferred method) making multiple puncture holes using a large diameter (18- or 19-guage) hypodermic needle. At this point, a constrained TKA may be required and should be available as a backup prosthesis for all severe varus deformity cases.

If coronal plane balancing has been achieved in extension, then it must also be assessed in flexion. If the medial compartment is tight in flexion, then femoral component rotation should be assessed first—an internally rotated component will result in medial flexion tightness. If the femoral component is properly rotated, then release of the anterior fibers of the superficial MCL and Pes Anserine tendons will yield increased medial laxity in flexion.

A final note should be made regarding bony resections in TKA: extreme caution should be used and it is not advisable to resect additional bone from the distal femur or proximal tibia as a means to achieve soft tissue balance. Additional bone resection can alter the mechanical alignment of the TKA and lead to early implant failure. Increased distal femoral resection raises the joint line and can lead to mid-flexion instability due to laxity of the collateral ligaments throughout the range of motion, and can necessitate the use of a constrained implant or, if not identified intra-operatively, may result in early TKA failure.

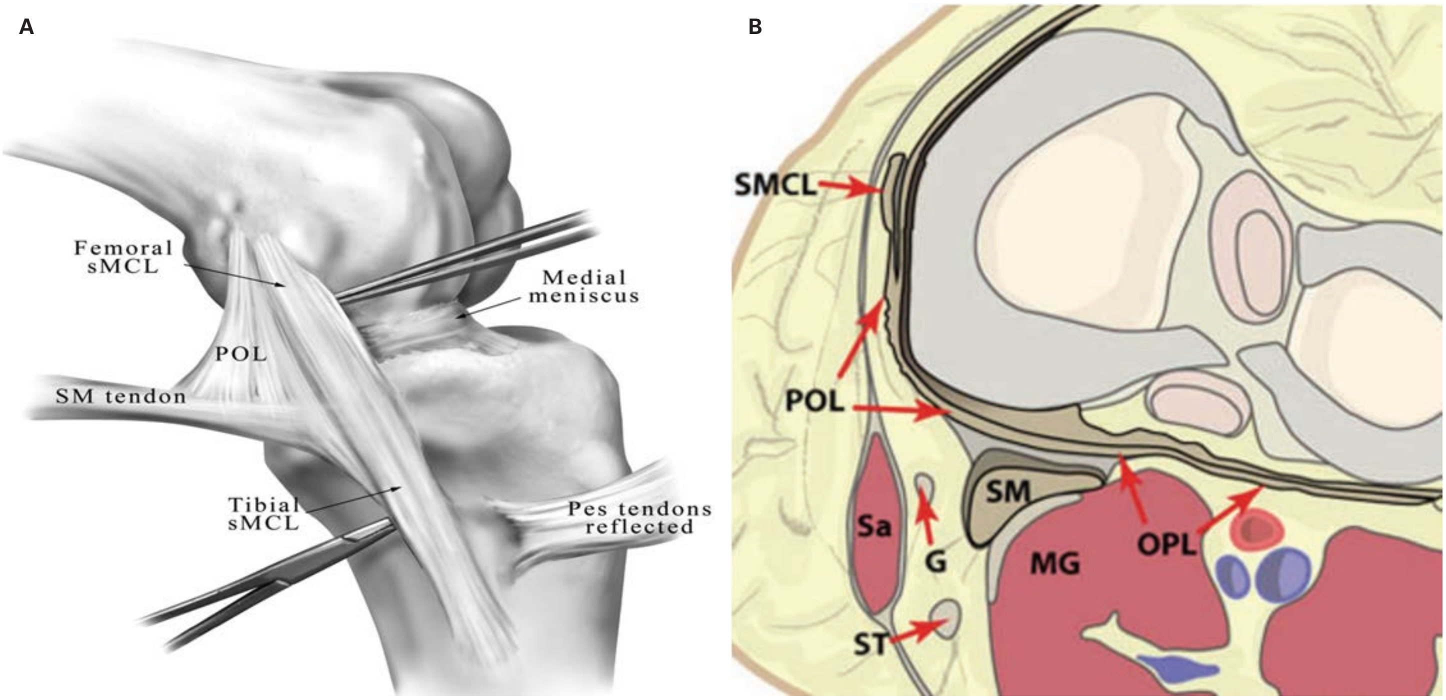

Figure 3. Soft tissue anatomy of the medial knee. (A) Sagittal view illustration of the knee demonstrating relevant medial structures, including the superficial medial collateral ligament (sMCL), posterior oblique ligament (POL), semimembranosus (SM) tendon, and pes anserinus tendons. Reprinted with permission from LaPrade RF. The Anatomy of the Medial Part of the Knee. J Bone Jt Surg Am. 2007;89(9):2000. (B) Illustration depicting the axial plane of the posteromedial corner of the knee at the level of the menisci. Relevant soft tissue structures for TKA include the superficial medial collateral ligament (sMCL), posterior oblique ligament (POL), semimembranosus tendon (SM), the structures that combine to form the pes anserinus, including the sartorius muscle (Sa), gracilis tendon (G), and semitendinosus tendon (ST). Also indicated here are the medial head of the gatrocnemius muscle (MG) and the oblique popliteal ligament (OPL). The posterior capsule lies immediately anterior to the OPL, while the deep medical collateral ligament lies immediately deep to the sMCL. Reprinted with permission from Norris MA. Posteromedial Corner Injury of the Knee. Radsource. http://radsource.us/posteromedial-corner-injury-of-the-knee/. Illustration by Michael Stadnick, MD.

Post-operative Protocol

Post-operatively, patients with a pre-operative varus deformity may be allowed to weight bear as tolerated (WBAT) without restrictions. In the setting of an iatrogenic MCL rupture or superficial MCL pie crusting, the operative extremity is braced in a hinged knee brace with unrestricted range of motion. Routine post-operative antibiotics and anticoagulation should also be utilized.

References

1. Kurtz S, Ong K, Lau E, et al. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Jt Surg*, 89(4):780-785 (2007).

2. Whiteside LA, Saeki K, Mihalko WM. Functional medial ligament balancing in total knee arthroplasty. *Clin Orthop*, 380:45-57 (2000).

3. Dixon MC, Parsch D, Brown RR, et al. The correction of severe varus deformity in total knee arthroplasty by tibial component downsizing and resection of uncapped proximal medial bone. *J Arthroplasty*, 19(1):19-22 (2004).

4. Mullaji AB, Padmanabhan V, Jindal G. Total knee arthroplasty for profound varus deformity. *J Arthroplasty*,;20(5):550-561 (2005).

5. Teeny SM, Krackow KA, Hungerford DS, et al. Primary total knee arthroplasty in patients with severe varus deformity: A comparative study. *Clin Orthop*, 273:19-31 (2005).

6. Mihalko WM, Saleh KJ, Krackow KA, et al. Soft-tissue balancing during total knee arthroplasty in the varus knee. *J Am Acad Orthop Surg*, 17(12):766-774 (2009).

7. Matsumoto T, Muratsu H, Kawakami Y, et al. Soft-tissue balancing in total knee arthroplasty: cruciate-retaining versus posterior-stabilised, and measured-resection versus gap technique. *Int Orthop*, 38(3):531-537 (2014).

8. Matsumoto T, Muratsu H, Kubo S, et al. Soft tissue balance using the tibia first gap technique with navigation system in cruciate-retaining total knee arthroplasty. *Int Orthop*, 36(5):975-980 (2012).

9. Meloni MC, Hoedemaeker RW, Violante B, et al. Soft tissue balancing in total knee arthroplasty. *Joints*, 2(1):37 (2014).

10. Takahashi T, Wada Y, Yamamoto H. Soft-tissue balancing with pressure distribution during total knee arthroplasty. *J Bone Joint Surg Br*, 79-B(2):235-239 (1997).

11. Chen W, Nagamine R, Kondo K, et al. Effect of medial soft-tissue releases during posterior-stabilised total knee arthroplasty. *J Orthop Surg*, 19(2) (2011).

12. Koh IJ, Kwak D-S, Kim TK, et al. How effective is multiple needle puncturing for medial soft tissue balancing during total knee arthroplasty? A cadaveric study. *J Arthroplasty*, 29(12):2478-2483 (2014).