Gap Balancing Through Small Incisions: Competing Goals

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Abstract

Significant controversy exists in the literature regarding the pitfalls and benefits of minimally invasive total knee arthroplasty (TKA). Regardless, most surgeons today use smaller exposures than in previous years. Although more difficult, rigid adherence to classical gap balancing techniques can allow a surgeon to achieve ideal ligament and flexion/extension gap balance in TKA through a minimally invasive approach. There are certain groups of patients (obesity/medical comorbidities/vascular insufficiency) in whom small incision approaches should not be attempted due to increased risks of wound complications. Additionally, achievement of gap balance requires sequential and safe removal of bone starting with the patellar cut, followed by the distal femoral cut, then by the tibial cut, and concluding with completion of the femoral component cuts. Use of special instruments such as protective metal patellar buttons, medial to lateral distal femoral cutting blocks, and low profile spacer blocks can facilitate the surgical process. Accurate femoral component rotation is more difficult in minimally invasive approaches and must be carefully checked. A tight extensor mechanism in flexion can mislead the surgeon to place the femoral component in an internally rotated position. Furthermore, with limited visualization, surgeons must avoid overaggressive ligament releases early in the procedure prior to completion of bone cuts. However, with appropriate patient selection and a systematic approach to minimally invasive total knee arthroplasty, surgeons can continue to achieve ideal ligament balance with a more soft tissue friendly operation.
The past decade in the field of total joint arthroplasty has witnessed widespread controversy with regards to techniques known as minimally invasive or smaller incision surgery. Although the literature is conflicting with regards to complication rates, clinical benefits, and risks of such techniques, no doubt exists that every orthopedic surgeon who performs total joint arthroplasty uses an incision that is smaller than the one he/she used just 10 years ago. What is also indubitable is that through rigorous adherence to gap balancing surgical techniques and principles, one can achieve outstanding short- and long-term results through the use of a smaller incision in TKA. The purpose of this article is not to debate the merits or pitfalls of minimally invasive knee arthroplasty. Rather, the purpose is to describe with meticulous detail how one might achieve excellent flexion/extension gap balance, varus/valgus balance, component alignment, and outstanding range of motion (ROM) through rigid adherence to gap balancing techniques and a less destructive soft tissue exposure. The achievement of these goals is more difficult through minimal exposure. The principles proposed in this manuscript are most applicable to posterior stabilized knee designs. However, these concepts of gap balancing are equally as relevant to cruciate retaining designs.

**Contraindications**

There are certain groups of patients in whom the theoretical and proposed benefits of smaller incision techniques are outweighed by the risks of intraoperative and postoperative complications that result from inadequate exposure (Table). An obese patient whose knee is enveloped by a thick soft tissue envelope is more difficult to tackle through smaller incision techniques. Also, the sheer weight of the patient’s leg can make assessment of the flexion gap balance difficult to assess. Additionally, patients with flexion contractures, large articular deformities, and patella infera also present significant surgical challenges. Achievement of excellent balance and component alignment in such patients is difficult even when using traditional incision techniques with large quadriceps mechanism incisions and full patellar eversion. Patients with dermatological problems (eg, psoriasis), vascular problems (eg, venous stasis, peripheral vascular disease), or medical problems that impair wound healing (eg, diabetes mellitus), should generally not undergo smaller incision surgeries, as the additional retraction of tissues required for these exposures can often harm susceptible soft tissues in these patients. Finally, although not intuitive, lean and muscular patients, particularly men who require large component sizes due to large bony anatomies, present exceedingly difficult obstacles for such procedures, as their musculature makes retraction challenging. Additionally, the simple act of placing large femoral and tibial components in smaller wounds can be an arduous process.

**Introduction to the Balanced Gap Technique**

The traditional balanced gap technique encourages surgeons to perform ligament releases with knee in extension prior to the completion of any bone cuts. Surgeons would perform the initial arthrotomy and knee exposure, followed by release of the medial collateral ligament and/or lateral structures to the extent that would achieve varus/valgus balance. Other variants of the technique allow surgeons to perform releases after the tibia has been cut; this technique provides the opportunity to address the posterior cruciate ligament and posterior femoral osteophytes. After the tibial cut has been made, the femoral component is then rotated the amount necessary to create a rectangular flexion gap. The distal femoral cut is then made to create an extension gap of equal size and dimension to the flexion gap.

In either case, these techniques are more complicated and significantly less reproducible because they require that the surgeon assess the extensor gap balance and adequacy of the collateral ligament releases with no aid of simple guides that could assess varus/valgus ligament tension. For inexperienced surgeons, overrelease of the medial or lateral structures in an attempt to achieve varus/valgus balance prior to any bone cuts could easily lead to significant instability later in the case after bone cuts have been made. Although complex tensor devices are available, such devices are difficult to learn to use reproducibly. The gap balancing techniques that we will describe here greatly simplify
this process and can be reliably accomplished with smaller incisions.

SURGICAL TECHNIQUE AND EXPOSURE

Achievement of gap balancing through smaller incisions is affected most by the surgeon’s ability to visualize the knee. A significant factor in visualization is the progressive removal of bone in a safe and sequential pattern that allows increasing visualization with subsequent bony resections. Because it is most easily and readily visualized, the patella is cut first to its final thickness so that tension is reduced in the extensor mechanism. A protective metal spiked patellar button is then placed onto the cut patellar surface to prevent injury for the remainder of the operation (Figure 1). The next cut is made at the distal femur. Because it is readily and easily visualized, even in a small incision, the distal femur is cut next. Instruments that allow the surgeon to make an accurate distal femoral cut from a medial to lateral direction rather than the traditional anterior posterior direction are used. Such instruments obviate the need for increased quadriceps mechanism violation that is required for proper placement of a traditional anterior-posterior distal femoral cutting guide. A fixed angle intramedullary checking guide is then used by the authors to confirm the varus/valgus angulation of the distal cut (Figure 2). Next, the tibial cut is made. With the patellar resection and distal femoral having been completed, visualization of the tibia is facilitated. In general, low profile tibial cutting jigs that anchor on the medial plateau are used. The tibia is then cut perpendicular to the mechanical axis.

EXTENSION GAP BALANCE

At this point, the surgeon has achieved well-aligned distal femoral and proximal tibial cuts. With a cut distal femur and a cut proximal tibia, gap balancing is done in extension in accordance with the principles of the balanced gap technique. After these cuts have been made, the surgeon uses simple spacer blocks of varying thickness to determine both the size of the extension gap, as well as the medial and lateral ligament tension in extension. At this point, the surgeon can and should perform additional careful ligament releases medially or laterally to create a rectangular extension space with equal ligament tension medially and laterally. Low profile spacer blocks are simple to use for this purpose and are the only “instruments” that are needed (Figure 3). These spacer blocks generally start at a minimum thickness of 10 mm and increase in 2-mm increments.

The only caveat to the technique at this point is that unspecified and excessive ligament release in extension can still present a problem later in the case if there are large posterior femoral osteophytes that can affect the balance in extension. Therefore, in cases where the preoperative radiographs demonstrate posterior osteophytes medially, the surgeon should proceed with slightly less release medially in extension than is necessary to create a full rectangle in anticipation that that removal of these osteophytes and release of posterior capsular contractures will open up the medial gap sufficiently to achieve ideal ligament balance.

One final additional consideration relates to the later use of symmetrical tibial baseplates. Generally, when such baseplates are to be used later in the case, appropriate external rotation of symmetric baseplates will necessitate posterior medial uncovered bone on the tibial plateau. Later removal of this posterior medial bone will have a mild loosening affect on the medial compartment in extension. Similarly, if there is a large overhanging me-
dial tibial osteophyte, later removal of this osteophyte will affect medial ligament tension. Therefore, the authors recommend that the surgeon keep these points in mind at this stage of the surgery to avoid overrelease of the medial structures.

**Flexion Gap Balance**

After a balanced extension gap has been achieved, the surgeon need only accomplish 2 further goals on the flexion side of the knee to achieve excellent balance. The first of these goals is appropriate external rotation of the femoral component such that the posterior condylar cuts are parallel to the cut tibial surface. The second goal necessitates that the surgeon choose a femoral component that will achieve a flexion gap of equivalent size to the extension gap that was previously created.

To achieve the first goal, the authors recommend that the surgeon physically draw the Whiteside’s line on the distal femur to use as a reference for determination of femoral component rotation. The femoral component cutting block is then rotated the appropriate amount necessary to create a rectangular gap, using Whiteside’s line as an additional check (Figure 4). In general, the rotation of the femoral component should be perpendicular to Whiteside’s line. However, on occasion, slightly increased femoral component external rotation will be required than is indicated by Whiteside’s line to achieve posterior condylar cuts that are parallel to the cut tibial surface (3°-5°). However, when it appears that the femoral component is less rotated than Whiteside’s line, the surgeon should be vigilant to look for potential causes. It can be reasonably stated that the femoral component should never be more internally rotated than a perpendicular position to Whiteside’s line. If the posterior femoral cuts appear to resect more posterolateral bone than posteromedial bone, the surgeon should seriously consider repositioning the femoral cutting block, as it is most likely internally rotated. Potential causes of an internally rotated femoral component include a valgus knee with inadequate lateral release, or a varus knee in which overrelease of the medial structures has been performed.

If the technique described above is followed, one should then have a gap in flexion that is rectangular and parallel to the extension gap. At this point, the surgeon must focus on the achievement of the second goal, namely a flexion gap of equivalent size to the extension gap. This is accomplished by using the same spacer blocks used earlier in the operation for assessment of the extension gap. The surgeon should affix the femoral cutting block to the distal femur and then use a space block between the posterior aspect of the cutting block and the cut tibial surface. If this space is equivalent to the extension space, then the surgeon has achieved balanced gaps. If it is not, then he/she should consider switching to a different femoral component size. However, unless the patient had significantly reduced femoral component size, the surgeon should always aim for a secure flexion gap.

Finally, femoral components that are narrower in the medial/lateral dimension are now available. Such components can allow the surgeon to achieve secure flexion gaps with no concerns of medial/lateral component overhang.

**Completion of the Operation**

After the femoral component cuts and the notch cut have been completed, the next steps involve clearing the posterior aspect of the knee of bone and soft tissue remnants to improve both flexion and extension kinematics. The surgeon should first look and feel closely for posterior femoral osteophytes. Any palpable bony structures should be removed with a curette and/or rongeur. Additionally, any significant capsular adhesions to the posterior femoral condyles should be released. These maneuvers will optimize the patient’s ultimate extension. One important aspect of this release of posterior capsular adhesions is that the dissection should always start centrally, in the femoral notch area, and then move medially or laterally, while staying close to the bone. By using this technique, creation of a vascular injury is less likely.

The next step involves exposure of the tibial plateau for base plate preparation. Accurate positioning of the baseplate generally necessitates subluxation of the tibia forward. Additionally, the use of femoral components with “high-flex” posterior condylar cuts creates more space between the posterior femur and the tibial plateau.
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thereby facilitating placement of the tibial baseplate trial (Figure 5). A key maneuver to achieve tibial baseplate subluxation involves the release of roughly 1 cm of distal tissue around the posteromedial tibial corner just proximal to the multiple insertions of the semimembranosus, the predominant posteromedial dynamic stabilizer.

Rotation of the tibial base plate is set to match the tibial crest at the junction of the proximal and middle thirds of the tibia. This landmark is often ideal for use in small incision operations where the tibial tubercle cannot be seen and/or palpated.

**POTENTIAL PITFALLS OF THE BALANCED GAP TECHNIQUE THROUGH SMALL INCISIONS**

The biggest pitfall of using this technique with a small incision is an abnormally tight extensor mechanism and/or patella infera. In such situations, the lateral compartment will appear abnormally tight in flexion, such that the surgeon will tend to underestimate the amount of femoral component external rotation that is required to achieve a rectangular flexion gap. In more traditional larger incision approaches, the patella will be completely everted, thereby nearly eliminating the possibility of such a scenario. Again, as described earlier, the surgeon should consider a tight extensor mechanism when the femoral component rotation is not concurrent with that predicted by Whiteside’s line.

A tight extensor mechanism can also be mitigated if the patella is cut to the final thickness at the beginning of the case. Addressing the patella early on in the operation in this fashion will reduce tension of the extensor mechanism.

Another noteworthy pitfall of the balanced gap technique involves overrelease of the medial structures early in the operation such that later bone cuts, posterior femoral osteophyte resection, or posterior capsular release will result in a pathologically lax medial compartment. The best way to avoid such a scenario is for the surgeon to proceed with slightly less medial release in extension than is required to create a rectangular extension gap. Once the femoral bone cuts are completed, the surgeon can then proceed with subtle adjustments to the medial release to achieve balance. Additionally, complete retention of the pes musculature (dynamic anteromedial stabilizers) and the semimembranosus (dynamic posteromedial stabilizer) will retain medial knee stability even when the entire superficial medial collateral ligament has been released.

Another common pitfall is for surgeons to make errors with the initial distal femoral cut. If the cut has too much valgus, this will significantly affect later extension gap balance. Therefore, the authors strongly recommend the use of an intramedullary distal femoral cut alignment checking device (Figure 2). Finally, another commonly seen pitfall is malalignment of the tibial cut. If such malalignment is present, the surgeon will make subsequent mistakes when attempting to rotate the femoral component later in the case to achieve a parallel position to the cut tibial surface. A tibia that is cut in varus will result in an internally rotated femoral component, while a valgus tibial cut will result in a femoral component that is overrotated externally.

**FINAL COMMENT ON NAVIGATION**

The authors propose that navigation could provide significant benefits for the balanced gap technique. A navigation device that could ensure perfect varus/valgus alignment of the distal femoral and tibial cuts could greatly facilitate execution of the balanced gap technique.

**REFERENCES**
