ICL #19: The Importance of Surgical Technique in the Outcome of TKR – Gap Balancing vs Measured Resection Technique for TKR: with Specific Reference to Final Outcome

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Introduction

With the increasing number of TKAs performed each year, in addition to the procedures being performed in younger and more active patients, the number of revision procedures is also increasing. One of the most common causes of failure is instability. Therefore, soft-tissue balancing is essential to a successful TKA.

In order to achieve a well-balanced knee (which has been defined as symmetric and balanced flexion and extension gaps), two distinct surgical techniques have been identified: measured resection and gap balancing. Since these two methods utilize different techniques to determine ligament balancing and femoral component rotation, controversy exists regarding the best technique.

Measured Resection Technique

The measured resection technique uses bone landmarks such as the transepicondylar axis (TEA), the anterior posterior axis (AP), or the posterior condylar axis to determine proper femoral component rotation and subsequent gap balance. Bone cuts are initially made independent of soft-tissue tension.

Gap Balancing Technique

The gap balancing technique places the femoral component parallel to the resected proximal tibia with each collateral ligament equally tensioned to obtain a rectangular flexion gap. The gap balancing technique relies on ligament releases prior to each bone cuts. The technique is based on the progressive release of ligaments to create equal and symmetric flexion and extension gaps. With this technique, surgeons need to understand which structures affect extension, flexion and both in order to create proper balancing. These ligament releases correct fixed deformities and bring the limb into correct approximate alignment before determination of femoral component rotation.

Differences Between the Two Techniques

One of the most fundamental differences between the two techniques is in setting the rotation of the femoral component to achieve a symmetric flexion gap.

Rotation of Femoral Component

The measured resection technique relies on bony landmarks in order to set femoral component rotation. Bony landmarks may provide accurate rotation of the femoral component as long as the surgeon is able to accurately and reproducibly find them intra-operatively. Research has suggested there are many variables in femoral component rotation when using bony landmarks, which may lead to asymmetrical flexion gaps and condylar lift off in flexion.

The gap balancing technique relies on symmetric tension placed on the ligaments in flexion to set femoral component rotation. The femur is rotated to create an equal and symmetric flexion gap and the size of the flexion gap is adjusted to match the gap created in extension. Therefore, the rotation and AP placement of the femoral component are used to create flexion gap symmetry (as opposed to fixed bony landmarks).

Soft Tissue Releases

With a measured resection technique, releases are made with trial component in place after all bony resections have been made. In addition, the femoral component rotation is set off of arbitrary bony landmarks. Releasing the tight medial side of the knee in extension for example, can then lead to the creation of laxity and asymmetry in flexion.

With gap balancing, the extension gap is created by bony resection of the distal femur and proximal tibia. Equal medial and lateral gaps are created in extension by a stepwise release of tight structures on the
concave side. For example, in a varus knee, tight structures in extension are the deep medial collateral ligament (MCL) and posteromedial corner of the knee. Releasing these structures will affect the extension space more than the flexion space.

What one must understand is that any releases that are done in extension, on either the medial or lateral side of the knee, can have an unpredictable effect on the flexion space. Gap balancing accommodates for this by allowing the flexion space to be set based on ligament tension and accommodates for releases that have already been made in extension, rather than fixed bony landmarks.

The creation of an extension gap is common for both techniques and can be considered as a measured resection technique. This step is where the joint line is primarily determined. In a gap balancing technique, the joint line is elevated in relation to measured resection technique in order to create symmetrical gaps. Surgeons who use the gap balancing technique should be aware of the variables in the elevated joint line even if their clinical consequences are unknown.

Depth of tibial resection and alignment (coronal and sagittal) are very important. In gap balancing technique, any deviation will result in femoral malrotation. Therefore, it is suggested to use trial components to ensure stability in both the coronal and sagittal planes throughout the entire arc of motion.

Factors to Consider Before Choosing a Surgical Approach

Implant Selections
Surgeon experience and familiarity with a particular implant most likely plays the greatest role, regardless of which technique is utilized. Today, there are likely more measured resection and cruciate-substituting users in the North America. In Europe, there is great variability among and within countries. The authors prefer a hybrid method.

Excellent results can certainly be achieved with either surgical technique or implant. However, one must understand the difference that the PCL plays in the knee when intact or removed. When the PCL is removed, the flexion gap immediately opens up (about 2 mm). Therefore, one must compensate for this by taking some additional initial bone off the distal femur to open up the extension gap. For instance, the distal femoral cut in a cruciate-retaining TKA may be 7 mm to 8 mm and 9 mm to 10 mm in a cruciate-substituting knee (assuming no flexion contracture). Additionally, releases on the medial side of the knee will have less effect when the PCL is intact. When the PCL is removed for a cruciate-substituting knee, the releases on the medial side of the knee will have more of an effect in flexion.

Pre-operative Coronal Alignment (Varus or Valgus)
Question - Is the deformity reducible or not?
• If yes, both techniques can be used
• In severe fixed varus or valgus deformity, a gap balancing technique may not be appropriate

Advantages and Disadvantages

Measured Resection Technique – Advantages of using TEA:
• Enhanced patellofemoral tracking and improved femoral-tibial kinematics can be obtained by placing the femoral component parallel to the TEA.
• TEA can be referenced in primary and revision TKA where there is posterior condylar hypoplasia or erosion

Measured Resection Technique – Disadvantages of using TEA:
• Numerous studies report that surgeons may be unable to accurately and reproducibly identify the TEA (difficult to locate the medial and lateral epicondyles precisely)

Measured Resection Technique – Advantages of using AP axis:
• When the femoral component is positioned perpendicular to the AP axis, patellofemoral problems are significantly reduced compared to when the femoral component is placed parallel to the posterior condylar axis
• The AP axis can be utilized in cases of posterior condylar bone erosion or hypoplasia
**Measured Resection Technique – Disadvantages of using AP axis:**
- A wide range of errors when the AP axis is used as the sole determinant of the femoral component rotation
- In knees with medial femorotibial osteoarthritis, the line perpendicular to AP axis is externally rotated 3-5 degrees relative to the posterior condylar axis compared to normal knee. This will lead to excessive external rotation of the femoral component and subsequent coronal plane instability in flexion.

**Measured Resection Technique – Advantages of using PCA:**
- Instrumentation has been developed to ensure a preselected amount of external rotation (3-5 degrees) relative to the PCA in neutral and varus knees with minimal deformity and no femoral bone erosion

**Measured Resection Technique – Disadvantages of using PCA:**
- Due to a wide anatomic variation in relationship with PCA to the TEA, a significant percentage of patient would incur greater than 2 degrees of malrotation relative to the TEA. If femoral component were automatically rotated 3 degrees with regard to posterior condyles.
- Difficult to rely on PCA to set rotation for arthritic knees with deformities and revised knees.

**Gap Balancing Technique – Advantages:**
- Improved flexion gap stability and patellar tracking
- Better femoral component rotation providing coronal stability

**Gap Balancing Technique – Disadvantages:**
- Precise proximal tibial resection is critical; a varus tibial cut will result in increased internal rotation of the femoral component, while a valgus tibial cut will lead to excessive external rotation.
- Over or under resection can lead to mismatch of the flexion & extension gap. Over resection of the distal femur results in an enlarged extension gap. This is usually compensated with a thicker tibial component to accurately tension the extension gap.
- Integrity of the collateral ligament and precise ligament balancing are critical. When the lateral collateral ligament – popliteus tendon complex is deficient, positioning the femoral component parallel to the resected tibia can result in excessive external rotation.
- Having equal tensions of ligaments at 0 and 90 degree is not enough to prevent mid flexion instability. The gap balancing technique does not allow for mid-flexion balancing since the technique requires the tibial cut to be used as platform to create flexion gaps at 90 degrees.
- Natural laxity on the lateral of the knee will cause more joint space opening on the lateral side which will result in a balanced but a more externally rotated flexion gap when equal tension are applied to the medial and lateral collateral ligaments.

**Patient Reported Outcome Measures (PROMs)**

With the current literature, controversy remains whether the measured resection or gap balancing technique is superior. No difference has been observed in PROMs between the two techniques. As for survivorship, long-term studies have reported good survival with both techniques. Although this debate started in the 1970s, no study has shown a definite benefit from one technique over the other.

Most literature comparing femoral component rotation and kinematics rather than actual PROMs since there are limitations as follows:
- Scoring systems are not sensitive enough to identify subtle differences in patient outcomes
- Inability to quantify intra-operative ligament tensioning, balance and patellar tracking
- No knowledge of the degrees of external rotation to be given to the femoral implant or whether the degree of rotation should be universal for all patients
- Inability to accurately determine the degree of rotation without knowing the proper tensioning required
- Knee is a dynamic joint while surgeons have to make static decisions regarding balancing and component intra-operatively

The goals of a TKA are for it to be well-aligned and well-balanced with improvements in patient function and satisfaction. Rather than trying to decide which technique has overall better outcomes, it is more important to determine in a particular surgeon’s hands, which technique provides the most reliable and reproducible results of achieving the above-mentioned goals. As with most surgery, if it is done well, the goals and outcomes can be achieved, regardless of technique.
Hybrid Approach

Patients desire a TKA that is mobile, pain free, and stable in the long-term. While this may seem obvious in 2015, the fact remains that almost 20% of the patients are unsatisfied post TKA due to a variety of reasons, including limited range of motion, continued pain, and/or instability. Since this occurs regardless of which technique was used, a hybrid approach is worth considering. The authors believe that the 20% dissatisfaction is mostly due to lack of understanding the anatomy of each individual. We currently treat every knee the same when it comes to a TKA, and while that may be good for 80%, we leave another 20% dissatisfied. Newer imaging techniques and advanced technology should allow for customization of individual anatomy and may require a change in how we currently think about TKA.

The concept of a hybrid technique is ideal because TKA is both a soft-tissue and bony procedure. Combining the two techniques, with established intraoperative checks-and-balances between the two techniques, allows for minimization of inappropriate ligament releases and component malalignment. The risk of using a strict gap balancing technique is that this is rather subjective, and can introduce significant bias not only between surgeons, but also within a surgeon’s practice. Also, as noted above, almost all gap balancing tensioners are used with the patella subluxed, which influences the ligament tension between the medial and lateral sides. This may lead to femoral component malrotation.

Conclusions

In reality, most surgeons including the instructor use a hybrid approach that combines both techniques to achieve the best results in TKA. While neither the measured resection or gap balancing technique has been proven to be definitely superior than the other, the fact remains that it is crucial to emphasize the key elements of both surgical techniques are proper placement of components in the coronal, sagittal and axial planes and appropriate soft tissue balancing.

References