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Operative Techniques in
Orthopaedics

Treatment of Hip Instability

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Prosthetic instability after total hip arthroplasty is a multifactorial complication with both patient- and surgeon-related etiologies. A fundamental knowledge of potential causes and solutions allows for a comprehensive approach to identifying causative factors and leads to the formulation of the appropriate plan for resolution. This chapter will detail the etiologies of hip instability, the clinical evaluation of the complication, and surgical and nonsurgical treatments that can be used to resolve the problem.
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Introduction

Total hip arthroplasty (THA) is a common orthopaedic procedure used for a variety of indications and performed to alleviate pain and restore function of the hip joint. It is considered to be one of the most successful orthopaedic surgeries and is performed with increasing numbers in our aging population.[1] Among complications following THA, instability is one of the most frequent with a historical incidence of approximately 2%-3%,[2] although with modern techniques and components some studies have shown an incidence less than 1%.[3] This chapter serves to review concepts of THA instability, including risk factors and causes as well as clinical evaluation and management of this challenging complication.

Surgeon and Implant-Related Risk Factors for Instability

Surgical Approach

While the surgical approach for THA has been a long studied and often debated topic concerning THA instability, it is important to note that the general risk of dislocation with all approaches is quite low. The 3 most common approaches are the modified-Hardinge, posterior, and direct anterior approaches. The modified-Hardinge approach, which preserves the posterior capsule, has been shown to have the lowest rate of dislocation, even in the absence of formal postoperative hip precautions.[4,5] The posterior approach, which violates the posterior structures of the hip, has been historically associated with a higher rate of dislocation.[6-10] Yet, with modern implants and meticulous surgical technique, including repair of the posterior soft tissue structures, the relatively high rate of dislocation associated with the posterior approach has been substantially reduced.[11,12] Sioen et al examined torque required for dislocation in cadaver hips with a posterior approach with either no repair, soft tissue only repair, or transosseous repair through the greater trochanter. This study found significantly greater torque and rotation angle required to dislocate hips with transosseous capsule repair.[13] The direct anterior approach, which requires release of posterior structures in order to achieve femoral exposure, is associated with a risk of dislocation closer to the posterior approach than the modified-Hardinge approach.[8] It is important to note that each surgical approach has unique advantages and disadvantages, including the risk of dislocation, that the surgeon must consider.

Component Positioning/Impingement

Femoral and acetabular component positioning is a critical determinant of prosthetic stability. Component malpositioning may lead to prosthetic impingement, resulting in the femoral head levering out of the acetabular component. The concept of a “safe zone” for component positioning has been considered in the literature for nearly 50 years. Components positioned outside of this range may lead to impingement within a functional range of motion, leading to prosthetic

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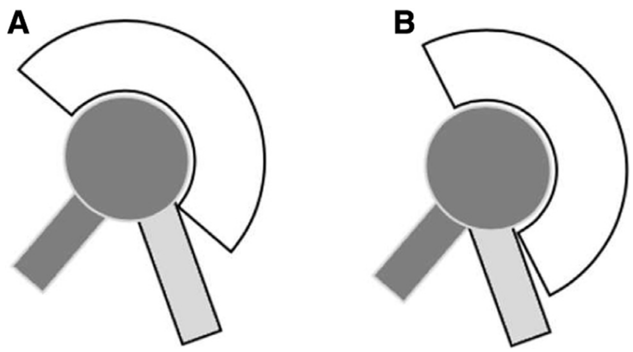

Figure 1 Demonstrates the importance of component position and the result of component malpositioning (A) Shows the acetabular component in proper position. (B) The acetabular component malpositioning, resulting in prosthetic impingement within a functional range of motion.

instability (Fig. 1). The generally accepted guidelines for component positioning include $40^\circ \pm 10^\circ$ for acetabular inclination, $15^\circ \pm 10^\circ$ for acetabular anteversion, and 10°-15° for femoral component anteversion, for a combined total anteversion of $35^\circ \pm 10^\circ$.[14]

Studies have demonstrated higher dislocation rates when the acetabular cup was placed out of the designated "safe zone".[14] Fujishiro et al examined clinical effects of THA component positioning in patients by obtaining computed tomography (CT) scans 1 week following surgery. Acetabular anteversion $> 30^\circ$ and $<10^\circ$ was a predictor of dislocation anteriorly and posteriorly, respectively. Stem anteversion $> 40^\circ$ and $< 20^\circ$, and combined anteversion $> 60^\circ$ and $< 40^\circ$ were each found to be risk factors for dislocation.[15] Jolles et al studied over 2 thousand THAs and found dislocation rate to be 6.9 times higher when total anteversion was $<40^\circ$ or $>60^\circ$, highlighting the importance of proper component positioning.[16] Additionally, accurate component positioning has prompted the advent of technologies such as robotic assisted surgery, computer navigation, and patient specific jigs for component positioning.[12]

Some studies have questioned the utility of the "safe zone" concept, as appropriate component positioning does not preclude instability, with many additional factors contributing to prosthetic stability.[17,18] In addition, the "safe zone" ranges may not apply to certain patient populations, such as those with dysplasia and those with prior lumbar spine fusions.

Osseous impingement may also play a role in prosthetic instability. The femoral component may encroach upon residual acetabular osteophytes that protrude beyond the acetabular component, decreasing the range of motion to impingement. Similarly, overhanging trochanteric osteophytes may encroach upon the acetabular component or osseous structures, again, decreasing the range of motion to impingement. Lastly, when the normal distance between the trochanteric bone and pelvic/acetabular bone is decreased due to improper restoration of the acetabular and femoral offset, the osseous structures may inappropriately impinge, leading to prosthetic instability.

Head-to-Neck Ratio

As THA technology has advanced, modern components have allowed for more options to improve prosthetic stability. The 2 most important factors include the acetabular liner thickness and femoral head diameter. The decreased rate of wear and increased structural integrity of ultra-high molecular weight polyethylene has allowed surgeons to implant much thinner acetabular liners than were previously used. This results in increased femoral head diameters allowed for a given acetabular component size (Fig. 2). In addition, many modern implants are designed to decrease the anteroposterior (AP) prominence of the neck of the femoral component. Larger femoral heads and redesigned femoral necks improves prosthetic stability by increasing the head-to-neck ratio, resulting in an increased arc range of motion prior to impingement. Larger femoral heads also lead to an increased excursion distance, subsequently reducing the risk of dislocation (Fig. 3).

Soft Tissue Tension

Proper soft tissue tensioning is another critical determinant of prosthetic stability. The tension of the elastic soft tissues that surround the hip joint, including the hip capsule and the numerous surrounding muscular and tendinous structures, are responsible for creating the compressive force between the femoral head and the acetabular liner. Improper restoration of leg length and hip offset leads to relative laxity of the soft tissues surrounding the hip joint. As a result of the decreased tension of these soft tissues, the compressive force between the femoral head and acetabular liner is decreased

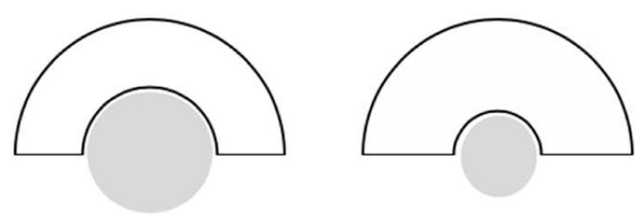

Figure 2 With a thinner polyethylene (PE) liner the surgeon has the ability to increase head diameter and subsequently increase THA stability.

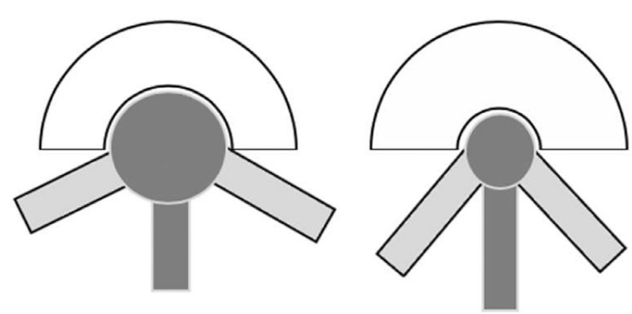

Figure 3 With an increase in head-neck ratio, there is an increase in range of motion prior to prosthetic impingement. The image on the left shows the increased range of motion (greater head-neck ratio) compared to the image on the right.

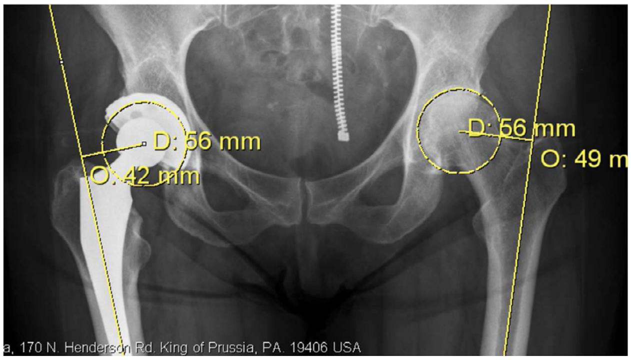

Figure 4 Demonstrates the pelvic radiograph of a patient indicated for revision for instability. In the index procedure, the patients native femoral offset was not restored, resulting in excessive soft tissue laxity. The patient underwent a successful femoral revision to a high-offset implant.

and the ease of dislocation is increased. Factors that lead to improper restoration of leg length include excessive superiorization of the acetabular component and improper femoral reconstruction that fails to restore proper height of the femoral head. Factors that may decrease the overall offset of the hip include excessive medialization of the acetabular component and improper femoral component selection and positioning (Fig. 4).

Patient-Related Risk Factors for Prosthetic Instability

Hip Dysplasia

Hip dysplasia can present unique challenges in achieving stability with THA and, as such, there is a higher incidence of instability in patients with hip dysplasia.[19-21] The acetabular bone of dysplastic patients displays varying degrees of bone deficiency and may have abnormal anteversion or retroversion. The surgeon is faced with achieving adequate component-bone contact and component fixation while avoiding undercoverage of the anterior aspect of the component and as a result, optimal component positioning is often challenging. In addition, achieving the reconstructive goals often requires significant medialization of the component, which may affect offset and soft tissue tensioning. On the femoral side, the surgeon is often faced with diminutive anatomy and abnormal anteversion or retroversion, making femoral reconstruction difficult. Lastly, soft tissue balancing is often difficult in dysplastic patients due to tissue atrophy, changes in the normal tissue elasticity, and patient hyperflexibility. To minimize the risk of instability in dysplastic patients, the surgeon must recognize and address individual variations in the dysplastic hip during preoperative planning and surgical execution.

Neuromuscular Disorders

Neuromuscular disorders afflict millions of patients worldwide, but fortunately modern medicine has allowed for slowing of disease progression. With this patient subset living longer, there have been more patients with conditions such as multiple sclerosis and Parkinson's disease undergoing THA for osteoarthritis. These patients are at an increased risk of instability following THA as sequelae of their disorders. Neuromuscular diseases cause significant gait deficits and postural instability leading to frequent falls.[22] Additionally, neuromuscular disorders can be an indirect cause of instability by exposing patients to other risk factors. For example, patients are more likely to experience femoral neck fractures and AVN from falls and steroid use, respectively. In a national database study of 3360 patients, Quinlan found the rate of THA dislocation in multiple sclerosis patients to be 1.5 times more likely at 1 year compared to control.[23] Other genetic disorders such as Ehlers Danlos and Marfan Syndrome share common features of joint hypermobility and ligamentous laxity. In these patients undergoing THA, the greater range of motion experienced in their native joint as well as abnormal soft tissue properties may prove to be a risk factor for dislocation status post THA.[24,25]

Femoral Neck Fractures/Avascular Necrosis

Displaced femoral neck fractures are often treated with hip arthroplasty. A meta-analysis by Goh et al demonstrated a higher incidence of dislocations in patients treated with THA compared to hemiarthroplasty (relative risk 1.50; 95% confidence interval (CI) = 0.26-8.70 within 1-2 years).[26] Liao et al reported similar results with their meta-analysis of 7 randomized controlled trials, with slightly higher incidences (relative risk 2.02; 95% CI = 1.26-3.25).[27] The incidence of patients with dementia or other cognitive impairments that preclude adherence to traditional hip precautions is higher in patients with femoral neck fractures as they are typically elderly.[28] Patients undergoing THA in the setting of avascular necrosis (AVN) have also been found to have greater dislocation rates compared to those with primary osteoarthritis.[29,30] Similar to patients indicated for THA for femoral neck fracture, patients with AVN have greater preoperative range of motion compared to those with a diagnosis of osteoarthritis as a result of the lack of joint stiffness associated with arthritic patients. As such, patients who receive THA for AVN or femoral neck fractures are more likely to achieve greater postoperative range of motion, increasing the likelihood of instability.

Post-Traumatic Arthritis/Revision Arthroplasty

Post traumatic arthritis (PTA) often results after acetabular fractures and femoral head fractures.[31] THA is a salvage procedure for patients with debilitating PTA following trauma. In a meta-analysis of 270 THAs in 6 studies, the reported dislocation rate for THA indicated for PTA was 6%. PTA increases the THA instability for several reasons. First, appropriate exposure and visualization often requires additional dissection and removal of scar tissue. These factors affect the integrity and quality of the soft tissues. In addition, prior

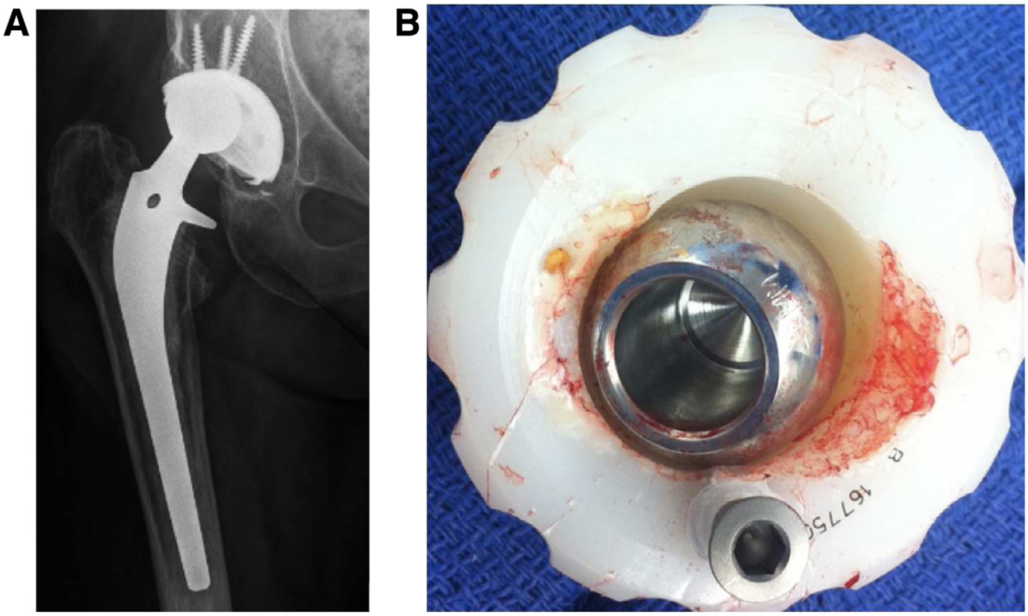

Figure 5 Demonstrates PE wear resulting in late instability of THA. (A) Radiograph of the affected hip. Note the eccentric position of the femoral head relative to the acetabular component. (B) Gross image displaying PE wear. The screw located in the inferior aspect of the liner was used to assist with removal.

hardware, extensive osteophytosis, and fracture malunion may increase the risk of early impingement. Similarly, the risk of instability is higher for revision arthroplasty than primary arthroplasty. The incidence of dislocation has been reported from 4% to as high as 30%.[32,33] A meta-analysis of 8 studies between 2002 and 2016 investigated the cause of dislocation in revision THA as a multitude of factors have been implicated including component size, soft tissue deficiency, surgical approach and malposition of components. The dislocation rate in this meta-analysis of revision THA found a rate of 9.04%. The most common risk factor for dislocation is history of previous dislocation and prior revisions surgeries. Patients with a previous dislocation were 2.74 times more likely to experience recurrent instability following their revision THA. Additionally, patients with > 3 revisions were found 2.23 times higher risk for dislocation compared to primary THA.[34]

Spinopelvic Motion

Spinopelvic motion is in a dynamic relationship with acetabular positioning and hip motion.[35] Due to rigid sacroiliac attachments, anterior and posterior pelvic tilt are directly related to lumbar straightening and lordosis with sitting and standing, respectively. These normal physiologic motions help accommodate rotation of the hip preventing impingement and dislocation of THA. In the setting of posterior spinal fusion (PSF), spinopelvic motion diminishes, causing increased compensation of hip motion to accommodate sitting and standing leading to impingement and possible dislocation.[36] Malkani et al examined dislocation rates with patients having THA and posterior spinal fusion and found the greatest risk of dislocation existed in patients undergoing THA after already having PSF. There was less risk when undergoing PSF after THA, with risk being inversely proportional to length between THA and PSF.[37]

Classification

While some authors have described classifications for THA instability based on etiology, there is no universally accepted classification system. THA instability, however, can be loosely classified as early vs late instability. Early instability is described as within the first few months of the procedure. The literature supports a higher rate of instability and possible dislocation within this time period.[12] Early instability within weeks or months are typically caused by surgeon, implant, and patient-related factors, as described above.[11] Late instability should raise suspicion for particular pathologies such as implant wear (Fig. 5) or breakage and soft tissue compromise resulting from adverse soft tissue reactions.[12] Causes of adverse tissue reactions include infection, metallosis from metal on metal implants, and trunionosis. Additionally, regardless of the timing of dislocation, any instability or dislocation increases the chance of recurrent events.

Clinical Evaluation of Instability Patient

History and Physical Examination

Following a dislocation of a THA, a thorough patient history should be obtained. The mechanism of injury may provide clues to the direction of the dislocation. For instance, deep flexion with internal rotation of the hip typically is indicative of a posterior dislocation while external rotation and extension of the hip suggests an anterior dislocation.[38] A dislocation with no clear inciting event may be indicative of multidirectional instability resulting from severe soft tissue incompetence. Next, the clinician needs to determine the timing of the dislocation relative to the last surgical intervention to classify the instability as early or late, which will help narrow the differential diagnosis and guide treatment.

The number of prior dislocations is also important to consider. A single early dislocation may be due to a fall or lack of adherence to hip precautions prior to adequate soft tissue healing. Such cases may be more likely to respond to nonsurgical management. On the other hand, a single late dislocation is likely a marker of new pathology, such as asymmetric liner wear or an adverse soft tissue reaction and may be less likely to demonstrate successful nonsurgical management. The patient should also be questioned regarding symptoms that may exist outside the acute phase of the dislocation. Patients may report symptoms of impingement, such as apprehension, or may report pain, which may indicate causes such as component loosening, infection, adverse soft tissue reaction, or iliopsoas impingement on a retroverted acetabular component.

On physical examination, the examiner should avoid recreating the mechanism of injury in the office to prevent an instability event in the office. Rather, the examiner should focus on evaluation gait and Trendelenberg sign to evaluate the integrity and function of the abductor complex. Examination of the prior scar may help provide clues to the surgical approach used for the index procedure and abnormal soft tissue swelling may guide further evaluation for infection or adverse soft tissue reactions.

Laboratory Evaluation

To initially investigate for infection, CRP and ESR values may be a useful screening tool. In cases of abnormal serological markers, or when clinical suspicion exists, even with normal serological values, joint aspiration should be undertaken to evaluate for infection. To evaluate for a metal reaction that may be the cause of instability, serum cobalt and chrome levels may be useful.[11]

Imaging

It is important to obtain quality radiographic imaging in evaluating instability patients. A standing AP pelvis will demonstrate component height and fixation as well as leg length and offset. AP and frog-lateral views of the hip are used to evaluate the femoral component fixation and position while the AP and cross-table lateral views are used to evaluate the fixation and position of the acetabular component. In addition, sitting and standing views may provide clues to abnormal spinopelvic mechanics.

CT imaging may be useful in determining component positioning especially if the patient is not tolerating or unable to be positioned for plain films. Acetabular anteversion is best assessed on axial CT cuts with the angle between the face of

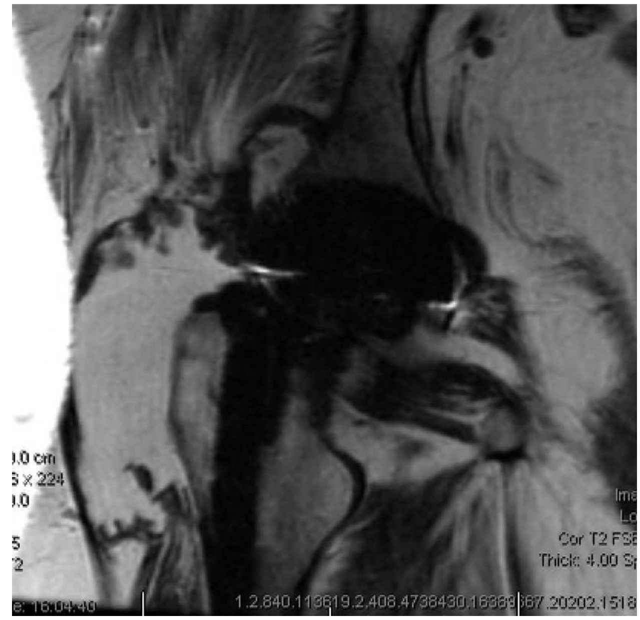

Figure 6 Demonstrates a MARS magnetic resonance imaging in a patient presenting with instability resulting from trunionosis. The images show a multiloculated periarticular fluid collection resulting from an adverse soft tissue reaction. MARS, metal artifact reduction sequence.

the acetabulum and the ischial tuberosities.[38] Assessing the version of femoral components can be accomplished on axial CT cuts by an angle formed from the widest metaphyseal portion of the implant compared to a line tangential to the posterior distal femoral condyle. In addition to CT being useful in determining component positioning, it will also reveal signs of osteolysis and eccentric wear of components. Adverse local tissue reactions causing local destruction of abductor musculature leading to THA instability are best evaluated by an experienced ultrasonographer or with an appropriate metal artifact reduction sequence magnetic resonance imaging (Fig. 6).

Management

Nonsurgical Treatment

The nonsurgical management of hip instability, with closed reduction, should be considered for cases of early postoperative instability and for patients with the risks of surgery outweighing the benefits. A pearl for successful reduction of THA includes obtaining adequate muscular relaxation. This can be done via conscious sedation, however the surgeon should council the patient on the possibility of using more aggressive sedations, such as general anesthesia.[11] Reduction maneuvers are based on the direction of dislocation. If closed reduction is successful, the patient should practice hip precautions. Devices that may help patients in avoiding provocative positions include abductor braces, foam pillows between the legs for the nighttime, and hip abduction braces. More aggressive immobilization techniques, such as a spica cast can be utilized if the patient is noncompliant for any number of reasons. While closed reduction is successful a majority of the time

(67%), there is an established recurrent dislocation rate of 16%-33%.[11,39] If post reduction radiographs demonstrate nonconcentric reduction this could indicate soft tissue interposition. In this circumstance, and in cases of failed closed reduction, the surgeon should be prepared to perform to an open procedure. 3% to 6% of THA dislocations are not amenable to closed reduction and require advance treatment.[11]

Surgical Treatment

For cases of recurrent instability that fails nonsurgical treatment in patients who are surgical candidates, revision surgery is indicated. After anesthesia is induced, the hip is examined in order to recreate the patient's instability pattern. This gives the surgeon an indication of the direction and ease of dislocation. The surgeon should use his or her most comfortable surgical approach. Upon completing the surgical exposure, the hip may then again be examined to identify prosthetic impingement, bone impingement, and assess for soft tissue laxity. After dislocating the hip, component fixation and position can be assessed, and overhanging osteophytes and other impinging bony prominences can be removed. With a better understanding of the cause of instability, the surgeon is primed to correct the abnormalities.

Exchange of Modular Bearings

In some patients, isolated femoral head and acetabular liner change may successfully treat prosthetic hip instability. Instability from liner wear may result from a variety of mechanisms. With severe liner wear, the limb may shorten by several millimeters, resulting in soft tissue laxity. In addition, older implant designs often involve a low head to neck ratio that leads to impingement, causing a wear trough within the liner. The combination of a worn liner with a wear trough, in the setting of a low head to neck ratio leads to prosthetic instability. By exchanging modular bearings, the surgeon may be able to correct abnormalities while increasing soft tissue tension through increasing length and offset, and also increasing the head to neck ratio by using a larger femoral head. In addition, most implants allow for fine tuning of slightly suboptimal acetabular position with a face-changing liner.

It is critical to understand that in most instability cases, exchange of modular components does not appropriately address soft tissue laxity and component malposition. Earll et al. retrospectively reviewed a cohort of revision THA. From the group examined, 55% of patients who underwent only modular component exchange had at least a single redislocation, with 31% experiencing multiple dislocations and 17% needing subsequent surgery.[40] Ayaz et al. published a more recent study with improved outcomes following modular component exchange. Their reported success rate was 73%. It is important however for the surgeon to understand and relay to the patient that modular exchange alone carries a significant risk of re-dislocation, with unpredictable risk factors.[41]

Component Revision

Component revision allows the surgeon to improve component position and to utilize modern components, thus increasing bearing options. With acetabular revision, the surgeon may position the new component with an inclination and anteversion that will optimize impingement-free range of motion. The surgeon may also opt to use an offset polyethylene liner in order to increase length, offset, and soft tissue tension. If the main cause of instability had been related to acetabular component position, and soft tissue tension may be optimized with neck lengths available for use, the femoral component may be retained. The femoral component revision allows the surgeon to improve the rotational alignment of the component and to substantially increase femoral component offset and length. Reconstruction with a stem that involves diaphyseal fixation and/or use of a modular femoral component allows for free rotational component positioning. Femoral component revision is also necessary when gross trunnion damage results from trunionosis. Component revision may also allow the surgeon to increase the femoral head size to enhance prosthetic stability. The use of large femoral heads and dual mobility components have been shown to improve hip stability in revision surgery.[39]

Constrained Liner

In cases involving severe soft tissue incompetence, constrained liners may be necessary to achieve stability. Constrained liners secure the femoral head to the acetabular liner through a locking mechanism. As a result, mechanical stresses that would ordinarily lead to dislocation are transferred to the components. As such, the use of constrained liners should be avoided in cases involving acetabular shell revision as subsequent stresses may lead to component pullout prior to achievement of ingrowth. Due to the substantial decreased range of motion to impingement that is inherent to constrained liners, in time, the component can break or dislodge. As such, the use of constrained liners should be avoided in cases of acetabular component mispositioning. The longevity of constrained liners is relatively poor and this option should be reserved for cases of instability caused by soft tissue incompetence, such as a multiply operated hip, failed prior surgery for instability, and severe adverse soft tissue reaction.[42]

Soft Tissue Reconstruction

Soft tissue insufficiency can lead to hip instability despite well-aligned components. In this setting, reconstructive efforts to address soft tissue inadequacy may be necessary whether it involves bony, tendinous, or muscle-based procedures. Trochanteric osteotomy and advancement may be used in hip arthroplasty to alter abductor tension as well as increase exposure for difficult primary or revision cases, complex acetabular reconstructions, or for any situation with unacceptable abductor laxity. Various techniques have been described in the literature.[43-45] Regardless of method, the basic principle behind these techniques involve increasing peritrochanteric soft tissue tension in order to increase compressive forces and therefore stability about the hip joint. The standard approach begins with the optional release of the vastus lateralis from its origin. An osteotomy cut is then made parallel to the greater trochanter, beginning laterally just distal to the vastus tubercle between the origin of the vastus intermedius muscle and insertion of the gluteus medius and maximus, ending at the junction between the greater trochanter and the lateral aspect of the femoral neck.[45] After the osteotomy is complete, the greater trochanter fragment is advanced and then reattached using wires and/or screws.

A limited number of clinical studies have reported results on the use of Achilles allograft for reconstruction of a deficient abductors mechanism.[46-50] An Achilles "sling" technique may be utilized to address posterior soft tissue insufficiency.[48] The technique by Van Warmerdam et al involves attaching the graft to the ischium near the acetabular rim, subsequently passing the graft superiorly to the neck and finally attaching the graft to the anterior aspect of the greater trochanter. This functions to provide tension during "at-risk" positions for dislocation, particularly flexion, internal rotation, and adduction. Van Warmerdam et al reported success in 7 of 8 patients treated with this technique, with 1 failure due to a neuropathic hip over 5 years.[48] The technique by Fehm et al involves attaching a calcaneal bone block of the Achilles allograft to the greater trochanter, then weaving the graft through the abductor-muscle tendon complex.[49] Fehm reported improvements in Harris Hip Scores from 34.7 pre-op to 85.9 post-op at 2-year follow-up.

Several authors have described a technique involving the use of muscle flaps to address significant posterior soft tissue deficiency in the setting of recurrent instability, as well as significant wound breakdown in the setting of complex revision THA. Gluteus Maximus Flap Advancement involves exposure of the gluteus maximus muscle belly via a posterolateral approach.[51] Once isolated, the flap is then advanced and inset into the defect. It can also be advanced through the posterior aspect of the greater trochanter, with the free end being used to reinforce the posterior capsule, or the greater trochanter in the event that osteolytic destruction exists.[52] Additionally, this flap can also be sutured to the vastus lateralis to help support abductor function. Ricciardi et al reported that no patients had repeat instability, flap necrosis, or nerve palsy; however, 2 patients did have recurrent wound infection requiring a subsequent procedure.[51]

Girdlestone Arthroplasty

Resection arthroplasty, most notably attributed to Girdlestone in the early 1900s, is a salvage option for patients with recalcitrant THA instability. Originally described as a native femoral head resection, a Girdlestone Resection Arthroplasty now typically involves removing all components of a THA resulting in a soft tissue pseudoarthrosis.[53] This option typically should be reserved for patients who have failed multiple revisions or are otherwise unfit to undergo further attempts at THA revision. Malcolm et al reported that 34% of patients experienced a major complication following GRA and an 11% death rate within 90 days.[54] Functionally, the new articulation of the proximal femur abutting the remaining acetabulum is relatively poor,[55] albeit successful in eliminating dislocations and instability. Patients should be counseled to expect a significant leg length discrepancy and dependency on a walking aid following Girdlestone resection arthroplasty.[56]

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