Prevention of limb length discrepancy in total hip arthroplasty

Total hip arthroplasty is a highly effective and cost-efficient surgical intervention (Chang et al, 1996). Limb length discrepancy following total hip arthroplasty is a recognized complication, and can adversely impact postoperative clinical and functional outcomes. Limb length inequality may lead to altered hip biomechanics, dysfunctional gait, lower back pain, sciatica, instability and increased risk of dislocation (Bhave et al, 1999; White and Dougall, 2002). A subset of symptomatic patients with postoperative leg length inequality will remain refractory to conservative treatment and require revision arthroplasty, with increased risk of complications and prolonged rehabilitation. Limb length discrepancy is the leading cause of patient dissatisfaction following total hip arthroplasty and the most common reason for litigation in orthopaedics (Hofmann and Skrzynski, 2000).

This article provides a systematic, stepwise approach for identifying and proactively managing risk factors associated with limb length discrepancy in total hip arthroplasty. This review explores the aetiology of postoperative limb length discrepancy, provides guidance on preoperative planning through focused history taking, clinical examination and radiographic templating, and describes intraoperative surgical techniques to assess and minimize leg length inequality following total hip arthroplasty.

ABSTRACT

Total hip arthroplasty is a highly effective and cost-efficient procedure but postoperative limb length discrepancy is a common source of patient dissatisfaction and litigation. This article provides a systematic, stepwise approach for identifying and proactively managing risk factors associated with limb length discrepancy following total hip arthroplasty. This review explores preoperative history taking, clinical examination, radiological templating, implant positioning, soft tissue balancing, and intraoperative surgical techniques for minimizing leg length discrepancy while maintaining stability and restoring mechanical function following total hip arthroplasty. A comprehensive understanding of the multifactorial nature and methods for reducing postoperative limb length discrepancy is essential for optimizing patient satisfaction, clinical outcomes and long-term function following total hip arthroplasty.

Classification of leg length discrepancy

Limb length discrepancy can be divided into two main groups: structural (true) and functional (apparent). In some patients, both structural and functional elements exist concurrently and may balance each other or exaggerate the leg length discrepancy further.

Structural limb length discrepancy is secondary to cumulative differences in the length of the osseous and cartilaginous surfaces of the lower limb. This may be attributable to conditions such as developmental dysplasia of the hip, osteoarthritis of the hip or knee, femoral or tibial dysmorphology owing to growth plates injuries, congenital growth abnormalities, or previous malunited fractures leading to valgus or varus deformities of the lower limbs (Ng et al, 2013). Structural limb length discrepancy may also lead to pelvic obliquity and compensatory lumbar scoliosis.

Functional limb length discrepancy relates to asymmetry of the lower limbs secondary to soft tissue contractures or pelvic obliquity. This may be caused by flexion contractures of the hip secondary to tightness of the hip capsule, iliopsoas muscle and/or rectus femoris muscle, knee joint contractures, and foot deformities such as pes planus and pes equinus (Ng et al, 2013). Primary lumbar lordosis or spinal disease may also produce pelvic obliquity with hip adduction or abduction contractures, which manifest as functional limb length discrepancy.

Medical history

Preoperative history taking provides an invaluable opportunity to gather pertinent information relating to risk factors for leg length inequality, discuss treatment options, and establish realistic treatment goals in patients requiring total hip arthroplasty. Both local and systemic risk factors for leg length discrepancy should be explored. Local risk factors include previous trauma, growth plate injuries, fractures, infection, soft tissue contractures, and previous surgery to the lower limbs. Systemic factors include skeletal dysplasias, spinal fusion, scoliosis, and existing neurological

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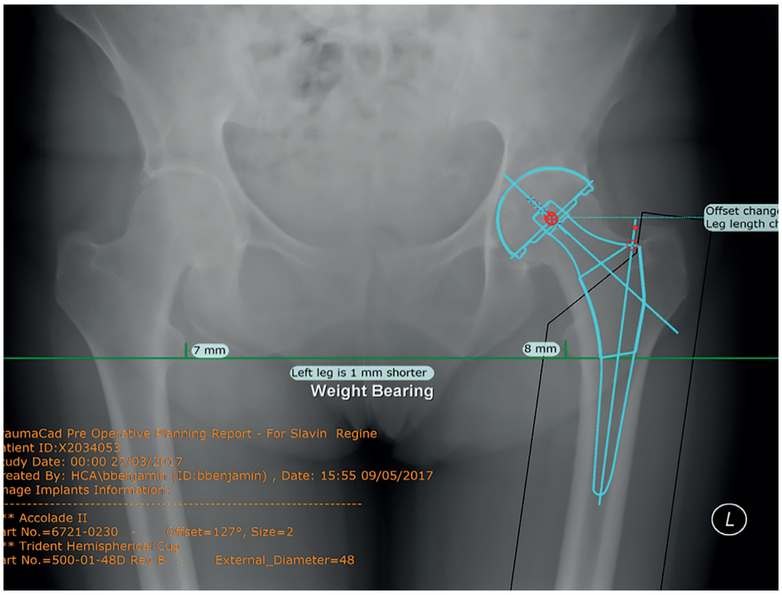
Figure 1. Plain radiograph of pelvis with preoperative templating for left total hip arthroplasty.



or musculoskeletal disorders. A thorough medical history is important as some pathology or previous surgery may create leg length discrepancy that is not visible on plain radiographic imaging alone.

Patients should clearly understand the realistic technical objectives of total hip arthroplasty and the hierarchy of their importance (Berend et al, 2010). The first priority is to ensure that the acetabular and femoral components are well fixed. The second priority is to ensure that the artificial construct is dynamically stable. The third priority is to ensure that the leg lengths are equal. Preoperatively, patients must understand that the surgeon will need to make various intraoperative assessments to ensure optimal implant fixation, stability, soft tissue tensioning and maintenance of hip biomechanics, which may affect leg length equality. Patients must also be informed that in the early postoperative period, there is often a ‘perceived’ sensation that the operated leg is longer. This is caused by intraoperative release of soft tissue contractures around the diseased hip joint, which causes correction of any pre-existing pelvic inclination. This perceived leg length inequality usually resolves with time and physiotherapy, and is poorly correlated to a true radiological leg length inequality (Rösler and Perka, 2000).

Clinical examination

Clinical examination should include complete evaluation of the spine, hip and knee with full neurological examination of both lower limbs. Preoperative findings relating to leg length discrepancy or joint contractures should be discussed with the patient before surgery, as one-third of the general population may have an asymptomatic leg length discrepancy of 5 mm to 2 cm (Hellsing, 1988).

Examination of the gait pattern in patients with a limb length discrepancy may reveal the use of compensatory mechanisms including toe walking on the shorter side, pelvic tilt, and circumduction during the swing phase or knee flexion during the stance phase on the longer side. The function of the abductors, previous trauma or injury to the lower limb, and the use of any walking aids should be recorded. Examination of the spine should include measurement of any coronal or sagittal deformity with the patient standing, Adams forward-bending test to assess for thoracolumbar scoliosis, and Thomas test performed to record any fixed flexion deformities at the hip joints. A compensatory, flexible scoliosis may develop in patients with a leg length discrepancy. A block should be placed under the shorter extremity to measure the discrepancy more accurately and assess if the coronal scoliosis is flexible or rigid.

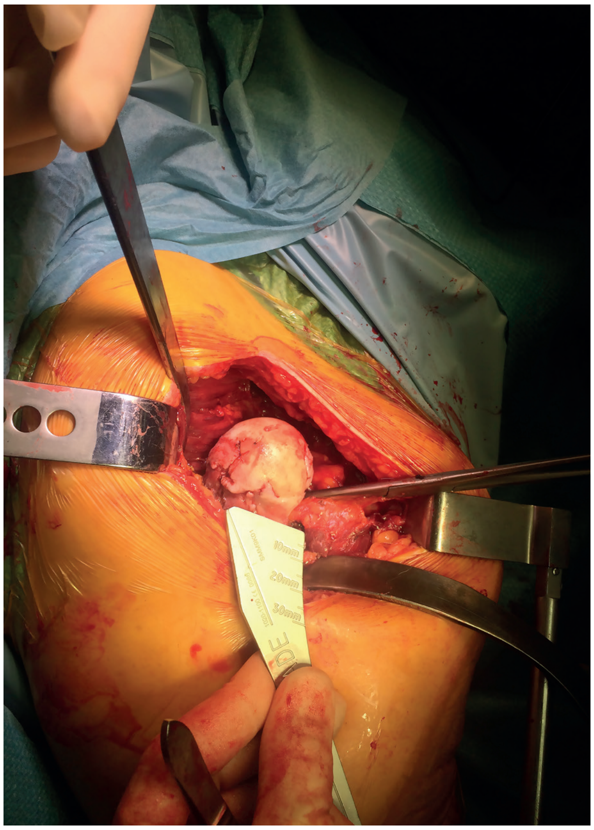
Structural leg length measurements should be recorded from the anterior superior iliac spines to the medial malleoli bilaterally (Paley, 2003). Apparent leg lengths are assessed using block testing, which places graduated 5 mm raises under the shorter leg until the patient feels level and the anterior superior iliac spines feel even to the examiner. Using this technique, pelvic obliquity secondary to structural leg length discrepancy, flexible spinal deformities, and hip or knee contractures will resolve.

Preoperative templating

Preoperative templating may help to determine the centre of rotation, select implant size and position, establish level of the femoral osteotomy, and restore femoral offset with the required leg length correction (Sabharwal and Kumar, 2008; Ng et al, 2013). The centre of rotation should first be established by positioning the acetabular implant within the radiographic teardrop in the vertical plane. The acetabular implant size must be selected to avoid any overhang that may lead to impingement. Following this, the femoral component type and size should be selected to ensure satisfactory stability within the canal, restoration of femoral offset and positioning in the acetabular centre of rotation (Berend et al, 2010). The radiological leg length is calculated by measuring from the vertex of the lesser trochanter to a defined pelvic landmark, which may include the inferior aspect of the acetabular teardrops, the obturator foramina or the ischial tuberosities. The required leg length correction can then be applied and the level for femoral neck osteotomy established based on the type and position of the prostheses selected (*Figure 1*).

Preoperative radiographs and templates should be available throughout the procedure. Specific anatomical landmarks established in the templating process can be used to facilitate correct implant positioning and minimize the risk of lower limb inequality (Berend et al, 2010). The relationship between the centre of the femoral head and tip of the greater trochanter should be established radiographically, and the femoral offset distance should be recorded (Ng et al, 2013). These measurements can then be rechecked intraoperatively following insertion of trial prostheses. The femoral neck osteotomy level may

Figure 2. Intraoperative photo showing use of measuring guide to confirm level of femoral osteotomy.



be measured from the tip of the lesser trochanter or the tip of the greater trochanter and this should be matched intraoperatively on the femur. The osteotomy guide for the planned implant type and size may be used to mark the level of the femoral osteotomy (*Figure 2*).

Implant positioning: acetabular component

External and internal reference marks may be used to guide acetabular implant positioning (Woolson et al, 1999; Berend et al, 2010). External reference points for acetabular positioning must be used with caution as the position and orientation of the pelvis can change when the patient is in the lateral decubitus position. Fixed internal anatomical landmarks such as the transverse acetabular ligament, acetabular sulcus on the ischium, and the superior aspect of the acetabulum are less dependent on patient positioning and better indicators of implant positioning. These anatomical landmarks may be used for accurate positioning of the acetabular component in the safe zone with reduced risk of dislocation (Woolson et al, 1999). Eccentric inferior reaming of the acetabulum and placement of the cup below the planned level of the teardrop will increase the leg length.

Implant positioning: femoral component

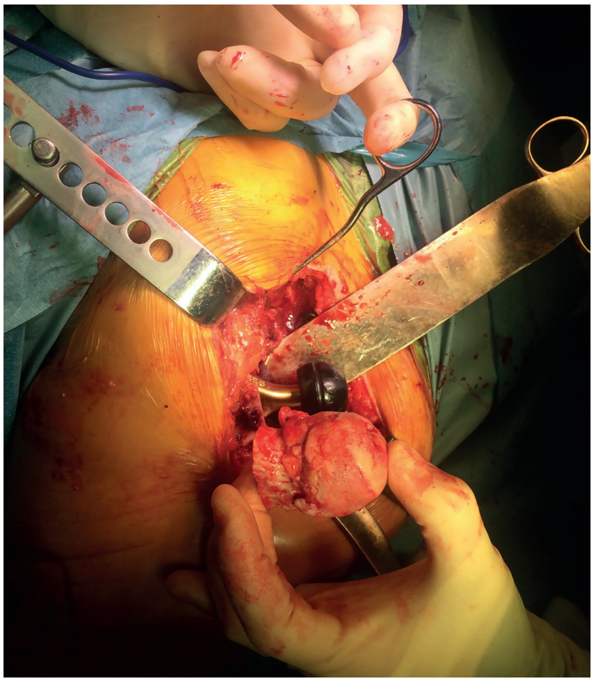
Achieving the correct angle and level of the femoral osteotomy is important for seating the femoral implant accurately and avoiding leg length inequality. Measurements from preoperative radiological landmarks such as the femoral head, tip of the greater trochanter, and most superior part of the lesser trochanter are useful intraoperative reference points. The posterolateral approach allows good access to the piriformis fossa and enables palpation of the lesser trochanter to aid correct femoral neck resection. Osteotomy guides and trial prosthesis can be positioned next to the femur and the femoral neck osteotomy site marked with diathermy. Mismatch of the metaphyseal-medullary canal or an inaccurate femoral neck osteotomy may impact seating of the femoral stem and adversely affect leg length equality (Goldstein et al, 2005). It is important to understand the desired fit for type of implant: press fit implants are based on proximal metaphyseal locking whereas straight stems require diaphyseal fixation (Ng et al, 2013).

A high femoral neck cut may lead to more visible space in the medial calcar and the stem may appear undersized. Changing to a larger stem to fill this void may lead to inadvertent lengthening of the limb. If the femoral osteotomy is too low, the femoral stem may not seat within the metaphysis and appear too large. Changing to a smaller stem size to improve seating may lead to shortening of the limb (Ng et al, 2013). Following insertion of a trial prosthesis, a Langenbeck retractor can be used to check that the centre of the femoral head is in line with the tip of the greater trochanter. The resected head and neck can also be positioned over the trial components to assess the femoral neck length and ensure the centre of rotation is restored (*Figure 3*).

Selecting the appropriate prostheses for maintaining soft tissue tension and stability while maintaining leg length equality may be challenging. Inadequate femoral offset may decrease soft tissue tension and increase the risk of dislocation. Increasing the femoral neck length to restore this soft tissue tension may increase the leg length (Parvizi et al, 2003). Lengthening the femoral neck alone will lead to increased femoral offset and limb length. Using implants with a high offset or lateralized femoral component may help to increase the femoral offset while preserving the limb length, although this may increase the risk of trochanteric bursitis and adductor tendinitis (Ng et al, 2013). Restoration of the femoral offset is associated with improved pain, stability and gait efficiency (Paley, 2003). A lateralized polyethylene liner may also be used to improve the abduction lever arm but this is associated with accelerated wear of the polyethylene liner and increased joint reactive forces.

Preoperative templating should include measurements of the neck shaft angle to guide the femoral osteotomy level and choice of femoral implant. Mean neck shaft angle for adult males is 129.6° (range 113.2–148.2°, standard deviation 5.9°) and for adult females is 131.9° (range 107.1–151.9°, standard deviation 6.8°) (Boese et al, 2016). Patients with neck shaft values significantly lower than this represent coxa vara. These patients have increased femoral offset and this is often associated with shortening of the

Figure 3. Intraoperative photo showing use of the resected femoral head to confirm the centre of rotation with trial femoral prothesis.



affected limb. This can be compensated for by using a lower femoral neck cut with longer femoral neck or by using a component with a smaller neck shaft angle (Berend et al, 2010). Patients with a significantly increased neck shaft angle represent coxa valga. In these patients, there is a relatively low femoral offset and lengthening of the affected limb. To compensate for this, it is important to use a higher femoral neck cut and shorter neck length to restore the leg length and preserve femoral offset (Berend et al, 2010).

Figure 4. Intraoperative photo to show the Shuck test. Traction is applied to the leg and the degree of disarticulation of the total hip arthroplasty assessed.

Soft tissue considerations

The anterior approach is performed through the interval between sartorius and tensor fascia latae with detachment of the rectus femoris head if required. The patient is in the supine position and bony landmarks are easily palpable, which enables more accurate measurement of the true leg lengths compared to approaches in which the patient is in the lateral decubitus position. Plain radiographs and fluoroscopy may be used to further assist with component positioning and leg length measurements. Further advantages of this approach include minimal soft tissue damage around the hip, preservation of the hip abductors and dislocation rate of 0.6–1% (Seng et al, 2009). The mean leg length discrepancy with the anterior approach is 3.9 mm (Matta et al, 2005), which is usually well tolerated by patients. The anterolateral approach can also be performed in the supine position to improve the accuracy of on-table leg length assessment. The posterolateral approach is performed in the lateral decubitus position and so intraoperative leg length assessment is more challenging. Owing to the increased risk of dislocation with this approach, there is a tendency for the limb to be over-lengthened. Meticulous repair of the hip capsule and external rotators is important for reducing the risk of postoperative dislocation (Chivas et al, 2006).

Intraoperative assessments of soft tissue and appropriate balancing are important for reducing the risk of postoperative limb lengthening while preserving tissue tension and stability of the hip joint. The Ober test may be performed intraoperatively to test for tightness of the tensor fascia latae and rectus femoris muscles. A tight anterior capsule with limb lengthening may lead to internal rotation contractures and so this capsule must be directly palpated and released if required. The gluteus minimus should be directly palpated for tightness. The hip should be externally rotated to confirm that the posterior trochanter is within one fingerbreadth of the ischial tuberosity. If this manoeuvre is not possible then the anterior capsule may need to be released (Ranawat and Rodriguez, 1997).

Various intraoperative examination techniques may be used to assess soft tissue tension and hip stability. The Shuck test examines soft tissue tension under anaesthesia with both acetabular and femoral components in place (*Figure 4*). Longitudinal traction is applied to the hip joint in neutral and the extent of disarticulation at the hip joint assessed. The drop kick test involves extending the hip, bending the knee to 90° and leaving the knee free to assess the degree of recoil as the knee moves into extension (*Figure 5*). Both of these techniques are influenced by surgical experience, type of anaesthesia and degree of muscle relaxation. The findings of these tests in patients with spinal or epidural anaesthesia should be treated with caution as they induce motor blockade that affects soft tissue tension.

Another commonly performed examination to assess leg lengths involves palpation of the patellae and tibiae with the patient in the lateral decubitus position (*Figure 6*). This test should be performed preoperatively before the surgical skin incision and repeated intraoperatively with the trial implants in place. The size of the trial implants can be adjusted and the test repeated until the required leg length and hip stability is achieved. The permanent implants are then inserted into the same position and the tests repeated to confirm limb length equality. The main drawbacks of this technique are difficulty in palpating the bone landmarks through the drapes and greater adduction of the hip on the operated side.

Intraoperative leg length assessment

Intraoperative assessment of limb length and femoral offset can be undertaken using a variety of different surgical techniques. Before hip dislocation, a suture can be placed in the skin just superior to the surgical skin incision. A point can then be marked with diathermy on the lateral aspect of the greater trochanter. The length of the suture tail to this point is then measured and compared to the length obtained after insertion of trial components. The main limitations of this technique are the laxity of the skin and soft tissues, and variations in tensioning the suture.

Another technique that has been previously described involves the use of a Steinmann pin drilled into the ilium above the acetabulum (McGee and Scott, 1985). Pliers are then used to bend this pin down until the tip touches the lateral aspect of the greater trochanter and this point is demarcated with diathermy. The pin can be rotated in and out of the surgical field to monitor changes in offset and limb length. The main disadvantage of this technique is that the pin can become loose and impair the surgical viewing field.

Calipers may also be used to quantify differences in limb length and femoral offset (Takigami et al, 2008). The base pin is placed into the iliac crest above the acetabulum and the other end of the device slides along until the tip touches the lateral aspect of the greater trochanter. A vertical caliper over the greater trochanter can be used simultaneously to measure the combined offset. Measurements are compared before dislocation and following insertion of trial prosthesis to obtain the required leg length and femoral offset. Other techniques using calipers combined with preoperative scanograms, reference pin in the ilium, and a leveller to keep the limb have been described but are not routinely used.

To minimize inaccuracies resulting from patient positioning, a surgical technique using a vertical Steinman pin inserted into the infracotyloid groove of the acetabulum has also been described (Ranawat et al, 2001). The main advantage of this technique is that the reference point is close to the centre of rotation, which reduces inaccuracies caused by limb positioning. This technique was shown to reduce limb length discrepancy and completely avoid the need for a shoe raise following total hip arthroplasty in 100 consecutive patients (Ranawat et al, 2001).

Total hip arthroplasty techniques performed via a mini-incision through the superior capsule, posterior to the abductors and anterior to the posterior capsule, have been developed (Murphy et al, 2006). These enable in-situ femoral osteotomy with improved preservation of soft tissue envelope, femoral offset and postoperative recovery. Recent advances in surgical technology have also lead to the development of computer navigation programmes and robotics, which use preoperative patient-specific three-dimensional models to optimize implant positioning and minimize leg length errors.

Figure 5. Drop kick test to assess elastic recoil and soft tissue tension in the leg.

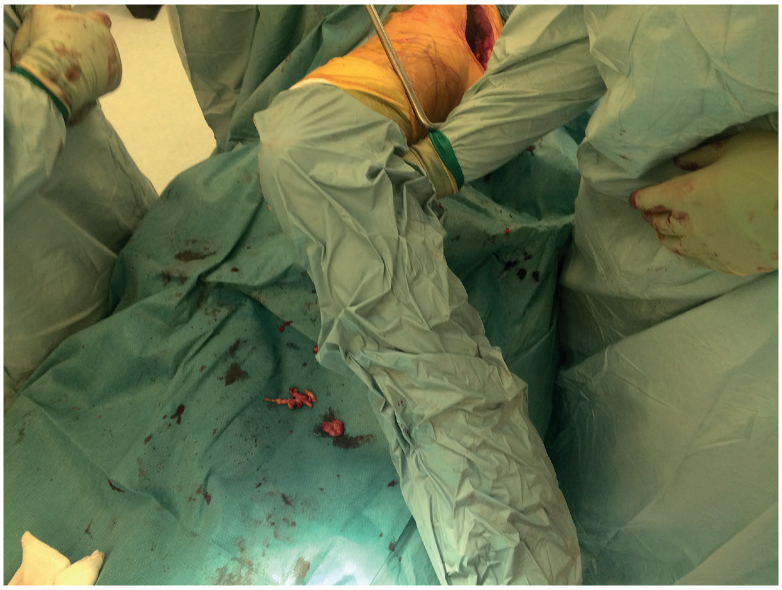


Figure 6. Intraoperative palpation of the patella tendons bilaterally to assess leg length.

Conclusions

Limb length discrepancy following total hip arthroplasty is multifactorial. A comprehensive medical history, clinical examination, and radiographic assessment will help to quantify any pre-existing leg length discrepancy and identify risk factors for postoperative leg length inequality.

KEY POINTS

- Limb length inequality following total hip arthroplasty may lead to altered hip biomechanics, dysfunctional gait, lower back pain, sciatica, instability and increased risk of dislocation.
- Preoperative history taking should be used to identify local and systemic risk factors for leg length inequality, and establish realistic treatment goals for patients undergoing total hip arthroplasty.
- Clinical examination must identify any pre-existing structural and/or functional limb length discrepancy.
- Preoperative templating helps to determine the centre of rotation, select implant size and position, and guide femoral osteotomy level for correction of leg length inequality and restoration of femoral offset.
- Fixed internal anatomical reference landmarks for acetabular and femoral implant fixation will improve implant positioning, joint stability and leg length equality.
- Intraoperative clinical assessment of soft tissue tension and limb lengths may be performed using the Ober test, Shuck test, drop kick test and Galeazzi test
- Intraoperative measurement of leg lengths may be performed using fixed reference sutures, horizontal and vertical calipers, Steinman pins in the ilium or acetabulum, and navigated or robotic devices for assistance.

Radiological templating should be performed to help establish the femoral osteotomy level, centre of rotation, femoral offset, and implant positioning while obtaining the desired leg length correction. Intraoperative fixed reference points for implant positioning, soft tissue balancing, and on-table measurement of leg lengths will help to optimize hip stability and minimize the risk of leg length discrepancy following total hip arthroplasty. **BJHM**

Conflict of interest: none.

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