

Hip resurfacing

Anatomy & Pathophysiology

BONY ANATOMY

- The hip is a multiaxial joint formed by the articulation between the pelvis and femur, connecting the axial skeleton and the lower extremity [7].
- The hemipelvis comprises three bones: the ilium, ischium, and pubis, which unite at the triradiate cartilage within the concave acetabulum [7].
- The acetabulum comprises an articular crescent-moon-shaped lunate surface and a nonarticular central fossa that serves as the attachment point for the ligamentum teres [7].
- The acetabulum is incomplete inferiorly, forming a notch through which vital blood vessels and nerves pass to supply the joint [7].
- The femoral head forms two-thirds of a sphere, with a small depression at its center from which the ligamentum teres extends to connect to the acetabular notch [7].
- The neck-shaft angle of the femur averages 125° [7].
- Normal version, defined as the head-neck angle in the frontal plane, averages 15 to 20° [7].
- The mean femoral neck-shaft angle in the adult is 130° ± 7° [13].
- The mean anteversion of the femoral neck is 10° ± 7° [13].
- The two prime trabecular groups of the proximal femur are the principal tensile group and the principal compressive group [13].
- The weakest area in the femoral neck is located in the Ward triangle [13].
- The calcar femorale is a medial area of dense trabecular bone that transfers stress from the femoral shaft to the inferior portion of the femoral neck [13].

SOFT TISSUE ANATOMY

- The acetabular labrum is a fibrocartilaginous ring attached to the rim of the acetabulum that extends the articulating surface area and increases femoral head coverage [7].

- The labrum is triangular in cross section, which contributes to its ability to create a pressurized seal of the central compartment of the hip during loading [7].
- Only the external one-third of the labrum contains blood vessels, leaving the majority of the structure avascular and limiting its healing ability following injury [7].
- The labrum is highly innervated, with the presence of both mechanoreceptors and nociceptors [7].
- The transverse acetabular ligament serves as the continuation of the labrum in the area of the inferior acetabular notch, connecting the anterior and posterior lunate surfaces [7].
- The hip is surrounded by a dense fibrous capsule extending from the periphery of the acetabulum to the intertrochanteric line of the femoral neck [7].
- The iliofemoral ligament is Y-shaped, with the medial portion connecting the anterior inferior iliac spine to the anterior intertrochanteric line and the lateral portion attaching to the anterior greater trochanter [7].
- The iliofemoral ligament functions to limit external rotation, while in isolation, the lateral arm limits extension of the joint [7].
- The ischiofemoral ligament extends from the ischial margin of the acetabulum to the greater trochanter of the femur and restricts internal rotation motion [7].
- The pubofemoral ligament extends from the obturator crest of the pubic bone to the femoral neck and acts to limit abduction of the joint [7].
- Deep fibers from the iliofemoral, ischiofemoral, and pubofemoral ligaments merge to form the zona orbicularis, which circumvents the femoral neck [7].
- The ligamentum teres arises from the apex of the cotyloid notch and attaches to the fovea of the femoral head [4].
- The ligamentum teres transmits an arterial branch of the posterior division of the obturator artery to the femoral head, which is less significant in adults [4].
- The hip joint capsule extends anteriorly to the intertrochanteric crest but posteriorly only partially across the femoral neck, leaving the basicervical and intertrochanteric crest regions extracapsular [4].
- The iliofemoral ligament becomes taut in full extension, preventing anterior dislocation and hyperextension of the hip [8].
- The twisted orientation of the hip ligaments provides a screw mechanism for the hip in full extension [8].

VASCULAR ANATOMY

- In adulthood, the major blood supply to the femoral head is from the medial femoral circumflex and lateral epiphyseal arteries [16].
- The medial femoral circumflex artery is the main blood supply to the femoral head and terminates in the posterior aspect of the extracapsular arterial ring [13].
- The lateral group of ascending branches from the extracapsular arterial ring is the main blood supply to the femoral head [13].
- The lateral epiphyseal artery penetrates the femoral head and is believed to be the dominant blood supply to the femoral head from the ascending cervical system [13].

- The artery of the ligamentum teres arises from either the obturator or medial femoral circumflex artery and does not provide sufficient blood supply to maintain the viability of the femoral head [13].
- Fractures that disrupt the ascending blood flow to the lateral epiphyseal vessel have an increased risk of osteonecrosis [13].

PATHOPHYSIOLOGY

- Femoroacetabular impingement (FAI) is recognized as a common cause of hip dysfunction and secondary osteoarthritis [3].
- In FAI, distinct structural abnormalities produce repetitive impingement between the acetabulum and the femoral head-neck junction [3].
- Cam impingement involves femoral-based abnormalities such as an aspherical femoral head and reduced head-neck offset, resulting in repetitive abutment of the acetabular rim and femoral head-neck junction [3].
- Pincer impingement involves acetabular-based disorders such as acetabular retroversion, global overcoverage, and acetabular protrusio, creating abnormal abutment of the acetabular rim and femoral head-neck junction [3].
- Impingement abnormalities can cause labral tears, degeneration, or ossification [3].
- Impingement abnormalities can cause acetabular cartilage delamination [3].
- Impingement abnormalities can cause secondary osteoarthritis [3].
- Hip microinstability refers to femoral head micromotion within the acetabulum, which is a prolonged phenomenon that leads to cartilage damage and eventually osteoarthritis of the hip [17].
- Acetabular hip dysplasia can contribute to hip instability because of a shallow acetabular component [17].
- Developmental dysplasia of the hip (DDH) is a gradually progressive disorder associated with distinct anatomic changes, many of which are initially reversible [10].
- In unstable hips at birth, the posterosuperior rim of the acetabulum loses its sharp margin and becomes flattened and thickened in the area over which the femoral head slides [10].
- A ridge of thickened articular cartilage called the neolimbus arises along the posterosuperior acetabular wall in dislocatable hips [10].
- In dislocated hips, the fatty tissue known as the pulvinar thickens in the depths of the acetabulum and may impede reduction [10].
- In dislocated hips, the ligamentum teres elongates and thickens, taking up valuable space within the acetabulum [10].
- In dislocated hips, the inferior capsule assumes an hourglass shape, presenting an opening smaller in diameter than the femoral head [10].
- The iliopsoas tendon is pulled tight across the capsular isthmus in dislocated hips, contributing to narrowing and acting as a barrier to closed reduction [10].
- Femoral neck fractures are considered intracapsular fractures at higher risk of nonunion due to the absence of a periosteal or extraosseous blood supply [13].

- Intertrochanteric fractures are considered extracapsular fractures where callus formation is common and nonunion is rare due to the presence of an abundant blood supply [13].
- Periprosthetic femoral fractures associated with hip resurfacing are categorized into Type A (biomechanical), Type B (acute postnecrotic), and Type C (chronic biomechanical) patterns [34].
- Type A periprosthetic fractures after hip resurfacing occur at an average of 41 days postoperatively and are characterized by acute fracture changes without signs of osteonecrosis [34].
- Type B periprosthetic fractures after hip resurfacing occur at an average of 149 days postoperatively and are all associated with osteonecrosis [34].
- Type C periprosthetic fractures after hip resurfacing occur at an average of 179 days postoperatively and are characterized by evidence of refracture or pseudoarthrosis through a previous fracture [34].
- The majority of periprosthetic femoral fractures after hip resurfacing occur inside the bounds of the edge of the femoral head component [34].
- Acute biomechanical periprosthetic fractures after hip resurfacing are located exclusively outside of the component and in the neck [34].

Investigations

CLINICAL EXAMINATION

- A thorough history is essential to differentiate between common causes of hip pain [1].
- A comprehensive clinical examination is required to determine a differential diagnosis because many hip conditions present with similar symptoms [1].
- Clinical examination tests and imaging findings should be used to confirm a suspected clinical diagnosis [1].
- Patients with symptomatic femoroacetabular impingement (FAI) frequently present with activity-related groin pain exacerbated by hip flexion activities [3].
- Patients with symptomatic FAI may experience difficulty with prolonged sitting, walking, running, or pivoting [3].
- The onset of symptoms in FAI is often insidious or follows minor trauma [3].
- Patients with FAI exhibit restricted hip internal rotation in 90° of flexion [3].
- The impingement test (flexion, adduction, internal rotation) elicits pain in patients with FAI but is not specific for the condition [3].
- The impingement test involves hip flexion to 90 degrees followed by hip adduction and internal rotation to yield a pain response [30].
- The roll test involves rolling the leg into internal and external rotation while the patient is supine, with a positive result indicated by stiffness or grabbing [30].
- The Stinchfield test involves an active straight-leg raise of approximately 20 cm against mild resistance, with a positive result indicated by pain in the anterior hip [30].

- The Patrick test involves positioning the leg in a figure-of-four position, with pain in the anterior or posterior hip region indicating a positive result [30].
- Pain located over the posterior pelvis during the Patrick test indicates referred pain from L5 to S1 facets or the sacroiliac joint rather than the hip joint [30].

RADIOGRAPHY

- Conventional radiographs remain critical in the initial imaging evaluation of the hip [2].
- Radiographs can be used to diagnose fractures, developmental dysplasia of the hip (DDH), femoroacetabular impingement (FAI), and osteoarthritis [2].
- A complete hip series usually consists of an anterior-posterior (AP) pelvis, a centered AP hip, a lateral view (frog-leg, cross-table, Dunn 45° or 90°), and a false-profile (Lequesne) view [2].
- Osteoarthritis of the hip can be categorized using the Kellgren-Lawrence classification, which is a 4-point grading system classified into doubtful, mild, moderate, and severe [2].
- Osteoarthritis of the hip can be categorized using the Tönnis classification, which is a 3-point grading system categorized into mild, moderate, and severe [2].
- Radiographic and clinical severity of osteoarthritis do not necessarily correlate, particularly if radiographs are non-weight-bearing or false-profile views are not included [2].
- Acetabular morphology is assessed on AP pelvis radiographs to evaluate acetabular overcoverage and undercoverage [2].
- The femoral head-neck junction morphology is often assessed using the alpha angle [2].
- Some studies have shown that radiographs, in particular the Dunn 45° view, may be more accurate for determining the alpha angle measurement than CT or MRI [2].
- The AP pelvis radiograph should be performed with the lower extremities in approximately 15° of internal rotation and centered over the pelvis [2].
- Coxa profunda is diagnosed when the acetabular fossa line touches or is medial to the ilioischial line [2].
- The femoral head extrusion index is defined by the length of the femoral head that lies beyond the acetabulum as a percentage of the total horizontal width of the femoral head [2].
- Femoral head extrusion index values greater than 25% are considered abnormal [2].
- The Tönnis angle is defined by the angle of the acetabular sourcil and a line parallel to the transverse pelvis axis [2].
- Tönnis angles between 0° and 10° are considered normal [2].
- The lateral center-edge angle of Wiberg is the angle between a line from the center of the femoral head perpendicular to the transverse pelvis axis and a second line from the center of the femoral head to the superolateral most point of the acetabulum [2].
- Center-edge angles of 20°–40° are considered normal, while angles from 20° to 25° are considered borderline [2].
- A normal alpha angle is less than 50°–55° [2].

- An abnormal alpha angle of 70° indicates femoroacetabular impingement [2].
- The “crossover” sign on an AP pelvis radiograph indicates acetabular retroversion related to lateralization of the anterior acetabular wall relative to the posterior acetabular wall [2].
- Pelvic tilt or rotation may lead to false-positive and false-negative “crossover” signs [2].
- For neutral pelvic tilt, the sacrococcygeal joint should be between 3 and 5 cm above the superior border of the symphysis pubis [2].
- An increased Tönnis angle of 19° and an increased femoral head extrusion index of 28% are indicative of developmental dysplasia of the hip [2].
- A reduced anterior center edge angle of 17° on a false profile radiograph is indicative of developmental dysplasia of the hip [2].
- Radiographs remain integral to the assessment of fractures and can be supplemented with CT to investigate suspected occult fractures, define fracture morphology, and assist in preoperative planning [2].
- Radiographs can serially assess hardware positioning and evaluate symptomatic hardware related to open reduction and internal fixation and total hip arthroplasty [2].
- Standard AP radiographs of the hip and pelvis are obtained to examine bony architecture, check for evidence of joint space narrowing or changes to bone quality, and quantify femoral head coverage [21].
- The Dunn view and frog leg view are appropriate to measure the alpha angle to determine the presence of impingement [21].
- Plain radiographs will identify the fracture in the majority of cases for femoral neck fractures [28].
- Anteroposterior (AP) and lateral radiographs are required for the evaluation of femoral neck fractures [28].
- In equivocal cases, the lateral radiograph can help determine whether a femoral neck fracture is displaced, which is usually essential to determine the choice of treatment [28].
- Full-length AP and lateral femur films are standard for femoral neck fracture evaluation [28].

MAGNETIC RESONANCE IMAGING

- MRI is the modality of choice for patients suspected of soft tissue or intra-articular pathology, given its superior sensitivity and specificity [21].
- Conventional MRI is effective at identifying osteochondral injuries, musculotendinous pathologies, and inflammation [21].
- Magnetic resonance arthrography (MRA) is more appropriate than conventional MRI to determine injuries to the labrochondral structures and the ligamentum teres [21].
- MRA is used to identify the presence of loose bodies and synovial chondromatosis [21].
- The utility of MRA in the accurate detection and staging of articular cartilage lesions is reduced, with sensitivity reported to be less than 50% compared with arthroscopic findings [21].
- Recent advances in MRI imaging techniques, such as delayed gadolinium-enhanced MR imaging and T2* mapping, allow for a more in-depth analysis of the structure of articular cartilage [21].

- Delayed gadolinium-enhanced MR imaging and T2* mapping were effective at detecting early changes to the articular cartilage surfaces of patients with hip dysplasia and femoroacetabular impingement [21].
- MRI provides information regarding the integrity of the acetabular labrum and articular cartilage [3].
- MRI can assess the anatomy of the proximal femur as well as the version of the acetabulum and femur [3].
- The sensitivity of MRI to acetabular rim chondral lesions is limited [3].
- MRI is used when osteonecrosis is suspected [30].
- Gadolinium-enhanced MRI arthrogram is useful when labral pathology is suspected, especially when associated with FAI [30].
- MRI may identify gluteus medius and gluteus minimus tears in patients with lateral hip pain and abductor weakness [30].
- Noncontrast MRI at 3T is generally adequate for diagnosing intra-articular pathology [26].
- If 3T imaging is unavailable, MRA can be considered at 1.5T for increased diagnostic accuracy [26].
- MRI is helpful in identifying femoral neck stress fracture in athletes and predicting patients that may require surgical intervention [26].
- MRI is helpful in assessing complications of conventional and resurfacing hip arthroplasties, particularly those with metal-on-metal bearing systems [26].
- Major MRI findings that help predict histologic ALVAL scores include synovial thickening, synovitis, synovial volume, abductor disruption, and soft-tissue edema [26].
- A prospective study found similar accuracies between noncontrast 3T MRI and 1.5T MRA in femoroacetabular impingement [24].
- In a retrospective study evaluating noncontrast 3T MRI versus hip arthroscopy, accuracy for labral tears was 98% and for acetabular cartilage lesions was 90% [24].
- MRI is the current additional imaging modality recommended where there is uncertainty about the presence of an intracapsular fracture [28].
- MRI is more accurate than CT in detecting occult hip fractures in patients with normal radiographs [28].
- MRI is more accurate than a bone scan in the early stages after injury for detecting occult hip fractures and has no radiation [28].
- MRI will demonstrate soft tissue problems that may be causing hip pain in the absence of a fracture [28].
- Positron emission tomography/computed tomography (PET/CT) at 6 weeks could detect recovery of vascularity and predict the risk of vascular necrosis [28].
- Dynamic MRI-positive enhancement integral color mapping (PEICM) can estimate femoral head perfusion preoperatively [28].
- In a study using dynamic MRI-PEICM, the nonunion rate was zero in the normal perfusion group, 6.7% in the reduced perfusion group, and 50% in the absent perfusion group [28].

COMPUTED TOMOGRAPHY

- CT scans are effective for examining cortical and cancellous bone [21].

- CT can be used to create three-dimensional reconstructions of the hip for use in surgical planning [21].
- Measurements of femoral head coverage and acetabular and femoral impingement can be performed reliably using CT images [21].
- Low-dose CT with three-dimensional reformats is particularly useful in surgical planning of complex or borderline deformities [3].
- CT overcomes the limitations of radiography by providing three-dimensional assessment of bony morphology and, to some degree, assessment of soft-tissue abnormalities [9].
- Combined with arthrography, CT can evaluate chondrolabral abnormalities, specifically in patients with contraindications to MRI [9].
- CT is helpful in fracture evaluation, particularly in the setting of negative radiographs or for further defining fracture morphology in patients requiring surgical reduction [9].
- Three-dimensional CT with pelvic remodeling may be indicated for preoperative planning for reconstruction associated with dysplasia surgery, femoroacetabular impingement, posttraumatic arthritis, or other complex primary total hip arthroplasty [30].
- CT scanning is a more accurate investigation than technetium bone scan for suspected fractures but exposes the patient to further radiation [28].
- Multidetector CT scanning reported 100% specificity and sensitivity in the diagnosis of hip fracture in a series of 209 patients with negative plain radiographs [28].
- In a series of 78 CT scans, CT scanning yielded a sensitivity of 86% and specificity of 98% for occult hip fractures [28].
- The multiplanar and 3D capabilities of CT make it an invaluable tool for assessing bone morphology, but at higher cost and radiation dose [26].
- 3D volume renderings are useful to aid in preoperative planning in FAI and subspace impingement [26].

ULTRASONOGRAPHY

- Ultrasonography provides real-time dynamic assessment of the hip [9].
- Ultrasonography is useful in diagnosing soft-tissue abnormalities about the hip joint and, to a lesser degree, within the hip joint itself [9].
- Ultrasonography is particularly useful in providing real-time guidance during diagnostic and therapeutic procedures [9].
- Although ultrasonography is a valuable tool to examine pediatric hip conditions, its utility in evaluating the adult hip is limited [21].
- Ultrasonography can be an effective modality to identify musculotendinous disruptions, effusions associated with intra-articular pathology, or inflammatory conditions such as bursitis [21].
- Ultrasonography is increasingly used for targeted injections into muscles, tendons, or intra-articularly around the hip for corticosteroids or biologic treatments [21].
- Ultrasonography allows bedside evaluation of the hip and can be used to guide interventions in the office setting [26].

Treatment

- Dislocation is a recognized complication following total hip replacement [33].
- Metal-on-metal total hip arthroplasty has specific modes of failure [33].
- Osteolysis is a current concept in orthopaedic management [33].
- The direct anterior approach is a technique used for total hip arthroplasty [33].
- Periprosthetic femoral fractures are a complication of total hip arthroplasty that require classification and treatment [33].
- Acetabular bone loss is evaluated and managed in revision total hip arthroplasty [33].
- Femoral bone loss is evaluated and managed in revision total hip arthroplasty [33].
- Nonarthroplasty surgical options are available for hip disease in the young, active patient [33].
- Osteonecrosis of the femoral head is evaluated and treated [33].

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