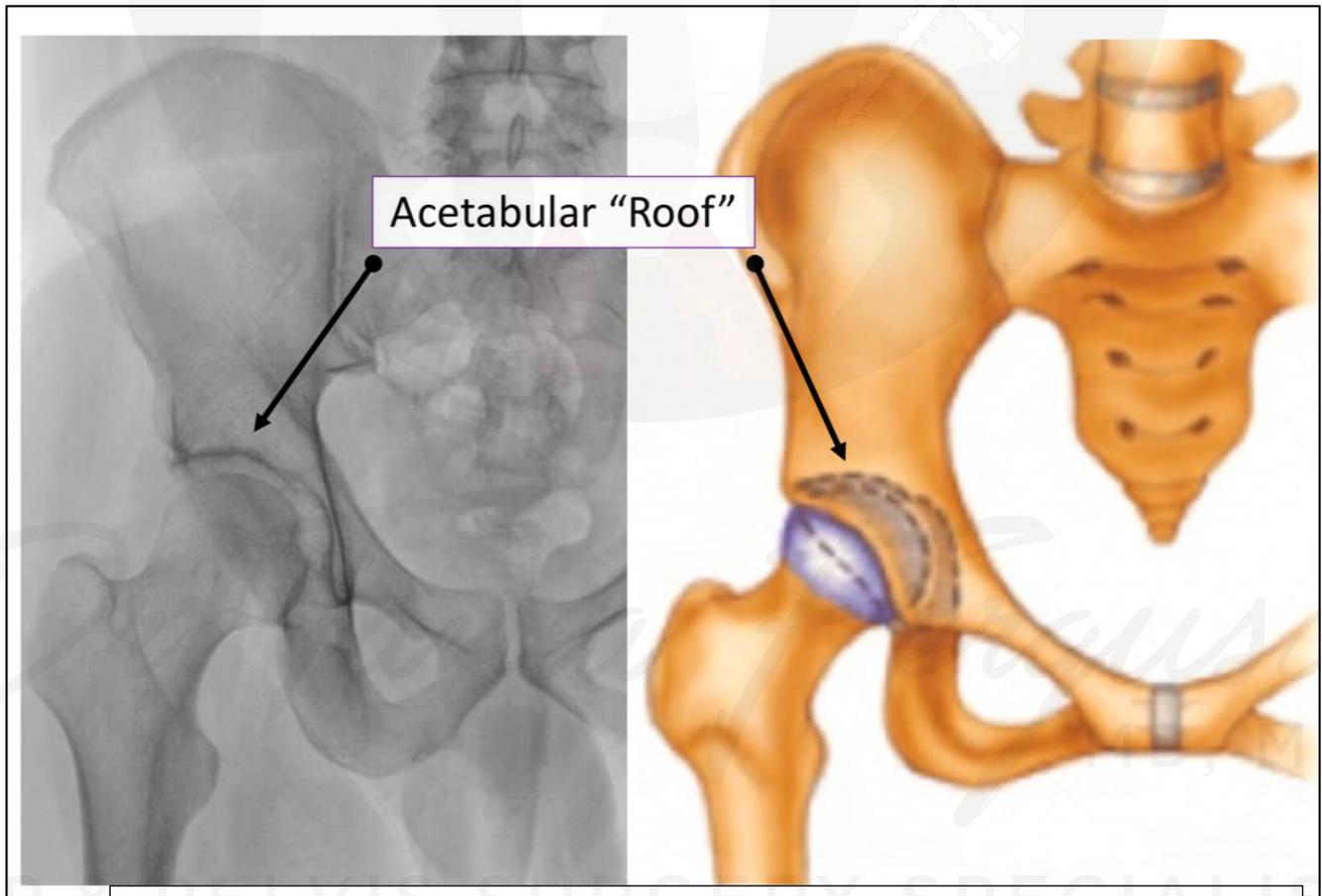


Hip Dysplasia and PAO Surgery

What is Hip Dysplasia?

Dysplasia is a Latin word meaning altered growth. The term “Hip Dysplasia” includes a broad spectrum of abnormal shapes (morphologies) of both sides of the ball-and-socket joint. These abnormal morphologies can lead to pathological mechanics of the hip joint, early breakdown of the soft tissues structures (the acetabular cartilage and labrum), and early arthritis. Diagnosis and treatment is aimed at identifying the abnormalities early in the disease process (before irreversible cartilage damage has occurred) and altering the architecture of the hip to normalize the hip biomechanics.

In a “normal” hip, the socket, or acetabulum, covers the majority of the head of the femur, and the ball of the femoral head is angled into the acetabulum. This relationship allows the force of weight bearing to be distributed throughout the acetabular cartilage surface, and allows stable motion due to the femoral head being centered in the socket.

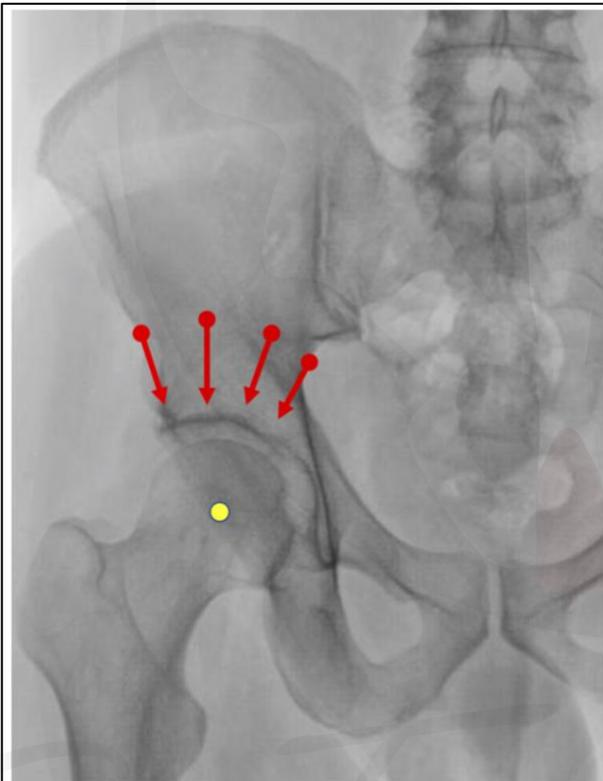


In a “normal” hip, the socket (acetabulum) covers the head ball (femur). During weightbearing the force is distributed throughout the cartilage of the acetabulum and the femoral head remains centered in the socket.

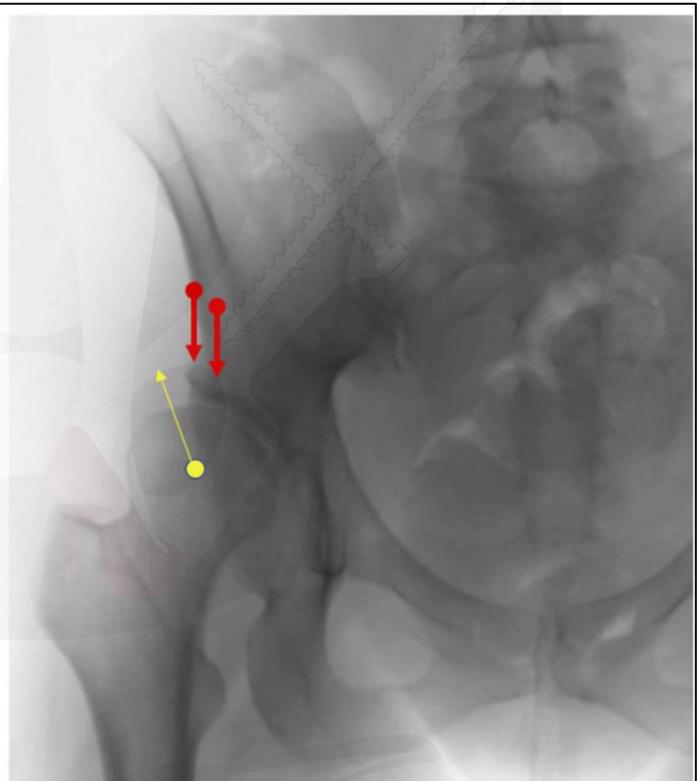
Ok, so what is “Hip Dysplasia?”

The term “hip dysplasia” most commonly refers to inadequate development of an individual’s acetabulum. The resulting acetabulum is shallow and provides insufficient coverage of the femoral head. The upper portion (roof) of the acetabulum is upward sloping rather than having the normal horizontal orientation.

When the acetabulum insufficiently covers the femoral head, the forces of weight bearing becomes concentrated on the periphery of the acetabulum, rather than distributed throughout the acetabular cartilage. This may result in early breakdown of the overloaded acetabular cartilage and, if left untreated, become irreversible injury and lead to arthritis. The femoral head may migrate from the center of the socket with motion, resulting in instability that further injures the cartilage and acetabular labrum.

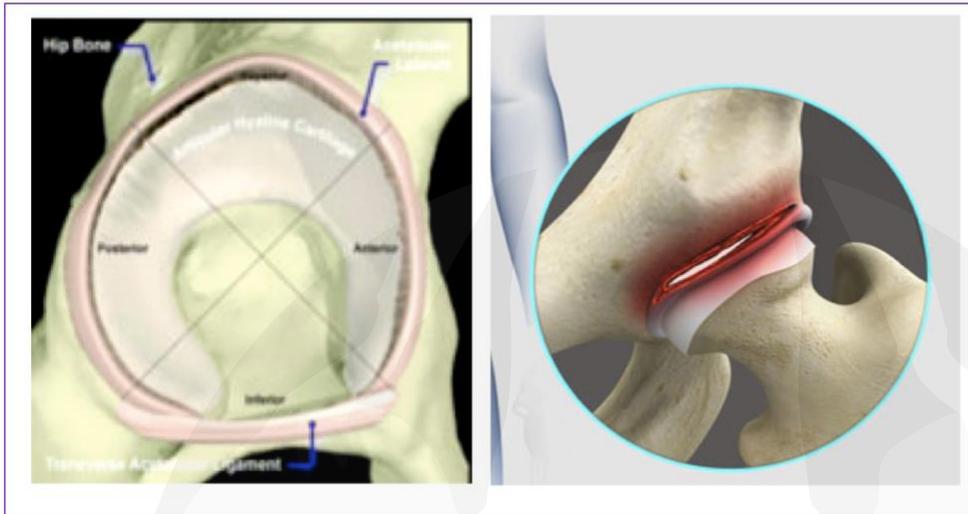


Normal Hip: Acetabulum covers the femoral head and is horizontal, “containing” the femoral head. This allows the hip center of rotation to remain stable during motion, and the ball stays centered under the roof. Further, the force of weight-bearing is distributed throughout the acetabular cartilage.



Dysplastic Hip: The acetabulum is shallow covering less than half of the femoral head. It is also oriented vertically, or sloped upwards. This architecture can not maintain a stable environment for motion, and the head may migrate during motion or stance. Force is concentrated at the edge of the socket and can lead to overload on the cartilage and labrum.

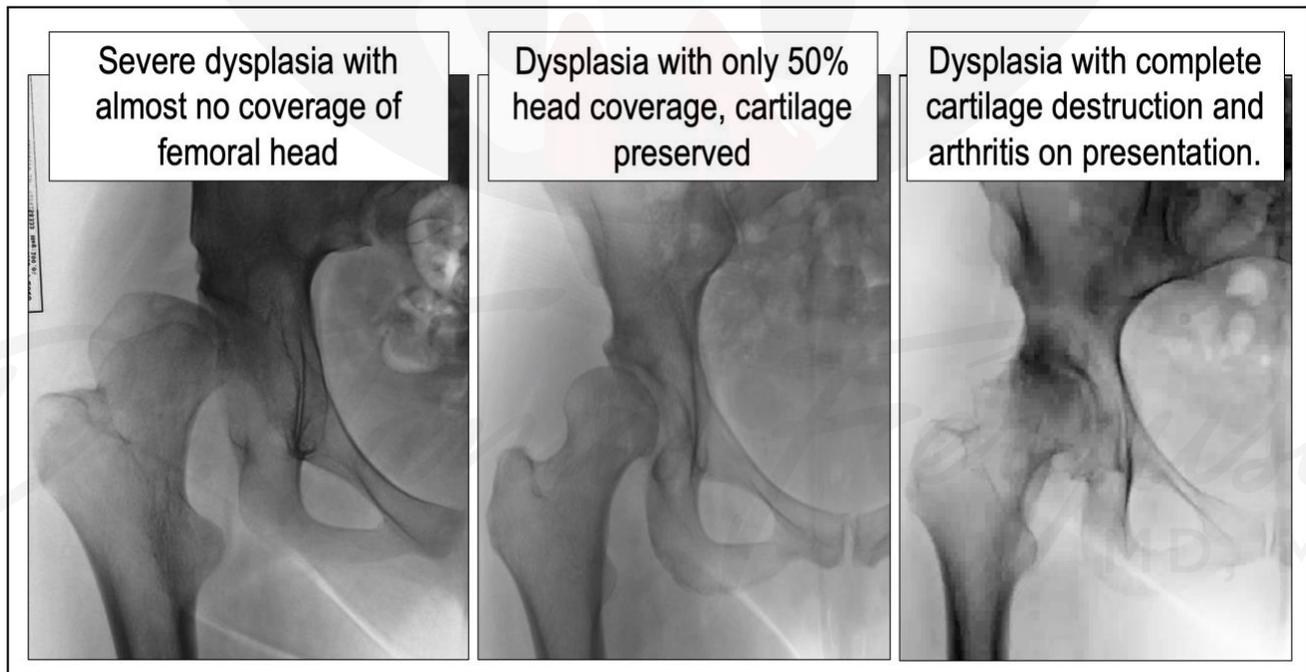
The hip socket is lined with the acetabular labrum, which provides a gasket seal to the socket and enhances frictionless motion in the hip joint. When there is excessive stress concentrated at the periphery of the socket, the acetabular labrum may be injured causing pain.



Labral Injury with Dysplasia:

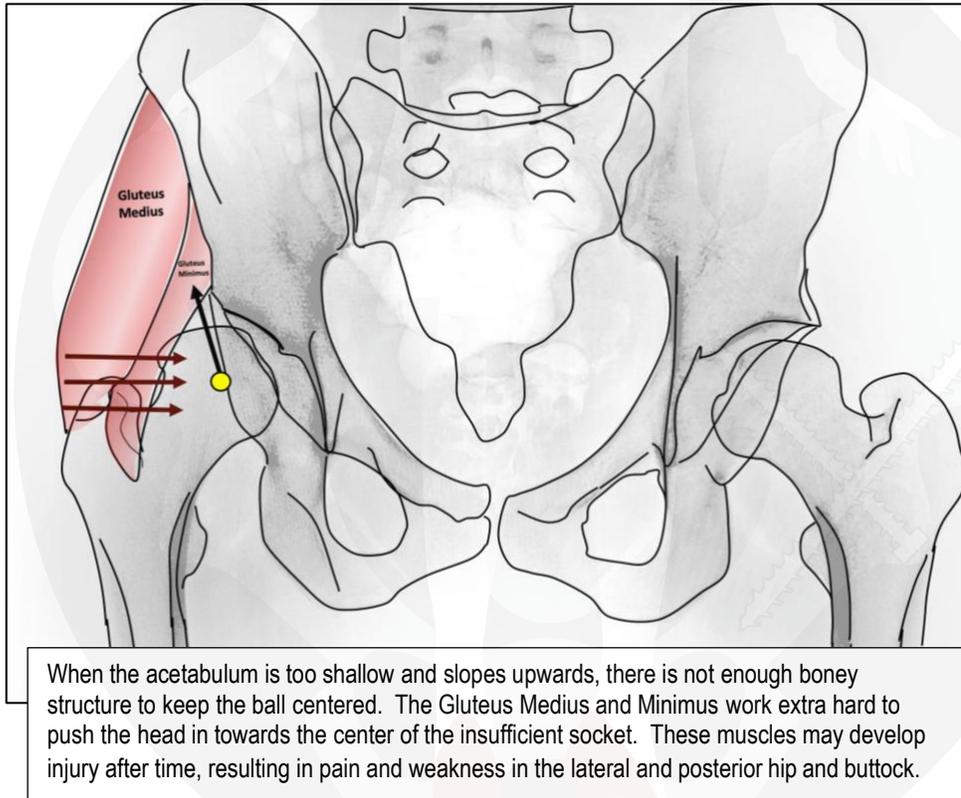
The acetabular labrum is a highly innervated fibrocartilage structure that lines the acetabulum, acting as a gasket between the femoral head and the acetabular rim. Excessive force concentration and instability associated with acetabular dysplasia may cause tearing of the acetabular labrum. This can cause significant pain, and may be the first hint that an individual has a hip problem

There is a great range of abnormalities that fall under the umbrella of “hip dysplasia,” and every individual’s anatomy is unique. The most drastic example is a congenitally dislocated hip where the femoral head is completely uncovered by the socket. These patients may have deformity, leg length inequalities, and pain from very young ages. Alternatively, a patient may have a shallow, upsloping acetabulum with just a small amount of the femoral head covered. These patients may not develop pain until their teens or early adulthood. Others may have dysplasia, but not develop pain until their later adult years when the cartilage has broken down and arthritis ensues. The treatment of dysplasia thus depends greatly each person’s underlying anatomy and the stage at which they seek medical attention.



What are the symptoms of Hip Dysplasia?

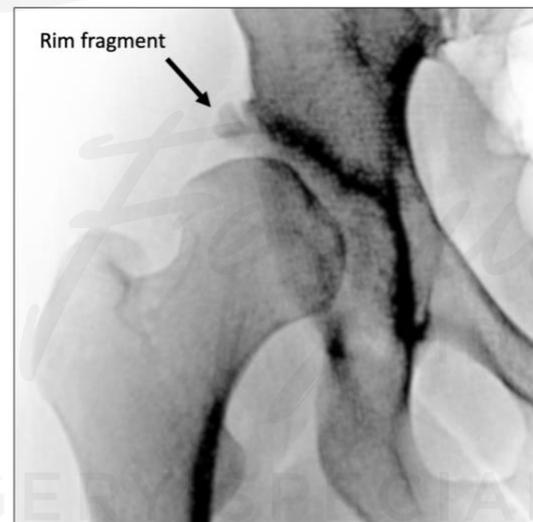
Some patients' early complaints involve pain in the muscles around the hip, particularly in the Gluteus Medius and Minimus (Hip "Abductors"). When there is insufficient bony architecture to support the femoral head (the acetabulum is too shallow and upward sloping), these muscles work extra hard to try to keep the head stabilized under whatever roof there is. These muscles often fatigue, and pain and weakness in the lateral and posterior hip is experienced.



At times patients present with pain in the front of the hip or the groin. This may be caused by injury to the acetabular labrum as shown above. The bone behind the cartilage of the roof can begin to breakdown and cysts may develop in this area.

Additionally, with the great stress directed on the acetabular periphery, fragmentation of the rim of the socket can occur. All of these conditions, amongst other pain generators within the socket itself, are often felt as pain in the groin.

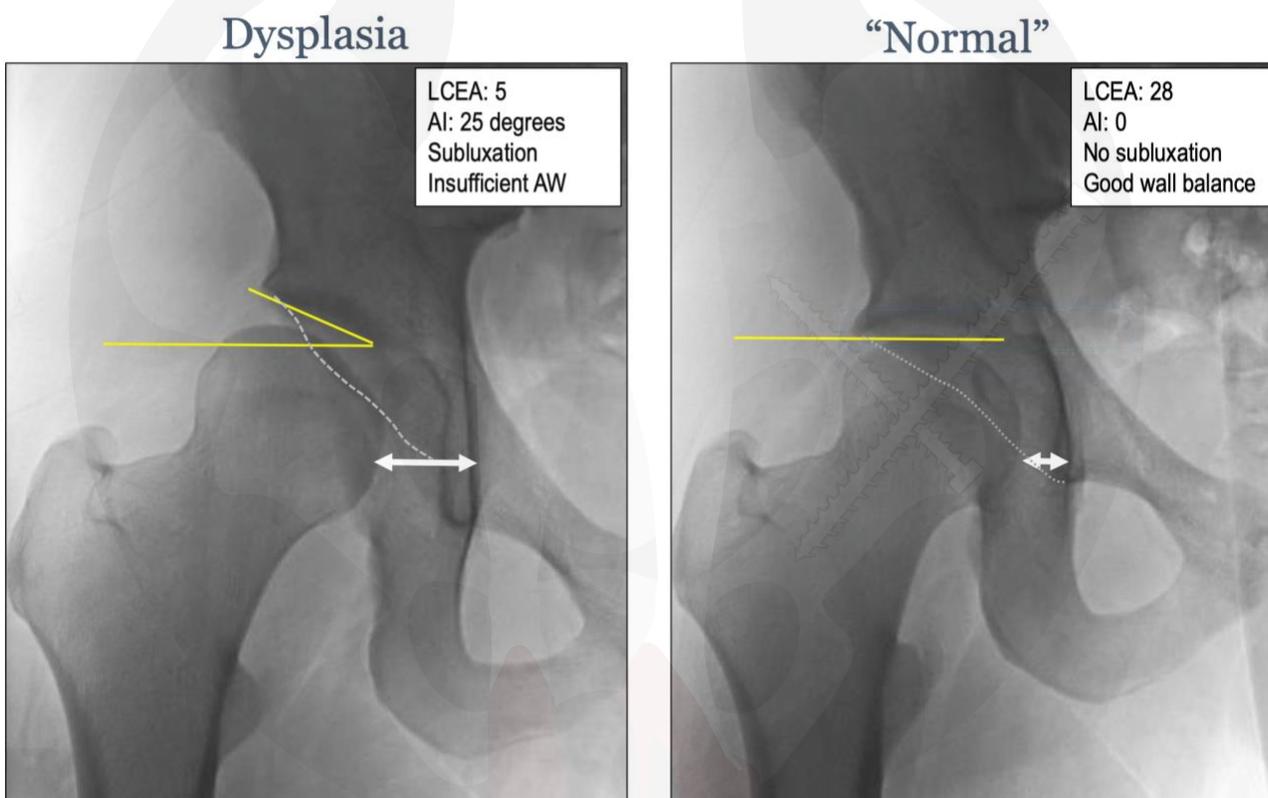
Injury to these structures may occur at any time, leading to the earliest sensations of pain.



Rim fragmentation can occur with the excessive stress focused on the rim of the socket

How is the diagnosis of Hip Dysplasia made?

While the physical examination and gait mechanical exam are critical to the diagnosis and treatment plan development, the diagnosis of Hip Dysplasia is reliant on radiographs. Conventional images aimed at fully understanding the depth, orientation and slope of the acetabulum are made and measurements compared in the standing and laying down position. The coverage of the femoral head by the socket is evaluated utilizing various measurements and various radiographic projections, a few of which are shown below.



Some measurements in Hip Dysplasia: The Lateral Center Edge Angle (LCEA) is used to describe how much acetabulum covers the femoral head laterally (normal >25 degrees*). The Acetabular Index (AI) measures the slope of the roof (normal <10 degrees). The anterior rim should be recessed compared to the posterior, but on the left barely covers the femoral head at all. On the left the hip is escaping and has moved out of the socket (subluxation.)

The radiographic interpretation is essential to understanding the mechanical pathology of the hip. Multiple specialized x-rays are required, and often CT scans and a high quality MRI are essential to this evaluation. *Note-we prefer to obtain a **NON-CONTRAST MRI** for evaluation, as the contrast dye can mask some of the subtle signs of hip injury like effusions and edema. The newest magnets used in high quality conventional MRI (T3 magnets) allow equivalent if not better assessment of the soft tissues in the hip, and are thus preferable to having a dye injected into the joint. If possible, we prefer to arrange your MRI by our known radiologists rather than have your primary doctor order these studies for this reason.

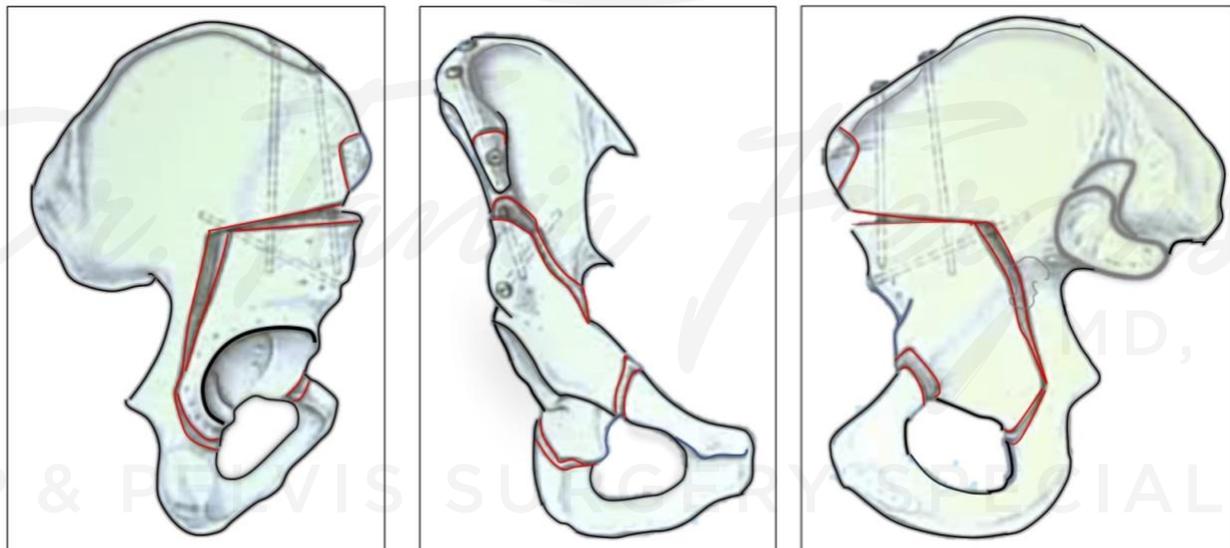
What is the treatment for Hip Dysplasia?

The severity of the dysplasia and the state of the intra-articular soft tissues at the time the patient develops symptoms define the treatment plan for hip dysplasia.

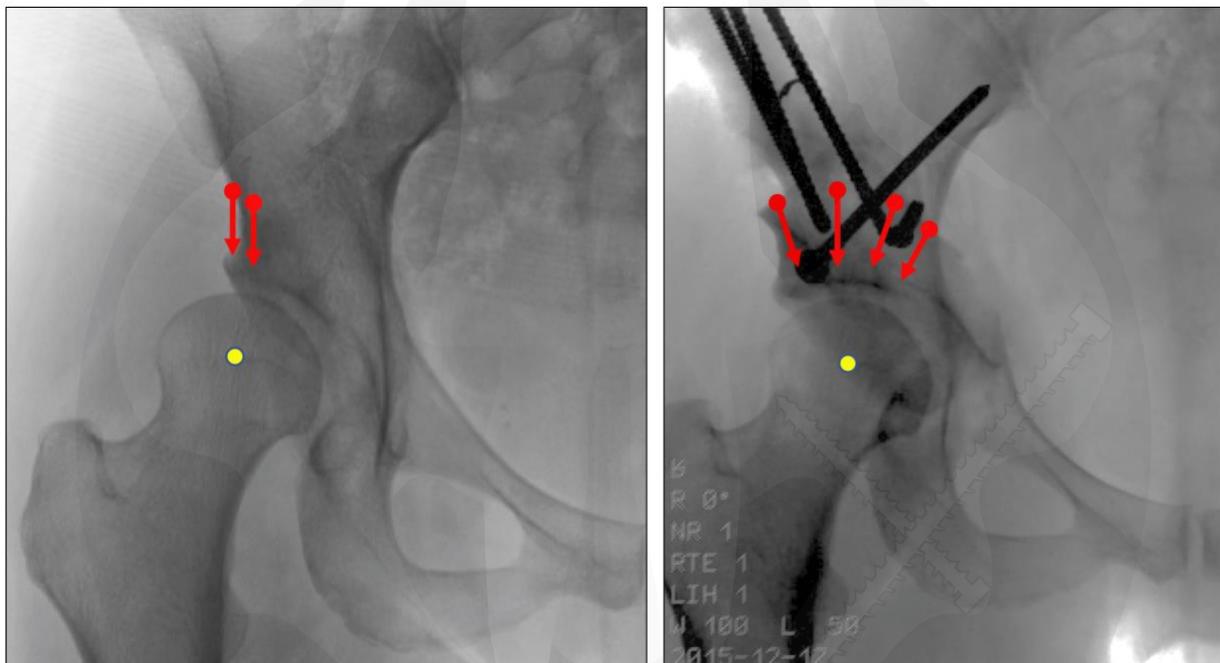
1. **Periacetabular Osteotomy (PAO):** When identified **before** the acetabular cartilage has been irreversibly damaged, PAO surgery is the preferred treatment for acetabular dysplasia. This is an operation in which Dr. Ferguson creates a series of 4 cuts in the pelvis bone to allow the hip socket itself to be moved or “reoriented.” The socket is then repositioned to better cover the femoral head, redistributing the concentrated forces. The femoral head becomes covered, the acetabular roof flat, and the forces of weight-bearing redistributed to the entire cartilage lining of the socket rather than the rim. This surgery is aimed at preserving the patient’s native hip joint and when performed in optimal conditions may prevent hip arthritis for more than 20 years.
2. **Total Hip Replacement:** Unfortunately, many patients present with hip dysplasia late after the cartilage has degenerated beyond repair and progressed to arthritis. In these cases, THA is indicated.
3. **Hip Arthroscopy:** In rare circumstances, there may be a role for an arthroscopic-only intervention to address the pain of a labral tear associated with very mild dysplasia or in patients who have developed some cartilage damage but not so much as to necessitate THA.

What is PAO surgery?

Periacetabular Osteotomy (PAO) is a surgical treatment for hip dysplasia that involves repositioning the acetabulum into a location that best covers the femoral head. Through a series of precisely planned cuts (osteotomies), the acetabulum is cut from the pelvis, reoriented, and stabilized with screws.



The dysplastic roof that incompletely covered the femoral head is brought over the head to give the head a normal coverage and also brings the roof from an oblique to a horizontal position. Other subtle changes typically also occur. Anterior coverage may increase or decrease. Also, the shortening of the extremity and lateralization of the joint, which are often a part of acetabular dysplasia, can also be improved.



Periacetabular Osteotomy. Pre-operatively (left) the socket is shallow, covering only part of the femoral head. It is upward sloping, and the force of weightbearing concentrated to the periphery rather than distributed throughout the acetabulum. After PAO surgery, the socket has been repositioned to optimize coverage of the head, and the peripheral labrum and articular cartilage no longer experience the loaded stress.

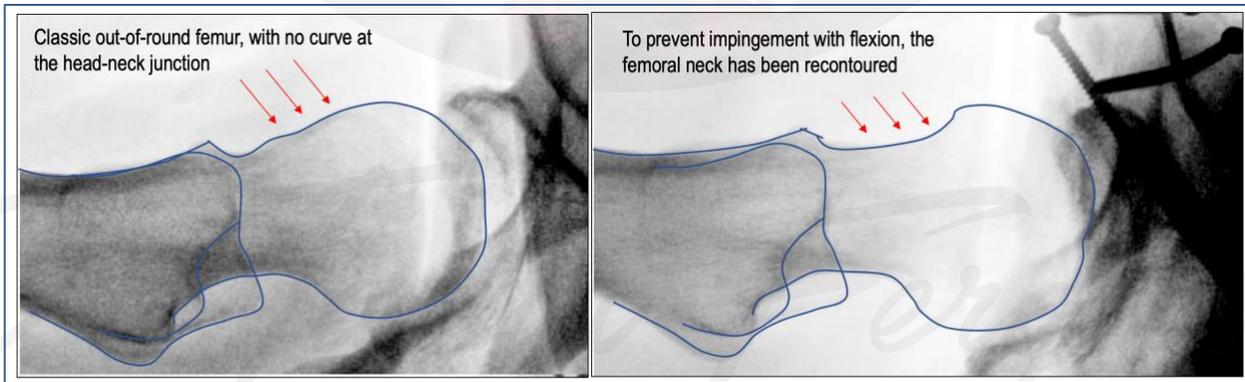
The “reorientation” of PAO surgery unloads the peripheral articular cartilage and acetabular labrum such that they are no longer subject to the force concentration associated with the shallow socket. Because the labrum has commonly suffered injury, it is often reattached or refixed during the PAO surgery. Further, the instability associated with insufficient femoral head containment is decreased and ideally abolished. PAO surgery preserves a patient’s native hip, stopping the damage to the articular structures (the cartilage and labrum), rather than replacing the joint with an artificial part.

Individual cases of dysplasia however present with their own unique deficiencies, and the PAO must often be tailored to solve these unique problems. Often, the abnormal mechanics associated with hip dysplasia have caused labral injury requiring reattachment at the time of surgery. Also commonly, the femoral head is not completely spherical (“Cam Lesion”) and requires recontouring during the PAO surgery.



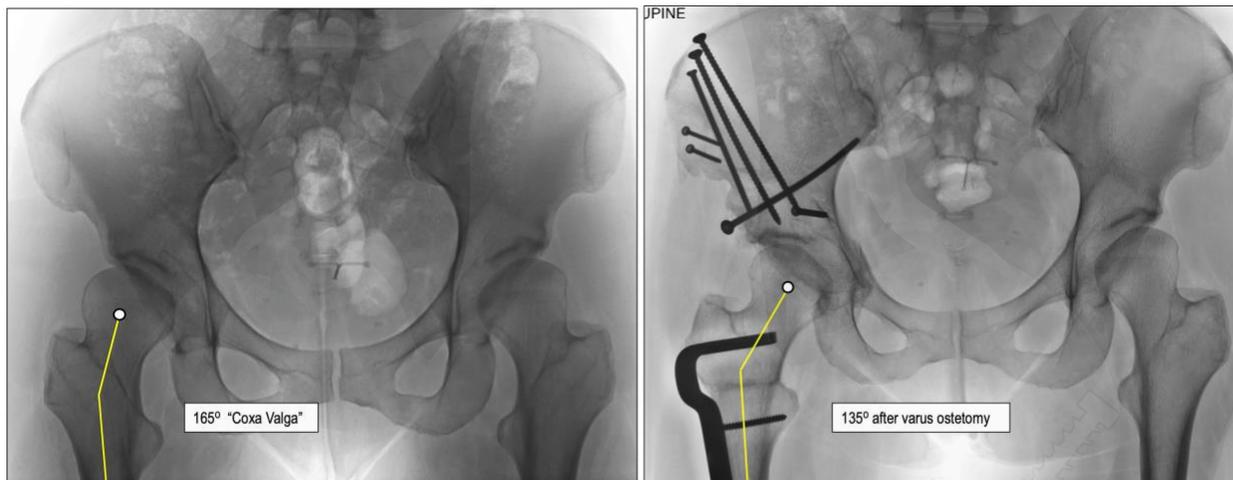
The labrum is seen to be detached from its origin along the socket in the cartoon drawing. This is common due to the excessive force and instability on the tissue. On the right, the MRI shows the labral injury commonly associated with dysplasia.

The femur may also be abnormally shaped in cases of acetabular dysplasia. Very commonly (about 70% of the time) the femur is “out-of-round,” or non-spherical as in “Cam Impingement.” In these cases, the femur may require recontouring to make it round and not impinge on the newly repositioned socket. This is a classic mixed “Dysplasia-Impingement” scenario which requires work on both the acetabulum and the femoral neck.



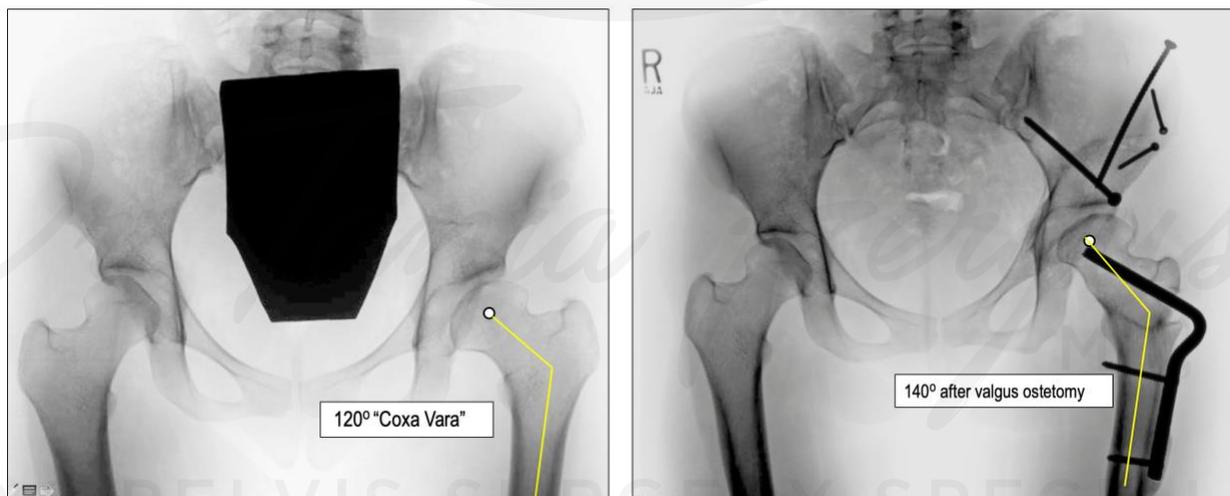
It is fairly common for the femoral neck to be flat when the socket is insufficient and shallow (as on the left). When the socket becomes more prominent after repositioning, this “out-of-round” area acts like a “Cam Lesion” and may impinge on the socket. This area of the femur needs to be recontoured and recessed so that there is no contact with the socket (and labrum!) when the patient flexes the hip after PAO.

Additionally, patients may develop alignment abnormalities of the femur during development requiring an osteotomy on the femoral side as well as on the socket side. 5-10% of Dr. Ferguson's patients require an additional femoral osteotomy at the time PAO surgery.



This patient had a combined picture of acetabular dysplasia, with a shallow upsloping socket, and a femoral deformity called "Coxa Valga." The proximal femur is virtually straight, rather than having a bend in the neck to direct the head into the socket. This is a common combined developmental deformity-when the socket is shallow the femur is often "Coxa Valga". The acetabular correction is not "enough" to optimize the forces with weightbearing, and the femur may need to be treated with an osteotomy to create a bend in the proximal femur.

The example below shows a different scenario, in which the woman's left hip has been effected by Legg-Calve-Perthes Disease. This causes a large femoral head and a small-angle femoral neck (120 degrees in this case). In these cases, the PAO is performed and the femoral osteotomy performed to increase the angle at the femoral neck.



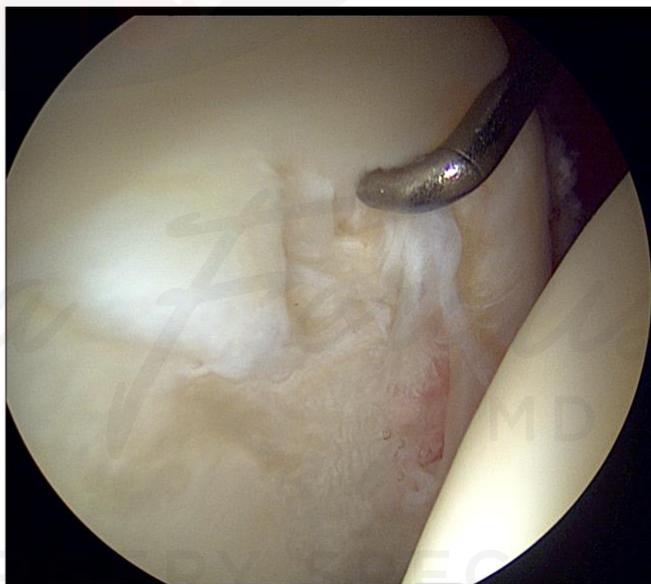
Outcomes after PAO surgery

When performed in young hips without early signs of cartilage damage, PAO surgery has been found to be a successful operation in preserving the hip joint. Recent data indicate that 80-90% of hips after an optimal PAO surgery may survive 20 years or more. Thus, while recovery times are meaningful, the operation has the opportunity of successfully maintaining the patient's hip joint for a very long time, and some patients go a lifetime without THA.

Why is PAO surgery preferable to hip arthroscopy in Dysplasia?

Hip arthroscopy is a surgery for addressing injuries to the acetabular labrum in the hip joint. Furthermore, arthroscopy is an excellent method of recontouring the hip when RESECTION of bone is required. With the arthroscopic techniques, surgeons can remove bone from the femur to recontour the head-neck junction in Cam Impingement (discussed above) to prevent contact with the socket when the femur is "out-of-round." We can also remove areas of the rim of the socket that are OVER covering the femoral head. Arthroscopy is thus an excellent tool for over-coverage and "Femoro-Acetabular Impingement" (FAI).

What cannot be done well with arthroscopic surgery is changing the mechanics of the hip by increasing coverage (as in the socket) or changing the angles or rotations of the femoral neck. Thus, in a situation where the underlying cause of labral injury is insufficient coverage of the femoral head, arthroscopy leads to predictable failures. The labrum can be refixed, but is subject to the same forces that lead to the problem in the first place. Imagine, in the picture below, that the labrum is simply repaired to the edge of the socket without repositioning the socket. It won't surprise you that this will predictably lead to recurrent labral injury. This socket requires repositioning to UNLOAD the labrum, so that when it's been reattached it isn't overloaded.



Why is PAO surgery preferable to THA?

Before the revolutionary advances made in total joint replacement (THA) seen in the late 90's, osteotomy surgery was very common in pre-arthritic and even post-arthritic hips. The PAO surgery became a popular surgery for preventing hip arthritis after its inception in the early 1980's.

Outcomes after THA improved significantly with the advances in implant engineering and septic technique brought forth by great work of Sir John Charnley and others like him. Encouraging early good results led many surgeons to abandon osteotomy surgeries and instead treat even young patients with THA instead of preservation attempts.

Despite good initial results of total hip replacement, the long-term follow up of these patients demonstrated high rates of failures. Implant loosening and complications associated with the demands and activities of younger patients became common. Osteolysis (bone loss) can cause loosening of the hip prosthesis (artificial hip) when patients outlive the longevity of their artificial hip, which is particularly likely in younger adults. Failure of THA requiring revision surgeries in active young to middle aged adults underscored the importance of preserving the hip rather than replacing it. This has led to a resurrection of the enthusiasm for preservation surgeries aimed at PREVENTING osteoarthritis and cartilage breakdown in young adults.

Osteotomy should not be thought of as an inferior second choice to total hip replacement that the young patient with early arthritis must undergo because he or she is too young for total hip replacement. The results after PAO justify its use, and **the long-term results can be better than what the patient could have obtained from a hip replacement.** The patient's own hip is a living tissue with self-maintenance capabilities, whereas deterioration with time is inevitable for an artificial part. The sensory capabilities of the joint are preserved, and the patient can continue to remain as active as symptoms or lack thereof permits.

While THA is an excellent (and ever improving) option in patients whose cartilage has degenerated, it is a greatly inferior option to preserving one's native hip with PAO surgery for these reasons and more.



In this case, the 49 yo patient presented with end stage arthritis, the final result of dysplasia. THA should be reserved for patients who are NOT a candidate for PAO surgery, in this case due to the lack of preservable cartilage.

FAQs and logistics of PAO surgery with Dr. F

- Dr. Ferguson does PAO surgery at St. Thomas Midtown Center in Nashville, Tennessee. Arrangements have been made to allow family members to stay in the room with patients during the hospitalization.
 - Hospital stays average 4 nights but range from 3 nights to 7 nights.
 - Many (if not most patients) fly or drive long distances to Nashville for surgery, and our office will assist with arrangements for “Out of Towners.”
- Surgery may be 4-8 hours depending on what more than the “PAO” itself must be done (femoral osteotomy, labral fixation, femoral head recontouring).
- Surgery is performed with both a general anesthesia and an epidural catheter, which remains in place for 2 days to minimize the immediate pains after surgery. Leaving the catheter in place has GREATLY decreased the amount of IV narcotic medications required.
- The Medical Hospitalist or Pediatric Hospitalist team will meet with you before surgery and assist Dr. Ferguson’s team with medical management during the hospitalization.
- Blood loss does occur, and during surgery we reinfuse your lost blood with a device called a “cell saver.” Blood loss may continue after surgery, and approximately 30% of patients require a blood transfusion during the hospitalization.
- We have developed a multimodal approach to pain control which involves the anti-inflammatory (Celebrex), Tylenol, cryotherapy (“Game Ready”), and oral narcotic medications (Oxycodone). While in the hospital IV opioid medications are provided as needed, as are medications for muscle spasm and nerve pain as needed.
 - At discharge you are given prescriptions for Celebrex for 3 weeks, Oxycodone for break through pain, and occasionally additional medications for nerve pain or muscle spasm.
 - On average patients require the Oxycodone about 2 weeks after discharge from the hospital.
 - The “Game Ready” ice machine provides both cryotherapy and compression to the hip. We recommend this machine during the hospitalization, and it is then taken home for 2 weeks after the surgery. This is what my patients call a “Game Changer” and has GREATLY reduced the use of narcotic medications after surgery, minimized swelling and decreases bruising.
- Physical therapy begins the day after surgery.
 - Weight-bearing is restricted to 30lbs on the operative side for 10-12 weeks after surgery to allow the osteotomy sites to begin healing.
 - Most patients begin walking with a walker. Some progress to crutches a week or two after surgery while others continue to use the walker for their entire 10 weeks of limited weight-bearing.
 - A continuous passive motion (CPM) machine is utilized, allowing safe and controlled motion starting the day after the surgery. Patients take this machine home and use it for 2 weeks after surgery to allow controlled motion without

threatening the fixation of the fragment, in attempts to minimize scar tissue in the joint.

- There are some restrictions on the range of motion after the surgery, including limitations to active flexion.
- If labral surgery is performed, there may be rotational restrictions also.
- After 2 weeks patients are encouraged to lay on their stomachs to start stretching out the muscles in the front of the hip.
- We try to avoid blood clots by the use of compressive stocking which are worn for 3 weeks after surgery. Aspirin is taken for 6 weeks after surgery. Patients with risk factors for blood clots may get a more aggressive medication like Lovenox or Xarelto for the first 3-4 weeks.
- Sometimes, after hip surgery, the muscle around the hip can form islands of bone called “Heterotopic Ossification.” To minimize this risk these muscles are injected with a prophylactic medication (Toredol) before the incision is closed in surgery, and patients take an anti-inflammatory medication (Celebrex 200 mg) 2x a day for 3 weeks (also an effective pain reliever).
- In women a “bikini line” incision that used. There are no sutures or staples to remove, and the incision is coated with a glue. The first bandage is water tight and comes down the day before or the day of discharge, and replaced with paper-based dressings which you will then apply at home for 2 weeks. You will go home with 7 of these bandages.
 - In males there may be a few sutures in the mid-portion of the incision to be removed 10 days after discharge. We can usually arranged this with a local physician or nurse closer to your home. The bandages are the same as for women.
- **Each surgery is individualized, and therefore the specific restrictions and precautions for each patient will be different for each patient.** We will spend a lot of time with you after surgery ensuring that you understand your unique protocols before you leave the hospital. Each person receives a surgery highly tailored to their hip and responds differently to surgery.



St. Thomas Midtown Nursing team. These nurses truly enjoy caring for patients after complex hip and pelvis surgery. They are specialized in orthopaedic patient care, and the floor only has patients that have had orthopaedic surgery. After PAO surgery, our patients commonly visit the hospital team when they return for follow up, and many stay in touch with their nurses after discharge.

Follow-up after surgery-returning to Nashville

Follow-up outpatient visits are necessary to monitor progress by X-ray and physical examination, and to graduate patients to the next phases of rehabilitation. The first follow-up visit is usually scheduled about 6 weeks after surgery, and the second at 3 months.

- Two weeks after discharge patients should start lying on their stomach to stretch the anterior hip muscles and scar tissue.
- At 6 weeks we will often allow a stationary bicycle without resistance and pool walking to increase mobility, without threatening the fixation and the fragment position. We will also stop all motion restrictions put in place to protect the labrum. Tissue mobilization can be started with a therapist at home.
- No active forward flexion is allowed until 10 weeks.

At 10 weeks after the surgery, the patient is allowed to be full weight bearing and work toward discontinuing use of the crutches (which usually takes 2-4 weeks). All restrictions are relieved, and patients are allowed to do whatever their muscles allow them to do. It generally takes 6 more weeks of PT to get to a state that walking without assistive devices feels “normal.”

Ultimately, your postoperative course depends on return of muscle strength. Working with a trained physical therapist adept in treating hip dysplasia is critical. These therapists will be critical in your post-surgical rehabilitation, particularly once weight-bearing is allowed after 10 weeks but as early as 6 weeks out. This will be prescribed at your first follow up visit.

You will be asked to visit us 6 weeks after surgery (or see your local surgeon who might be coordinating your care locally), again at 3 months, at 6 months, and at 1 year and 2 years for routine follow-up. After the second year, we schedule appointments at 2 year intervals.

There are several reasons that a second surgery might be necessary-from screw removal to ectopic bone removal to recurrent labral injury to bone grafting and fixation for nonunion of an osteotomy site. Approximately 50% of patients want their metal removed, for example. These topics will all be discussed during the follow-up period.

Dr. Tania Ferguson
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HIP & PELVIS SURGERY SPECIALIST