# Challenges and Solutions for Total Hip Arthroplasty in Treatment of Patients With Symptomatic Sequelae of Developmental Dysplasia of the Hip

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## Abstract

**Conditions that adversely affect a child's hip alignment, joint congruity, or articular surfaces often result in joint destruction associated with pain and motion limitation later in life. The usual culprits are developmental dysplasia of the hip (DDH), slipped capital femoral epiphysis, Legg-Calvé-Perthes disease, juvenile rheumatoid arthritis, infection, trauma, and neoplasm. In this review, we address DDH, the most common cause of secondary osteoarthritis of the hip.**

**Symptomatic sequelae of DDH present challenges for total hip arthroplasty, including excessive proximal femoral anteversion, narrowing of the medullary canal, acetabular anteversion, verticality, hypoplasia and incongruity, pseudoacetabulum, and neurovascular shortening. Presiding corrective femoral and/or acetabular osteotomies, as well as retained hardware, further complicate total hip arthroplasty. This review emphasizes evaluation of hip morphology while considering reconstructive techniques and implants.**


Developmental dysplasia of the hip (DDH) is the most common childhood hip disorder that leads to early degenerative joint disease of the hip. The arrest in development of the hip leading to DDH usually occurs during the third trimester of pregnancy. The result is that the fetal lower limbs become malpositioned in external rotation.[1] At birth, the most common abnormalities are excessive anteversion and excessive valgus angle of the femoral neck.[2] These abnormalities decrease articular surface contact area of the hip joint, which increases stress on the cartilage and results in arthritic changes. The majority of arthritic changes noted in adults with DDH occur at the anterior, posterior, and superior portions of the acetabulum.[1] Newborns diagnosed with this disorder are placed into a Pavlik harness and avoid the sequelae of DDH with a 95% success rate. If neglected, development of the femoral head and acetabulum becomes increasingly impaired with age, resulting in early onset of osteoarthritis (OA).[3] Because DDH often is neglected or treated inappropriately, it has become the most common cause of secondary OA of the hip.[4] Other factors in DDH incidence have been thoroughly studied. Jacobsen and Sonne-Holm[5] conducted a cross-sectional survey of 2,232 Danish women and 1,336 Danish men to investigate individual risk factors for hip OA. The correlation between DDH incidence and development of hip OA was statistically significant in both men and women. In 2000, Hartofilakidis and colleagues[4] reported significantly high rates of secondary OA caused by DDH. Six hundred sixty hips were examined between 1970 and 1996. Of the hips diagnosed with OA, 54% were secondary to DDH.

The natural history of neglected DDH in adults is highly variable. Disease progression is influenced by whether the disease is unilateral or bilateral; whether the hip is completely dislocated, or subluxated, or demonstrates dysplasia; and whether there is a false acetabulum. A chronically dislocated hip with a false acetabulum is usually symptomatic earlier in adulthood when compared with a chronically dislocated hip without the contact between the femoral head and the pelvis. Unilateral complete dislocations result in significant limb-length discrepancy associated with flexion-adduction deformities of the hip and secondary valgus deformities of the knee. Patients with complete dislocation of the hips usually report lower back pain and are found to have hyperlordosis of the lumbar spine.[3]

Hartofilakidis and colleagues[4] reported mean age to be 34.5 years at symptom onset for dysplastic DDH, 32.5 years for low dislocation, 31.2 years for high dislocation with a false acetabulum, and 46.4 years for high dislocation without a false acetabulum. Hip pain was the presenting symptom most commonly noted by patients regardless of classification.

Several classification schemes have been developed in an attempt to improve treatment approaches for

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DDH. The 2 most commonly used schemes are from Crowe and colleagues[6], who categorized degree of hip subluxation and Hartofilakidis and colleagues,[7] who described a classification system with 3 specific types of DDH based on position of the femoral head relative to the anatomical "true" acetabulum.

## Challenges and Solutions

Whether the condition is a complete dislocation or a dysplastic joint, decreased area of contact in the joint predictably results in debilitating, degenerative disease. Thus, it is imperative to understand the morphologic changes that the acetabulum and femur undergo when symptomatic DDH is neglected. Understanding these challenges facilitates preoperative planning by allowing the surgeon to choose the best technique or implant for each case.

As emphasized by Harris and colleagues[8] in 1977, the anatomy of the true acetabulum becomes disrupted from prolonged subluxation or dislocation of the hip secondary to DDH. Creation of a false acetabulum creates an even bigger challenge for total hip arthroplasty (THA). The bone stock of the ilium is very poor when the hip settles proximal to the true acetabulum. The soft tissues that provide secondary stability to the hip, especially the abductors, are weakened because of laxity caused by the proximally displaced joint. Because evaluation of iliac bone stock is crucial to acetabular reconstruction, advanced imaging plays a major role in preoperative planning.

Three-dimensional computed tomography (3DCT) can be very helpful in the evaluation of the complex joint morphology of the hips with degenerative disease secondary to DDH. Argenson and colleagues[9] and then Sugano and colleagues[10] used 3DCT to study the morphology of the proximal femur. They demonstrated that dysplastic proximal femurs had a narrower medullary canal and a significantly shorter distance from isthmus to lesser trochanter when compared with control femurs. The dysplastic femurs had significantly higher anteversion when compared with the controls. However, there was large variability in anteversion values (2° to 80°), which did not correlate with a particular Crowe class.

Argenson and colleagues[9] demonstrated a progressive decrease in offset of the medial femoral head with a higher Crowe classification when compared with control groups. In 1988, Gorski[11] described coxa valga as one of the commonly seen anatomical deformities presented by DDH. Robertson and colleagues[12] and Sugano and colleagues[10] demonstrated progressive coxa varus with increasing Crowe classes. Argenson and colleagues,[9] however, noted progressive coxa valga with only Crowe classes I and II when compared with controls.

The role of THA in patients with DDH has been discussed since the early 1970s. Initially, the procedure was advocated only for patients with subluxation of the hip joint as described by Charnley and Feagin.[13] Soon after, Harris and colleagues[8] recommended the procedure for both subluxated and completely dislocated hips secondary to DDH. Since then, establishing an appropriate acetabulum is the main emphasis in performing THA for both degrees of DDH. Even more important, the false acetabulum, as mentioned by Harris and colleagues, poses the biggest threat to a successful acetabulum reconstruction in patients with DDH.

Acetabular component placement has 3 main challenges: component location, fixation type, and component size. Amount of available bone stock, necessary for stability, is the main determinant of component location. The acetabular component may be placed at the false acetabulum or at the true acetabulum. The ilium becomes thinner the more proximal the femoral head is displaced from the true acetabulum, so bone stock available for acetabular shell fixation is decreased.[6,8,13]

Thus, the most secure area to affix the component would be at or near the true acetabulum.[1,6,8,13] Several challenges arise with this process. The disrupted pelvic anatomy makes it very challenging to identify the true acetabulum and to create a suitable bed for the implant.[8] Crowe and colleagues[6] established that the center of the triangle created by the anterior inferior iliac spine, the ischial tuberosity, and the obturator foramen. Their findings provided very helpful landmarks for identifying the true acetabulum. Many surgeons use autogenous structural bone graft from the resected femoral head, which allows them to increase the depth of the bed and to reinforce the anterosuperior portion of the newly created acetabulum.[6,8]

In 1996, a technique was described involving acetabular medial advancement creating a "controlled" comminuted fracture of the medial wall of the ilium, followed by supplementation with autogenous bone graft.[7,14-17] A similar technique, involving controlled perforation of the medial acetabular wall and bone grafting, has been used successfully.

With replacement of the hip joint at the site of the true acetabulum, the risk for sciatic nerve palsy becomes an issue, as the nerve is stretched. Femoral shortening of approximately 2 to 4 cm usually is needed at time of femoral preparation to avoid this complication.[1] Usually a bone segment below the level of the lesser trochanter is removed, negating the need for a greater trochanter osteotomy.[14]

On the femoral side, the most common abnormalities include excessive femoral anteversion caused by rotational deformity at the femoral diaphysis between the lesser trochanter and the isthmus, excessive valgus angle of the shorter femoral neck, and narrower and straighter canals.[2,18,19] Given these deformities, Crowe and colleagues[6] recommended a femoral stem straighter and thinner than that used for THA for primary OA. Noble and colleagues recommended using modular or specially designed femoral stems to accommodate these femoral abnormalities.[18,19] As DDH had often been treated with femoral osteotomies, many surgeons now encounter femoral deformities secondary both to DDH and those osteotomies.

In 1988, use of a modular noncemented titanium THA was introduced.[11] In the femoral component of that system, the neck and the distal stem are a single unit, and the metaphyseal sleeve is locked onto the stem with a Morse taper. A wide variety of metaphyseal sleeves and stems is available to accommodate the abnormal metaphysis and the narrow diaphysis. The ability to lock the metaphyseal sleeve in different degrees of version allows the surgeon to address the abnormal femoral anteversion in patients with DDH.[2,11,20-22]

Other modular systems combine the femoral neck and metaphysis as a single unit coupled with different distal stems to accommodate a narrow diaphysis. When this type of system is used, excessive femoral anteversion cannot be addressed without performing a derotational osteotomy distal to the junction of the neck-metaphyseal and distal stem components. Another option is use of implants with interchangeable necks that allow for placement of different versions to the neck. These implants have an oval reverse Morse taper or a round Morse taper that can be locked in different degrees of anteversion. Although this type of implant accounts for the variability of femoral neck anteversion, these stems have large proximal components that often do not fit the narrower proximal diaphysis seen in DDH. Excessive femoral valgus deformity mostly affects the metaphyseal region and can be addressed with use of stems with modular metaphyseal sleeves of different shapes and sizes to provide the best metaphyseal fit.[2]

Femoral osteotomies were developed to improve femoral head coverage, which was expected to prevent or at least slow down progression of degenerative joint disease. The 2 most common types of femoral osteotomies performed on patients with DDH are valgus and varus. The valgus osteotomy creates an excessive valgus proximal femur, and the more complex varus osteotomy displaces the greater trochanter medially. This medial displacement increases the risk for damaging the greater trochanter and the abductor muscle insertions while implanting the femoral stem. Removal of the retained hardware also can be challenging. Straight stems with distal fixations and/or stems with modular sleeves are recommended for femurs that have undergone a valgus osteotomy. Thin femoral cortex secondary to DDH may increase risk for intraoperative fracture. There is also increased risk for aseptic loosening of the thin and flexible stem.[2,11,23]

Reversing a varus osteotomy before performing THA may decrease the risks for damaging the greater trochanter and abductor muscles insertion.[2,21-23]

## THA Outcomes in DDH

Eskelinen and colleagues[24] reported on their experience with a cementless THA and placement of the cup at the true acetabulum, distal advancement of the greater trochanter, and femoral shortening osteotomy used for symptomatic patients with high DDH dislocation. They found a 19% rate of perioperative complications: several peroneal and femoral nerve palsies, 1 superior gluteal nerve palsy, 4 nondisplaced proximal femoral fractures, 1 malpositioned femoral stem causing a fracture, 1 wound infection, and 2 early dislocations. When failure of either component was defined by revision for aseptic loosening, the 10-year survival rates for the acetabular and femoral components were 94.9% and 98.4%, respectively. The results compared favorably with the performance of cemented THA components.[17]

de Jong and colleagues[25] reported on a study with a 19.5-year follow-up of DDH patients who underwent THA with a superolateral bone graft technique. Twelve percent of the acetabulum components were revised because of aseptic loosening, and 7 acetabulum components (6% from 116 hips) showed possible radiologic aseptic loosening at a mean follow-up of 14.5 years.

In 2005, Kim and Kim[26] compared the outcomes of hybrid THAs, which consisted of a press-fit acetabular component and a cemented stem, with those of THAs with cementless acetabular and femoral components. The cemented and cementless femoral stems had equivocal clinical results in hips with dysplasia, low dislocation, and high dislocation. The acetabular components demonstrated a higher rate of aseptic loosening with high dislocations compared with dysplastic and low hip dislocations. Over a 10-year period, overall incidence of aseptic loosening was 9%. The 11 hips with aseptic loosening had less than 60% coverage of the acetabulum component by the host bone. Kim and Kim recommended using bulk autogenous bone graft or allograft to ensure that the acetabulum component has more than 60% coverage.

Zhang and colleagues[27] used a circumferential acetabular medial wall displacement osteotomy to reconstruct a near true acetabulum during THA. This technique avoids bone grafting while achieving maximum host bone coverage and is contraindicated for medial walls thinner than 10 mm because the osteotomy is difficult to perform and the resulting fragment lacks strength and stability. Zhang and colleagues found no complications and reported statistically significant improvement in prosthetic hip center placement relative to the optimal center.

In 2005, Rozkydal and colleagues[28] reported results of an acetabulum reconstructive technique that used a cementless shell and a femoral head autograft to facilitate coverage. The cup was designed to match the elasticity of iliac bone in order to minimize the relative movement between the implant and bone. At 10-year follow-up, the clinical survival of the acetabular component with a revision as the endpoint was 100%, while the rate of survival of the component with radiographic signs of loosening as the endpoint was 88.2%.

Schöllner[29] created and tested a low-profile titanium cup that allowed use of a large (~38 mm) metal femoral head. The cup covered only 33% of the head. A complication rate of approximately 18% (3/17 hips) was reported with a mean follow-up of 20 months. Two of the complications were intraoperative femoral fractures, and the third was a hip dislocation. No aseptic loosening was reported.

## THA Complications in DDH

The complication rate of THA for patients with DDH is significantly higher than that of THA for patients with primary OA. Sochart and Porter[30] observed that THA for DDH resulted in revision rates 3.3 times higher, aseptic loosening rates 2.7 times higher, and postoperative infection rates 10 times higher than for other indications for THA, such as primary OA, Legg-Calvé-Perthes disease, and slipped epiphysis. The technical difficulty associated with THA for DDH leads to higher risk for implant failure, iatrogenic fractures, and soft-tissue disturbance. In addition, patients with chronic, symptomatic DDH are undergoing THA at younger ages, thus increasing the need for revisions. This demand for revisions results in further surgical difficulties and complications. Since 1977, when Harris and colleagues[8] introduced THA for symptomatic DDH, the complication rates have been variable but always significant regardless of technique or implant used. The complication rates have varied from 30% in older studies to 5% more recently. Overall, the most commonly reported complications in descending order are component aseptic loosening, deep infections, iatrogenic femur fractures, hip dislocations, sciatic nerve palsies, greater trochanter nonunions, and hip subluxations.[6,8,31-33] Harris and colleagues[8] reported a 30% complication rate, whereas Crowe and colleagues[6] reported a 19% complication rate. The major technical complications, out of 31 hips, included 1 hip dislocation, 1 hip subluxation, 1 fracture of the femoral shaft, and 1 sciatic nerve palsy. More recently, Klapach and colleagues[31] reported 28% aseptic loosening in 65 severely dysplastic hips that underwent cemented THA. In early 2006, Chougle and colleagues[32] reported a 7% complication rate in 262 hips that underwent cemented THA for DDH. The complications associated with these results were 6 deep infections, 5 sciatic nerve palsies, 4 intraoperative femoral fractures, 2 recurrent dislocations, and 2 periprosthetic fractures. Interestingly, the study found that history of previous acetabulum surgery, younger age, and accelerated polyethylene wear were the 3 factors most commonly associated with a higher rate of acetabular revision. Aseptic loosening of the acetabulum component tends to be the most common complication reported in the literature. Chougle and colleagues reported a revision rate of 87.2% for aseptic loosening of cemented acetabulum components. On the other hand, de Jong and colleagues[25] reported a lower revision rate (12%) for aseptic loosening of a cementless acetabulum component in patients who underwent THA with superolateral bone grafting. Unfortunately, the complication rates remain high and variable, despite efforts over the past 30 years to create the best technique or to find the best combination of implants to perform an ultimately successful THA on a patient with DDH.

## Conclusion

The outcomes of maltreated or neglected DDH are highly detrimental and can be debilitating for young adults. Degree of subluxation and time left untreated are the 2 main factors that contribute to severity of the sequelae of this disorder. These factors emphasize the importance of diagnosing and managing DDH appropriately. Many recent long-term studies have shown the successful use of THA for chronic or neglected DDH when compared to studies performed 30 years earlier. Most of these long-term studies have indicated that aseptic loosening is the most common cause of revisions. Acetabular components appear to loosen more often than femoral components do. Aseptic loosening of the acetabular component is the result of inadequate iliac bone stock and of malpositioned components, largely caused by abnormal shape alignment and acetabulum location. The femoral component problems are most commonly associated with malpositioning and incorrect sizing resulting from abnormal femoral neck alignment and a hypotrophic proximal femur. With the help of 3DCT, morphology of femur and acetabulum may be better delineated, thus allowing the surgeon to identify the specific challenges that may be faced during THA.

Although treating the symptomatic sequelae of DDH with THA can be challenging, THA can be very effective in improving patient quality of life. Improved long-term outcomes can be attributed to refined operative techniques, careful preoperative planning, availability of modular implants, and improved implant designs and materials.

## Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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