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REVIEW

Total hip arthroplasty in dysplasia and dislocation of the hip

John Vlamis

3rd Orthopaedic Department, Medical School, National and Kapodistrian University of Athens, General Hospital of Athens KAT, Greece

ABSTRACT

Developmental dysplasia of the hip encompasses a wide spectrum of hip pathology ranging from a shallow acetabulum to a completely dislocated "high-riding" hip. It is a common cause of secondary osteoarthritis and is the underlying diagnosis in the majority of young adults requiring total hip arthroplasty (THA) for coxarthrosis. It is clear we still do not have an agreed and correct terminology covering the entire pathology of congenital deformities of the hip. We recommend the use of the term "Dysplasia and Dislocation of the Hip (DDH)" that is by definition the most suitable term to describe the total spectrum of related deformities in adults. Various systems of classification of DDH in the adults are in use. The most practical classification seems to be that of Hartofilakidis et al. We propose a classification system of DDH in adults based on the CT of the pelvis to supplement the existing classification systems and to be used in the preoperative planning of a THA. The acetabular deficiency is classified, according to Crowe or Hartofilakidis classification, in the frontal plane based on a plain AP radiograph, and then further classified as "neutral", "anteverted" or "retroverted" in the transverse plane based on the CT scan of the pelvis. Careful attention to the morphology of the acetabulum, femur, pelvis, lumbar spine and knee in plain radiographs and CT scans in patients with DDH, is necessary, primarily to accurately classify the deformity and predict the bone deficiencies that will be encountered during THA. This will facilitate the selection of the proper reconstruction method and implants. In the present article useful surgical techniques and implants are presented for the management of these patients with a THA that presents difficulties because the majority of them are young with a considerable demand on their implants and they may require complex reconstruction on both sides of the joint.

KEYWORDS: total hip arthroplasty in developmental dysplasia of the hip, terminology of developmental dysplasia of the hip, classification of developmental dysplasia of the hip, reconstruction of the acetabulum, reconstruction of the femur

CORRESPONDING AUTHOR, GUARANTOR

John Vlamis, MD, PhD
Assistant Professor
3rd Orthopaedic Department, Medical School, National and Kapodistrian University of Athens, General Hospital of Athens KAT, Greece
2 Nikis Street, 14561, Kifissia, Athens 14561, Greece
e-mail address: Jvlamis@email.com

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Figure 1 *Classification of DDH in frontal and in transverse plane gives three-dimensional information of the hip, necessary to select the proper reconstruction method and implants. Examples of hips with (a) dysplasia, (b) low dislocation (B2 type), and (c) high dislocation (C2 type) according to Hartofilakidis classification, and (d) anteverted, (e) normal and (f) retroverted hips according to the proposed classification using CT imaging.*

Introduction

Developmental dysplasia of the hip encompasses a wide spectrum of hip pathology ranging from a shallow acetabulum to a completely dislocated "high-riding" hip. It is a common cause of secondary osteoarthritis and is the underlying diagnosis in the majority of young adults requiring total hip arthroplasty (THA) for coxarthrosis.

Hippocrates was well acquainted with this condition. In "De Articullis" he noted "Those suffer the greatest injury in whom, while still in the womb, this joint has been dislocated" and "However, it sometimes happens that an outward dislocation of both hips is found in one case from birth and in another as a result of disease". Dupuytren in 1826 wrote about the "Original or congenital displacement of the heads of the thigh-bones" when he observed some newborn infants with displacement of the head of the femur from the acetabulum [1]. Since then, the majority of authors have accepted the congenital nature of the deformity and used the term "Congenital Dislocation of the Hip" [2, 3].

Later the term "Developmental Displacement" was proposed because the disorder is of variable pathology, not always a dislocation, and even when dislocation occurs, it often happens postnatally, and therefore it is not truly congenital [4]. Many authors and the American Academy of Orthopaedic Surgeons accepted such concepts and used the term "Developmental Dysplasia of the Hip (DDH)".

Many disorders are, in that sense, developmental but the term is not used as part of the terminology.

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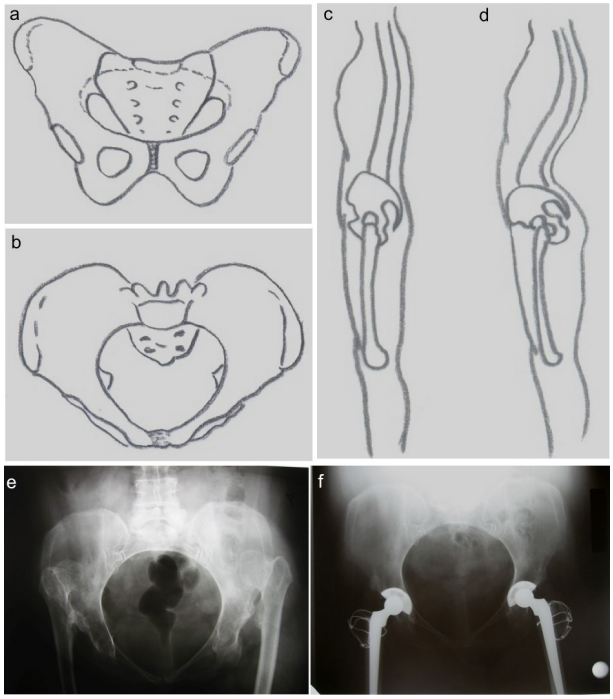

Figure 2 *In bilateral cases, the posterior shift of the femoral head increases the anterior tilt of the pelvis, which is compensated by hyperlordosis of the lumbar spine (a, c: normal; b, d: pathologic). Because of hyperlordosis, the pelvis is turned forward (d). In the plain AP radiograph, the pelvis can look like the "inlet view" (b). This structural deformity even without bony changes does not adequately improve after surgery despite the new location of the joints (e: preoperative radiograph, f: postoperative radiograph).*

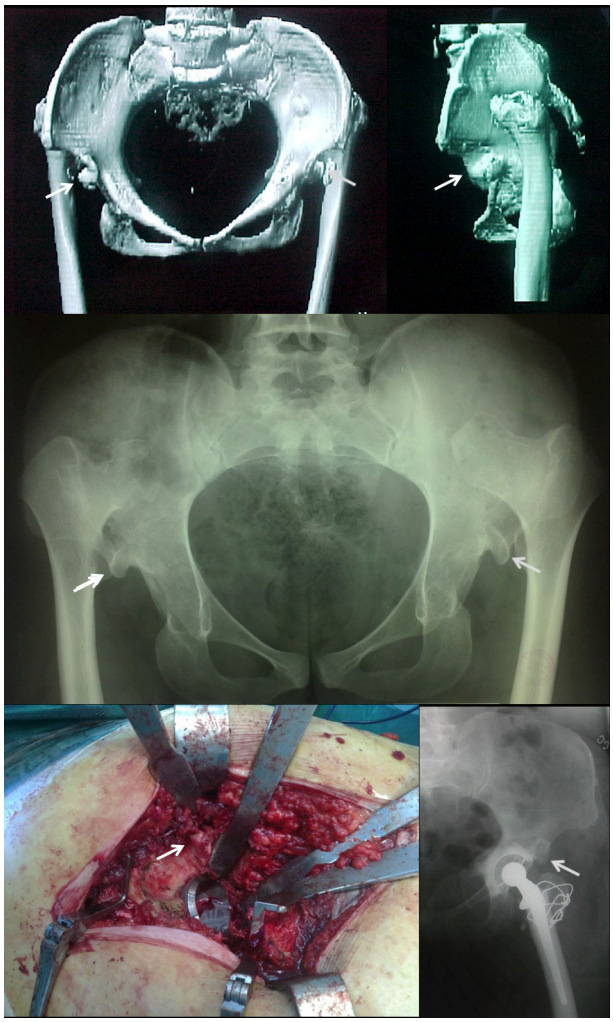

Figure 3 *As a rule, in high dislocation there is an anterolateral bony prominence beside the inferior iliac spine (arrows). This prominence in the plain AP radiograph can give the false impression of adequate bone at the weight-bearing area to achieve good coverage of the acetabulum, and in postoperative radiographs the cup can look too much medialized. This bony prominence is too anteriorly to offer any reliable anterosuperior support to the cup.*

That is why the term "Congenital Hip Disease" was recommended to substitute "Developmental Dysplasia" [5-8]. This term raised concerns because it is very general and it may include some other deformities (e.g., coxa vara, proximal femoral focal deficiency, femoral anteversion, epiphyseal dysplasia, etc.) that are also congenital hip diseases.

It is clear we still do not have an agreed and correct terminology covering the entire pathology of congenital deformities of the hip. Dysplasia by definition is an abnormality in form or development. Dysplasia comes from the ancient Greek words "δυσ-" or "dys-" meaning bad or difficult and "πλάσις" or "plasis" meaning formation. It is an ambiguous term used in pathology to refer to an abnormality of development or an epithelial anomaly of growth and differentiation (epithelial dysplasia). The terms hip dysplasia, fibrous dysplasia, renal dysplasia refer to an abnormal development at macroscopic or microscopic level. This term most commonly denotes a malformation of bone (e.g., epiphyseal dysplasia).

Development is the process of growth and

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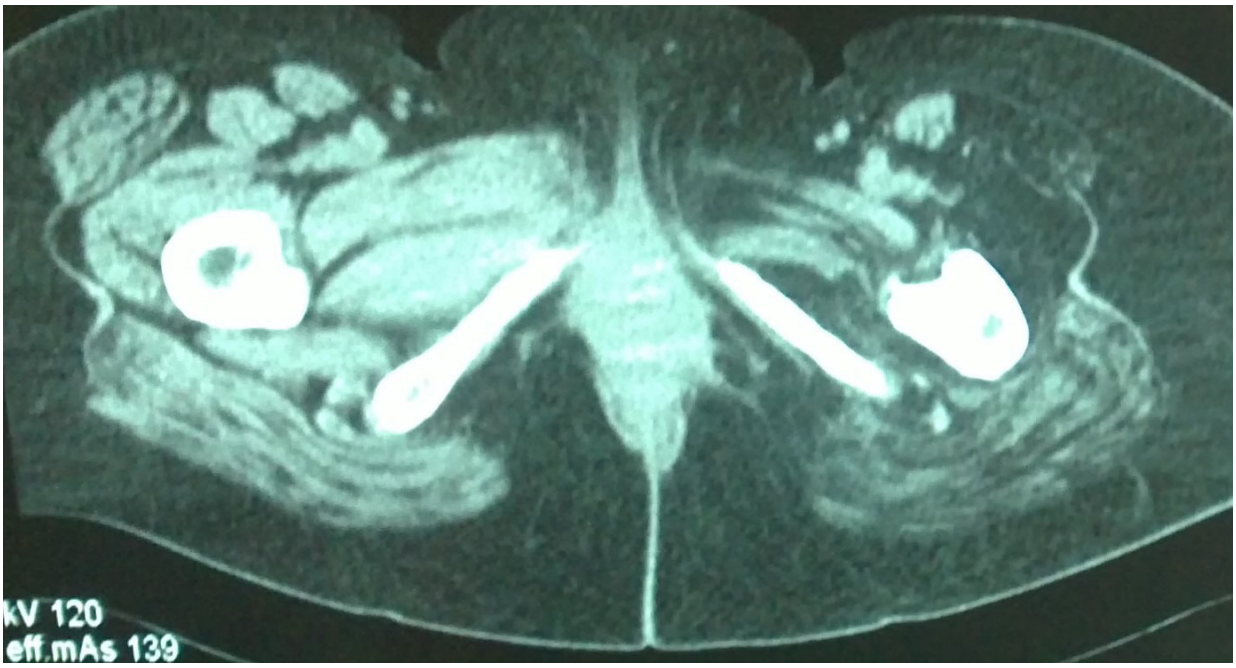

Figure 4 *The marked muscle atrophy around the left dislocated hip of this patient.*

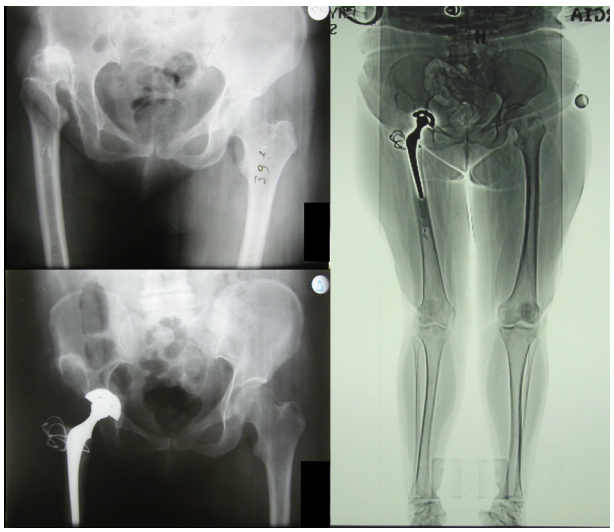

Figure 5 *In the DDH, the ipsilateral knee has valgus deformity in order to maintain the axis of the leg. When THA is performed with placement of the cup to the true acetabulum (which lies more medial than the false acetabulum) the lateralizing effect of the femoral shaft can aggravate the valgus deformity of the knee. This is even greater in cases where medial protrusio technique is used.*

differentiation. The most crucial stage of human development occurs before birth, as tissues and organs arise from differentiation of cells in the embryo. This process continues until birth, and disruptions in development result in congenital types of diseases. The developmental process continues after birth, as an infant or child grows physically. Interruptions in any of these stages can result in developmental delay or abnormality.

The term "Developmental Dysplasia of the Hip" has by definition repetition of the word development (developmental abnormality in the development of the hip). According to the above "Hip Dysplasia" could adequately describe the total spectrum of related deformities (abnormality in form or development of the hip). This term includes both the congenital and developmental nature of the disease.

However, to avoid confusion and diagnostic inaccuracies, it is preferable for the term "dysplasia" to be reserved for the milder types of hip deformities, where the femoral head is within the badly formed (dysplastic) acetabulum. Therefore, the term "Dysplasia" is not suitable for cases with dislocation.

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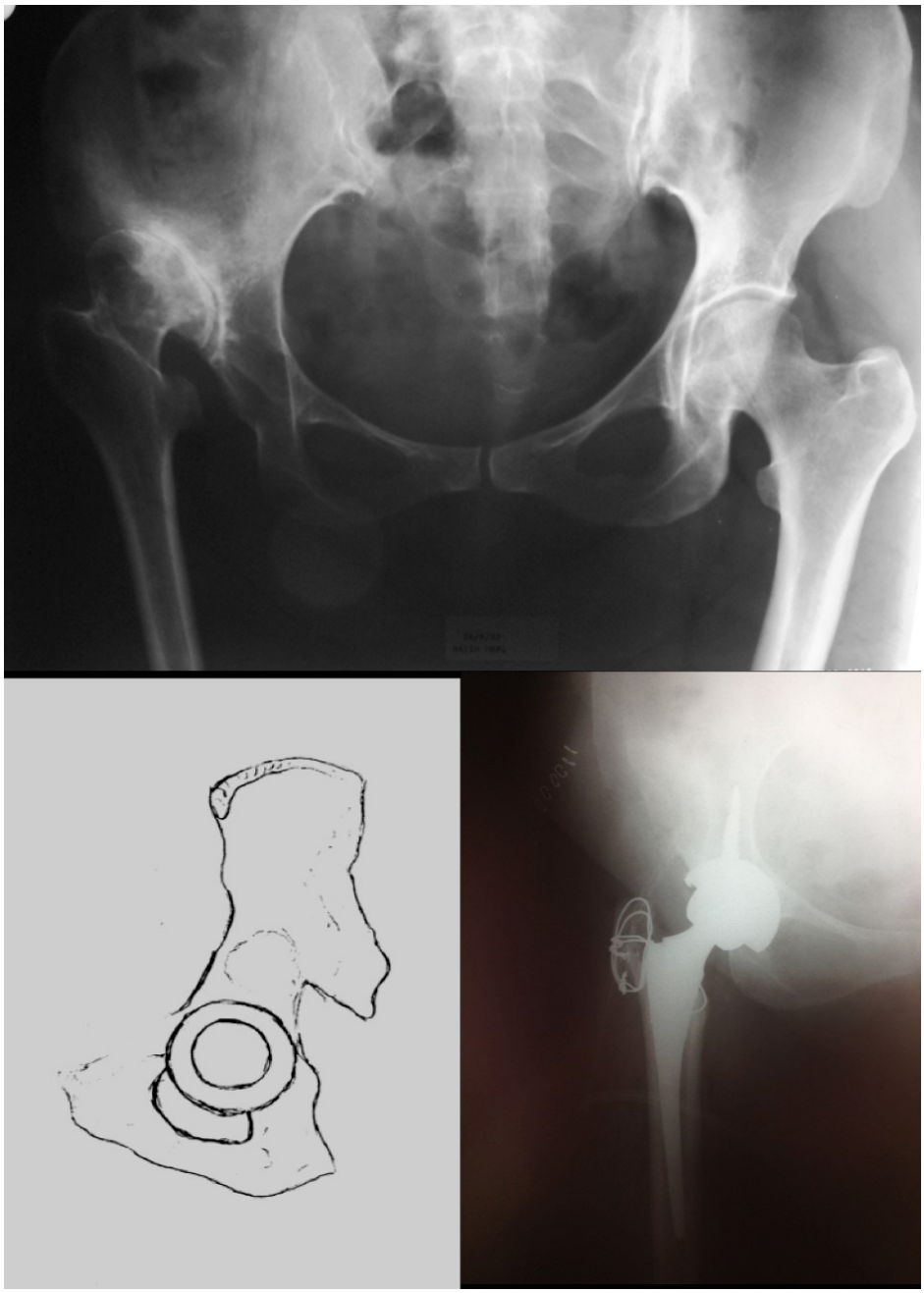

Figure 6 When the sagittal diameter of the true acetabulum is too small, the cup can be placed more inferiorly.

On the other hand, the need of a generally accepted term is obvious. It is clear that most orthopaedic surgeons will agree to use the most suitable term "Dysplasia and Dislocation of the Hip", reserving the term dysplasia for the milder types of hip deformities and then further classify the dislocated hips in low and high dislocation.

A suitable term would also be "Hip Dysplasia Disease or Syndrome". This term can cover the entire spectrum of the hip pathology of the disease in both adults and children. The term is also more suitable for authors from different specialties.

In conclusion, we recommend the use of the term "Dysplasia and Dislocation of the Hip (DDH)" that is by definition the most suitable term to describe the total spectrum of related deformities in adults

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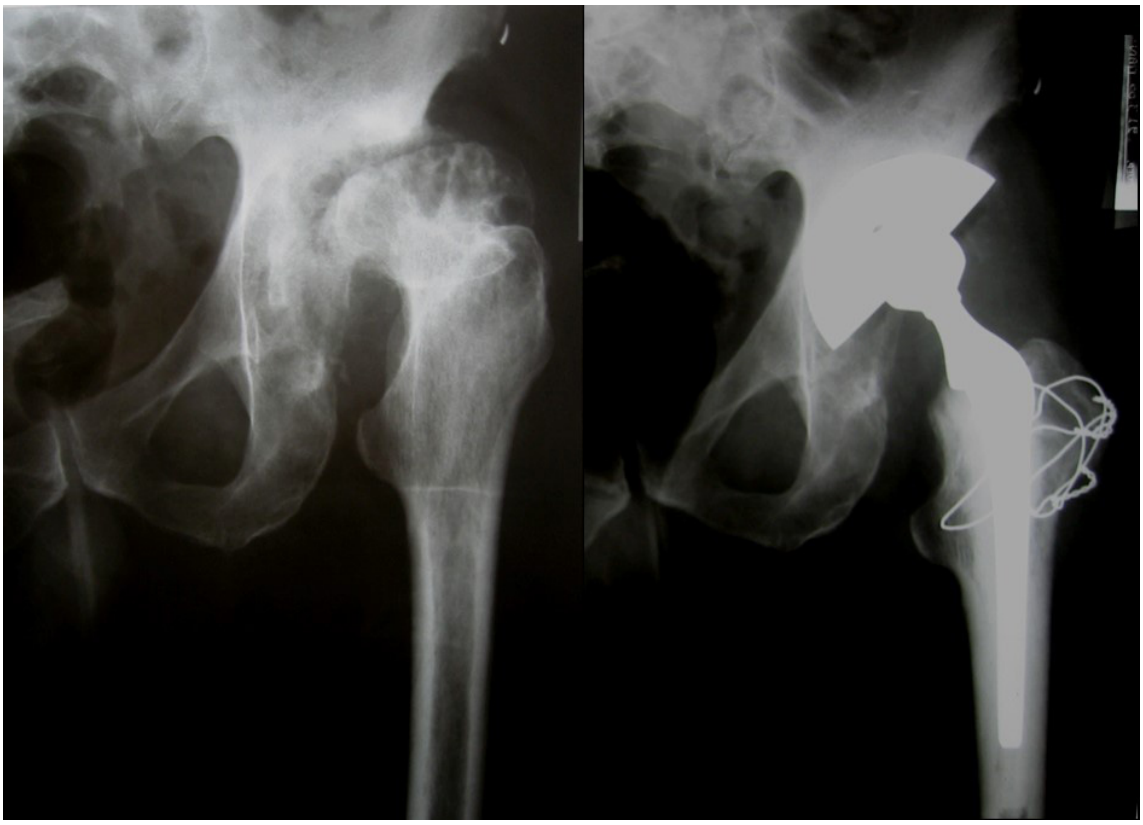

Figure 7 *Oversized hemispherical cup. This method can be used in some cases of low dislocation where there is sufficient bone stock.*

(congenital and developmental, dysplasia and dislocation) and because in addition the abbreviation is the same as the current widely used term there will be a smooth passage to the new term.

Classification

Ideally, a classification system of DDH in addition to being reliable should validly predict the intraoperatively anticipated structural bone deformities or abnormalities, and aid treatment planning. Various systems of classification of DDH in the adults are in use. The most commonly used methods for evaluating dysplastic hips are based in radiographic findings that consider mainly the shape of the pelvis and the proximal femur.

The Crowe classification [9] is based on the degree of subluxation of the femoral head in relation to the acetabulum. Crowe et al. defined a four-stage system classifying the degree of dislocation in terms of the percentage of proximal displacement of the femoral head in relation to the height of the pelvis. Type I hips are those with less than 50% subluxation. Type II hips are those with 50 - 75% subluxation. Type III hips are those with 75-100% subluxation and type IV those with greater than 100% subluxation.

Eftekcar [10, 11] also recognized four types. Type A includes hips with dysplasia in which the acetabulum is dysplastic and slightly elongated. Type B and C include those with intermediate and high dislocation. The lower border of the false acetabulum identifies the roof of the original acetabulum. Type D includes hips with old unreduced dislocation whose the head has never been in contact with the ilium.

The Kerboul system [12] uses the anteroposterior position of the femoral head to grade the severity of hip dysplasia and classifies as anterior dislocation where the femoral head is located in front of the original acetabulum, intermediate dislocation, where the femoral head articulates with the ilium

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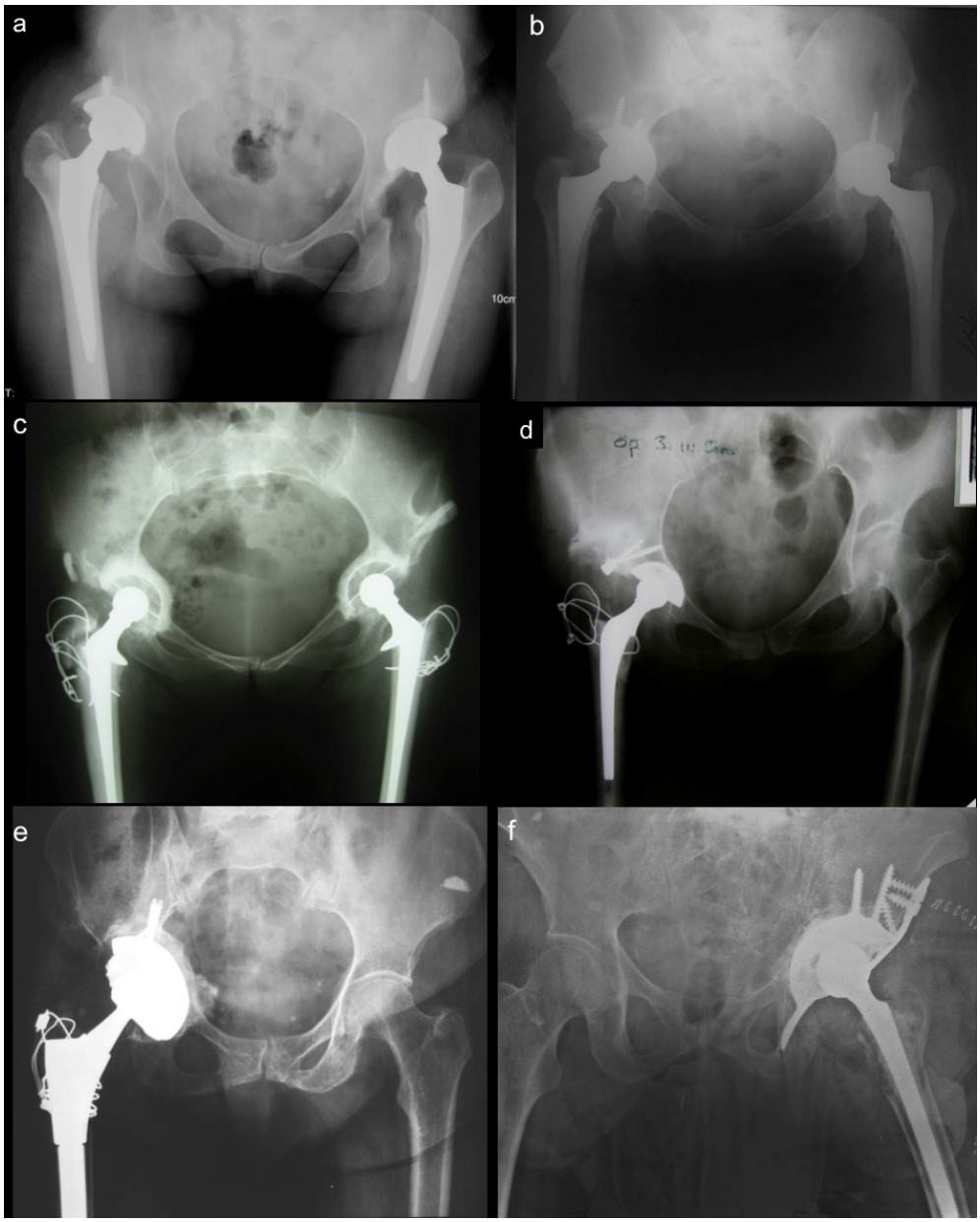

Figure 8 *Methods of acetabular reconstruction: (a) placement of the cup in the false acetabulum (lateralized position) (b) high hip centre without lateralization, (c) acetabular impaction grafting (cotyloplasty), (d) acetabular augmentation with structural graft, (e) oblong cup, (f) acetabular reinforcement rings.*

at the same anteroposterior level as the original acetabulum, and posterior dislocation where the femoral head is dislocated behind the original acetabulum.

Mendes et al. [13] and recently Gaston et al. [14] proposed a classification system for the adult dysplastic hip requiring THA.

The most practical classification seems to be that of Hartofilakidis et al. [8, 15, 16]. Hartofilakidis classification uses the pathology of the dysplastic acetabulum to classify DDH in three different types, identifying the true and the false acetabulum and the relation of the femoral head to these structures (Fig. 1). Type A hips are those with dysplasia, in which the femoral head is still within the true acetabulum. Type B hips are those with low dislocation in which

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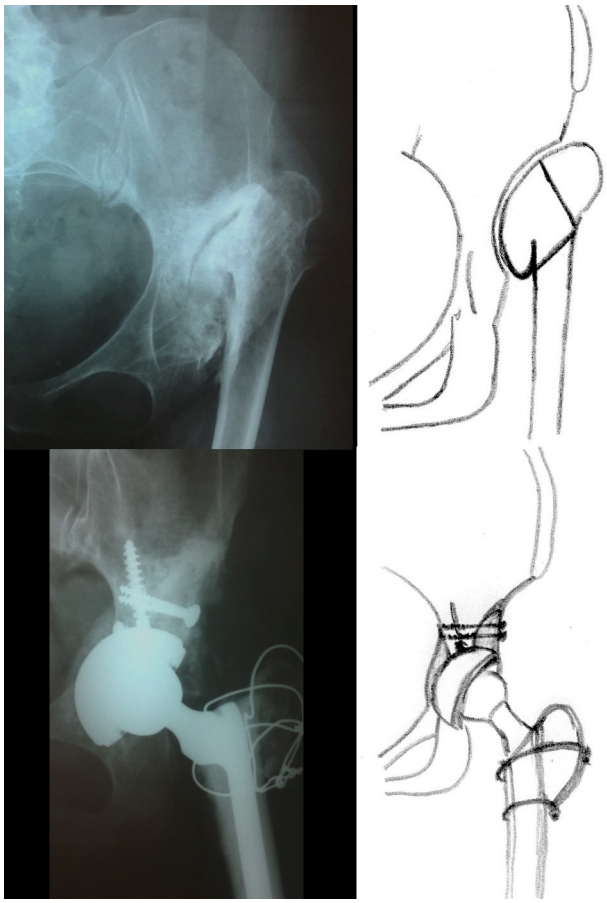

Figure 9 *Combination of cotyloplasty technique with minimal medial displacement and structural graft over the remaining uncovered acetabular component in a hip with low dislocation Hartofilakidis Type B2. Disadvantages of both techniques were avoided, and good coverage and position of the cup were achieved. The cup is not over medialized, most of the cup is in contact with host bone, and the defect that remains to be covered by the graft is less than one-third of the weight-bearing surface of the cup.*

the femoral head is in a false acetabulum, the inferior lip of which is in contact with or overlaps the true acetabulum. Type C hips are those with high dislocation, in which the false acetabulum has no contact with the true acetabulum.

Furthermore, Hartofilakidis et al. identified two subtypes of low dislocation: dislocation with extended or limited overlap between the false and the true acetabulum. When the coverage is extended (Type B1) the overlap between the false and the true acetabulum is more than 50%, and when the coverage is limited (Type B2) the overlap is less than 50%. In high dislocation, two subtypes were also identified: in Type C1, a false acetabulum is present, and in Type C2, there is no false acetabulum present and the femoral head is high-riding within the gluteal musculature.

Most of the traditional methods of analysis and classification for hip dysplasia and dislocation concentrate on a frontal-plane analysis of the hip. CT studies of the acetabular transverse plane anatomy showed that the dysplastic acetabula differ with respect to the location of dysplasia, some in the anterior position while others demonstrated just the opposite.

We proposed a classification system of DDH in adults based on the CT of the pelvis to supplement the existing classification systems and to be used in the preoperative planning of a THA [17]. The acetabular deficiency is classified, according to Crowe or Hartofilakidis classification, in the frontal plane based on a plain AP radiograph, and then further classified as "neutral", "anteverted" or "retroverted" in the transverse plane based on the CT scan of the pelvis. Hips with hypoplastic anterior wall and excessive anteversion of over 30° were classified as "anteverted". Hips, which, had a more or less normal distribution of bone stock and anteversion 0 - 30° were classified as "neutral". Hips with the bone stock located anteriorly hypoplastic posterior wall and retroversion were classified as "retroverted" (Fig. 1).

Careful attention to the morphology of the acetabulum and femur in hip radiographs and CT scan in patients with DDH is necessary, primarily to accurately classify the deformity and predict the acetabulum bone deficiencies encountered during THA and to select the proper reconstruction method and implants.

Anatomy

Acetabulum

Hartofilakidis et al. [18, 19] have described in detail the acetabular and femoral morphological variations in the whole spectrum of DDH. Dysplastic hips present a gradually increasing deficiency of the

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Figure 10 *Resection arthroplasty (Girdlestone procedure) after infection of THA for a hip with low dislocation. The reconstruction performed with the use of structural graft and cotyloplasty technique.*

superior segment and a secondary shallowing due to the formation of an osteophyte that covers the acetabular fossa. In low dislocation, the inferior part of the false acetabulum is an osteophyte that begins at the level of the superior rim of the true acetabulum. The visible part of the true acetabulum has a narrow opening, anterior and posterior segmental deficiency and inadequate depth. In high dislocation, the true acetabulum is hypoplastic and triangular in shape. It has a segmental deficiency of its entire rim, a narrow opening, inadequate depth, and excessive anteversion is usual [18, 19].

The total iliac wing can be hypoplastic, anteverted and the bone stock at the area of the acetabulum has an abnormal distribution, mainly located superoposteriorly [19]. Several CT studies of dysplastic hips have implicated increased acetabular anteversion as one component of the anatomic deformity [20-22]. Others have not found acetabular anteversion to be consistently increased [22-25]. Excessive anteversion can be attributed to the hypoplastic anterior wall, anteversion of the iliac wing or both.

Retroversion of the acetabulum was found mainly after pelvic osteotomy in a younger age or conservative treatment with plaster or traction. Anterolateral rotation, posterior deficiency of the acetabulum and inadequacy of posterior coverage was found after Salter, triple, Chiari and Bernese osteotomy [26-34] because anterolateral coverage is gained at the expense of posterior coverage, by virtue of the rotational redirection of the acetabulum. Interestingly hips, which had undergone additional femoral derotational osteotomies were associated with significantly more pronounced acetabular retroversion [35].

Femur

Even in the most mildly dysplastic hips, the femur has a smaller canal and are more anteverted in comparison with the normal. With increased subluxation, additional abnormalities are observed in the size and position of the femoral head. The size and shape of the human femur, however, vary with the gender, age, stature and ethnic background of the individual and it is difficult to isolate the effect of dysplasia on its shape. The degree of subluxation of the hip also leads to significant alterations in the shape of the femur because of profound changes in the magnitude and direction of the joint reaction forces.

In the dysplastic hip, the femoral head is initially spherical but gradually becomes elliptical and elongated, due to the formation of marginal osteophytes. The femoral neck and the diaphysis are within the range of normal anatomy. In low dislocation, the femoral head, also due to the formation of marginal osteophytes, is often large

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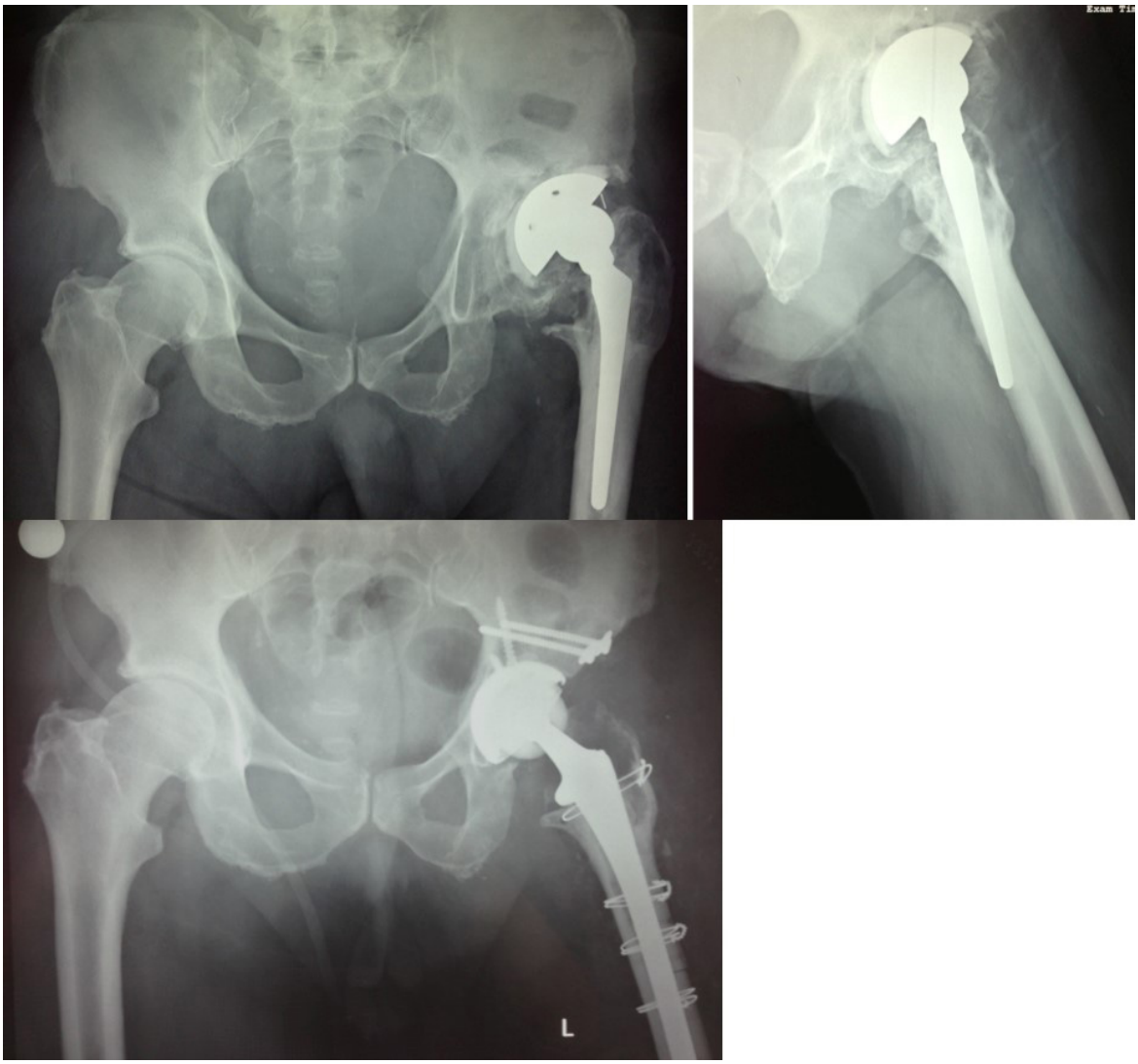

Figure 11 *Acetabular component loosening after THA for low dislocation. The acetabular component was placed in the false acetabulum. The femoral component penetrates the femur posteriorly. The revision, in this case, is difficult because of the destruction of valuable bone at the weight-bearing area. The reconstruction included the use of structural allograft for the acetabular defect and the performance of extended trochanteric osteotomy with the placement of a long stem for the femur.*

and elliptical. Occasionally, the femoral neck is anteverted, and the diaphysis is narrow. In high dislocation, the femoral head is small and non-spherical. It either articulates with a false acetabulum or moves freely within the gluteal muscles. The femoral neck always shows increased anteversion, and the lesser trochanter lies more anteriorly than normal. The diaphysis is hypoplastic with thin cortex and extreme narrowing of the canal [18, 19]. The presence or absence of a false acetabulum in high dislocated hips is associated with different loading patterns and influence the development and shape of the proximal femur. In the latter type, the deformity of the femur is greatest among all types of DDH.

It is widely believed that coxa valga is typically present in the femur of hips with DDH. However, in morphometric studies, there was no significant difference in the neck-shaft angle of dysplastic and normal femur [36, 37]. On the contrary, the mean

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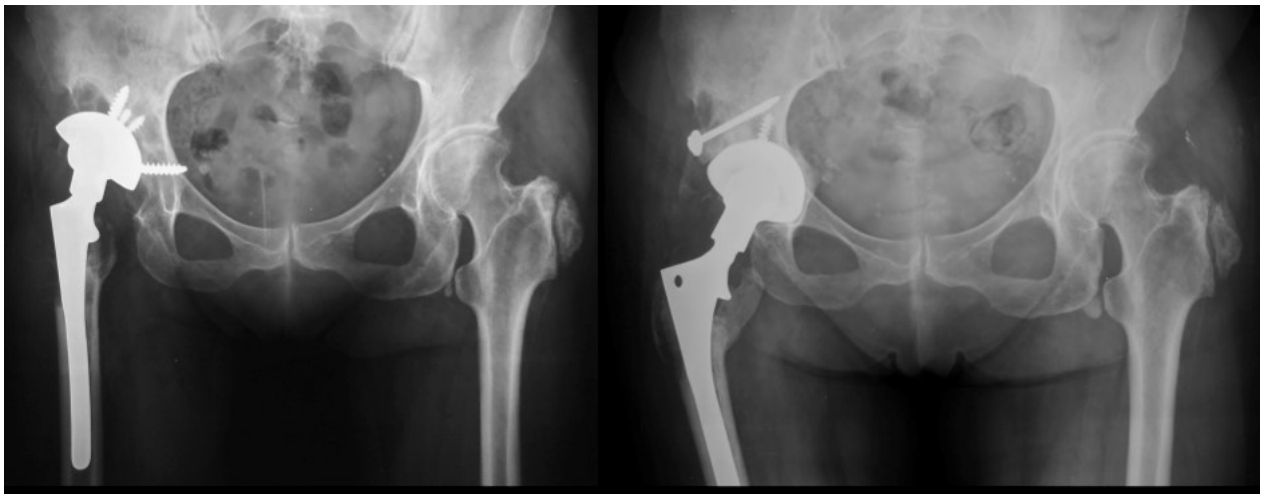

Figure 12 *Acetabular component loosening after placing the cup in the false acetabulum. The revision of these cases is difficult because of the destruction of the valuable bone during the index operation. The reconstruction performed using structural graft and cotyloplasty technique.*

inclination of the femoral neck decreased slightly with increasing severity of subluxation and therefore there were significantly more cases of coxa vara in patients with high dislocation than in the normal [36, 37]. The impression that the femur in DDH has a more valgus neck inclination is probably due to the normal effect of anteversion on the appearance of the proximal femur as projected on a standard AP radiograph. As the neck of the average DDH femur is orientated at 35° to the coronal plane, the AP radiograph gives an oblique view of the proximal femur, with significant foreshortening of the neck [36].

The length of the femur can be equal, shorter or longer than the other femur. In the unilateral cases, the femur may be longer than it is at the normal side but the leg is shorter due to the dislocation. Rarely the tibia can also be longer in unilateral cases. This is important when dealing with limb length discrepancy and when planning a shortening osteotomy.

Various studies show that the shape of the femur in DDH becomes more abnormal with increasing subluxation [36-38] The morphologic heterogeneity across the levels of hips with DDH suggests that the femoral prosthesis is difficult to be chosen based exclusively on the severity of the subluxation.

Lumbar spine and pelvis

In unilateral cases, leg length discrepancy leads to secondary scoliosis. These structural deformities of the pelvis and the spine may create a new imbalance of the hips and the posture of the trunk, especially if leg length is fully corrected. This is one of the most critical parts of the surgical treatment of these, usually young females, who consider their leg length discrepancy as their major problem and often causes considerable psychological effects.

In bilateral cases, the posterior shift of the femoral head increases the anterior tilt of the pelvis, which is compensated by hyperlordosis of the lumbar spine. Because of hyperlordosis, the pelvis is turned forward. In the plain AP radiograph, the pelvis can look like an "inlet view" (Fig. 2). Because of that, the weight-bearing area of the acetabulum is moving superoposteriorly, where the bone stock is usually located, and the gluteus medius musculature runs cephalad instead of laterally.

This structural deformity, even without bony changes, does not adequately improve after surgery despite the new balance of the joints. Appropriate modification of the socket and orientation in the functional position of the pelvis is indicated in both deformities. These deformities are also likely to cause chronic low-back pain.

As a rule, in high dislocated hips, there is

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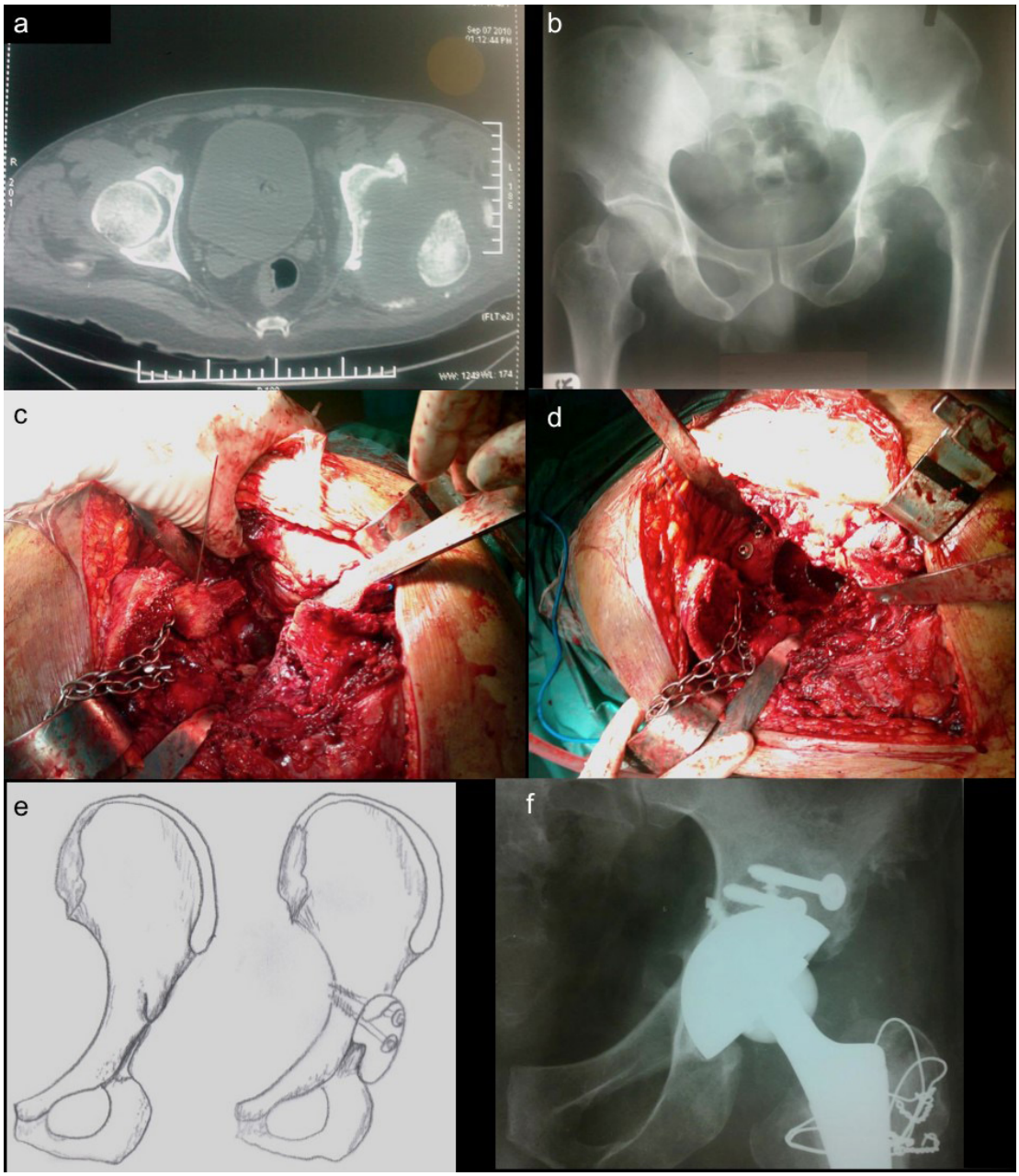

Figure 13 *(a, b) Retroverted hip. Complete absence of the posterior wall. This was the result of a fracture of the posterior wall and posterior dislocation of the femoral head that was left untreated in a younger age. (c-f) The resected femoral head and the neck segment are used for reconstruction of the posterior and upper part of the acetabulum.*

an anterolateral bony prominence beside the inferior iliac spine. This prominence in the plain AP radiographs can give the false impression of adequate bone at the weight-bearing area, and in postoperative radiographs, of a medialized position of the cup (Fig. 3). In CT studies and during surgery, it became clear that this bony prominence is too anteriorly to offer any reliable anterosuperior support to the cup. This prominence can be used as a structural graft if needed.

Soft tissue contractures

The abductor, adductor, iliopsoas, hamstrings and rectus femoris muscles are usually shortened

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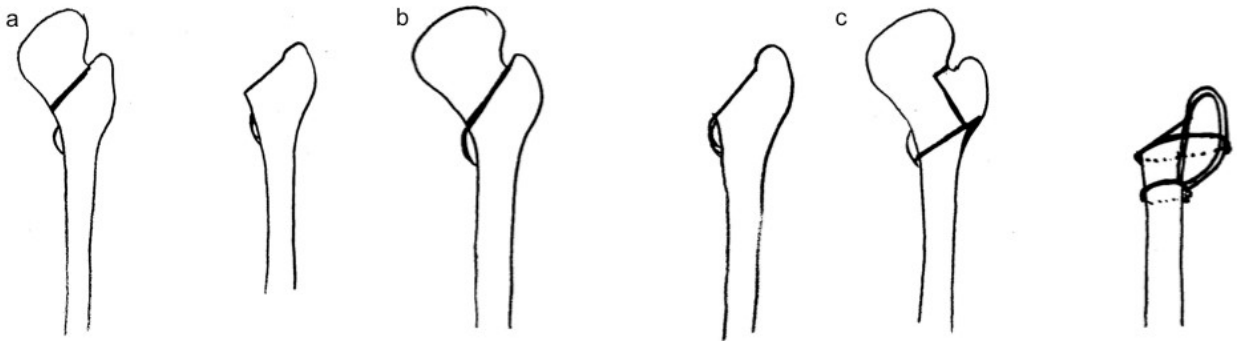

Figure 14 *The level of resection of the femur is estimated with x-ray templates. (a) In hips with dysplasia (Hartofilakidis Type A) and low dislocation (Hartofilakidis Type B1), an ordinary stem may be used. (b) If there is too much anteversion, a cut at the level of the lesser trochanter is needed to correct the version. (c) In hips with low (Hartofilakidis Type B2) and high dislocation (Hartofilakidis Type C), a transverse trochanteric osteotomy is usually required. In high dislocated hips, the femoral component must be mounted below the intertrochanteric level. At this level, the diaphysis is straight and narrow. Therefore, a small straight DDH stem is required.*

and hypoplastic (Fig. 4). The fixed contractures of the soft tissues must be released by tenotomy, fasciotomy and capsulectomy in order to perform a hip arthroplasty. Sometimes subcutaneous adductor tenotomy must be performed in order to relieve too much tension after reduction of the stem to the acetabulum. In the most difficult cases, it can be done before the limb is prepared and draped to facilitate the reduction of the hip during THA.

Knee

In DDH, the ipsilateral knee, in some cases, has an excessive valgus deformity in order to maintain the axis of the leg. When the hip arthroplasty is done with placement of the cup to the true acetabulum, which lies more medial than the false acetabulum, the lateralizing effect of the femoral shaft can aggravate the valgus deformity of the knee (Fig. 5). The valgus knee can cause adduction of the leg with the risk of dislocation. In such a case, the valgus knee should be restored with an osteotomy or a total knee replacement depending on the age of the patient and the stage of osteoarthritis of the knee.

Careful attention to the morphology of the acetabulum, femur, pelvis, lumbar spine and knee in plain radiographs and CT scans in patients with DDH, is necessary, primarily to accurately classify the deformity and predict the bone deficiencies that will be encountered during THA. This will facilitate the selection of the proper reconstruction method and implants.

Treatment

Dysplasia and dislocation of the hip (DDH) is a disorder that results in anatomic abnormalities leading to increased contact pressure in the joint and, eventually, coxarthrosis. However, many patients with DDH become symptomatic before the development of severe degenerative changes because of abnormal hip biomechanics, mild hip instability, impingement, or associated labral pathology. Several non-arthroplasty surgical treatment options are available [39].

Because in many hips the main deformity is acetabular, a reconstructive osteotomy that restores more nearly normal pelvic anatomy is preferred. The Bernese (Ganz) periacetabular osteotomy (PAO) is currently recommended because it provides satisfactory correction while creating limited secondary pelvic deformity or destabilization of the pelvis [40]. Proximal femoral osteotomy is sporadically needed as a supplement to pelvic osteotomy and may also be indicated as an isolated procedure when the dominant deformity is located on the femoral side (coxa valga subluxans). Arthroscopy can be beneficial when symptoms seem

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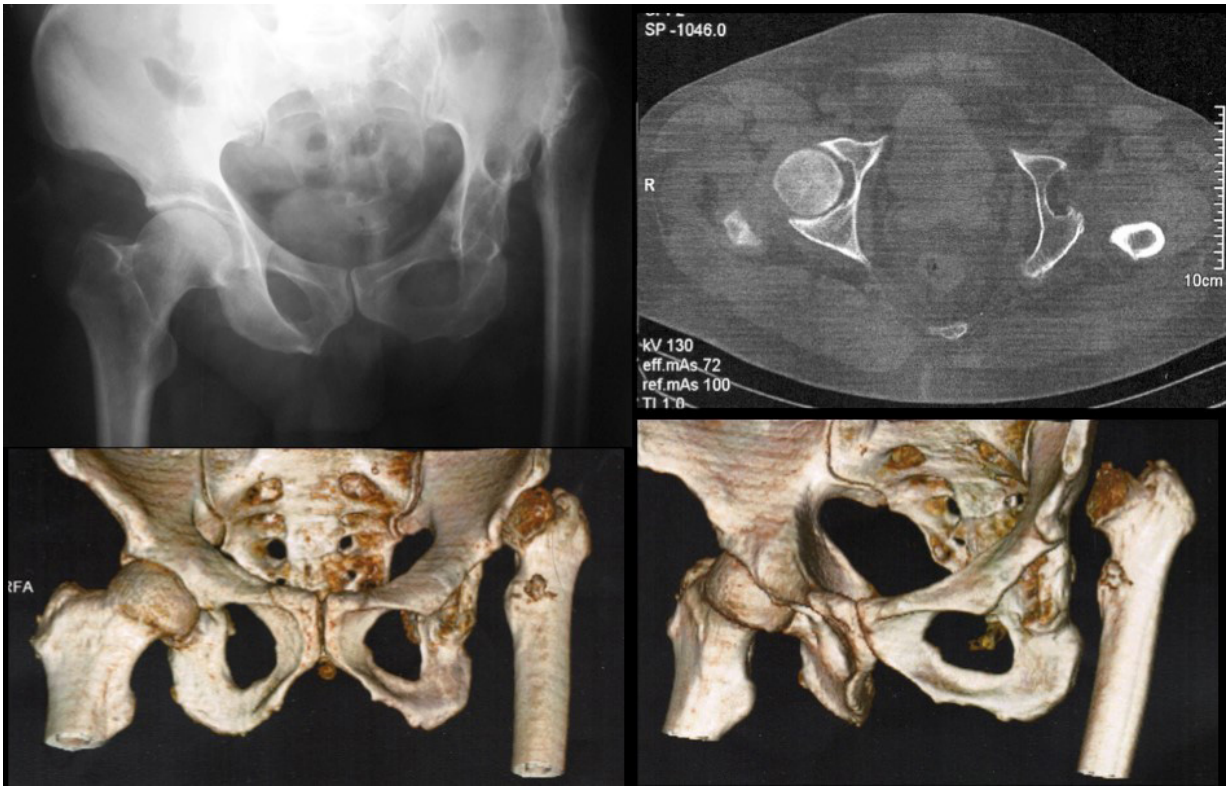

Figure 15 The use of hip radiographs and CT/3DCT scan can accurately classify the deformity and predict the acetabulum bone deficiencies in order to select the proper reconstruction method and implants according to the type of DDH.
In this case, the hip can be classified as Type C2 N (high dislocation without false acetabulum and normal anteversion). Perform transverse trochanteric osteotomy. Place the acetabular component within the true acetabulum. Small components make the procedure easier.

to be related only to labral tears or loose bodies in the absence of severe structural abnormalities of the hip. Fusion or "resection" arthroplasty are rarely indicated and are reserved for particular patients who are not candidates for total hip "replacement" arthroplasty (THA) or other procedures but who complain of intense hip pain [39].

The management of these patients with a THA presents difficulties because the majority of them are young with a considerable demand on their implants and they may require complex reconstruction on both sides of the joint.

Surgical approach

Hartofilakidis Type A and Type B1 hips can be approached through a conventional posterior, anterior or lateral approach without disturbing the greater trochanter unless the trochanter is riding high due to previous avascular necrosis of the femoral head. Under those circumstances, the surgeon may elect to perform a trochanteric osteotomy in order to advance the greater trochanter distally [41]. Hartofilakidis Type B2 and Type C hips may require a more elaborate approach in order to obtain extensive pelvic exposure and to advance the greater trochanter if indicated. A trochanteric osteotomy provides excellent pelvic exposure. It allows the surgeon to identify the false and true acetabula and, if necessary, to reconstruct the acetabulum. A trochanteric osteotomy also allows easier lengthening of the extremity [41].

A transverse osteotomy in which the vastus lateralis is dissected off the greater trochanter offers the best pelvic exposure but carries the

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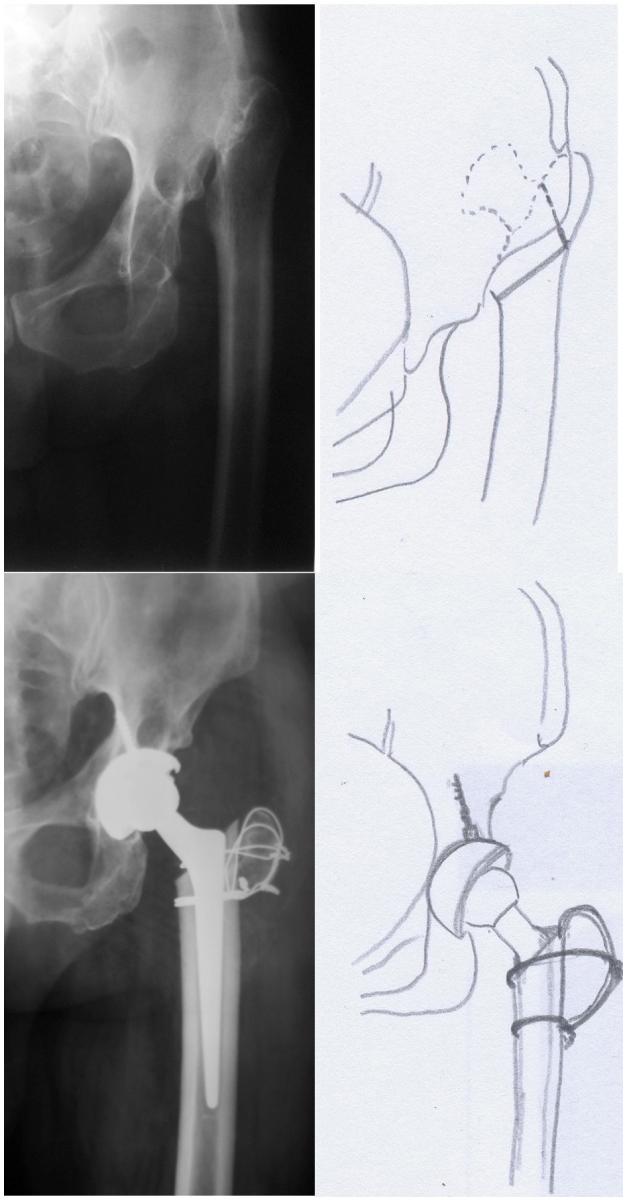

Figure 16 The same case: high dislocation Type C2 N. The level of resection of the femur was estimated just below the intertrochanteric level. At this level, the diaphysis is straight and narrow. Transverse osteotomy of the trochanter and proximal shortening of the femur were performed. Therefore, a small straight DDH stem is required. The stem was rotated to the correct anteversion. Small components and straight stem were used. No additional reconstruction method was needed.

risk of nonunion and trochanteric migration. A trochanteric slide osteotomy retains the attachment of the vastus lateralis, which protects against trochanteric migration, but the exposure is not as good as with the transverse osteotomy, and if the leg is lengthened, it is necessary to keep the trochanteric fragment long in order to ensure bone-to-bone apposition for healing [42].

A subtrochanteric osteotomy that is performed for femoral shortening and derotation can also be used for the exposure, allowing preservation of the greater trochanter while still providing good pelvic exposure for bone grafting. If a trochanteric osteotomy has already been performed, special care is needed to preserve the blood supply and muscular attachments to the femur proximal to the subtrochanteric osteotomy [43, 44].

When the hip is initially exposed, the femoral head is dislocated from the false acetabulum, and the site of the true acetabulum may not be immediately apparent. Using the thickened and elongated joint capsule as a guide can identify the true acetabulum. When the true acetabulum is exposed, a retractor is placed inferior to the transverse ligament and into the obturator foramen to ensure that the dissection has been carried far enough inferior. The depth of the acetabulum often is deceptive because it is filled with bone. Removal of the pulvinar exposes the depth of the cotyloid fossa and the medial wall of the acetabulum and allows the surgeon to determine the amount of medialization that can be accomplished by reaming. If the fossa is not apparent, a hole can be drilled, and a depth gauge is used to determine the thickness of the available bone. Absence of superior, anterior (Anteverted Hips) or posterior (Retroverted Hips) wall of the true acetabulum may be noticed at this stage of operation, and they should be developed during the reaming process.

Reconstruction of the acetabulum

The major technical difficulties encountered in a THA for DDH are during the reconstruction of the acetabulum and remains a significant challenge in modern joint reconstruction surgery. Placement of the cup depends on the amount of available bone stock and the magnitude of the limb length discrepancy and differs in the various types of

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the dislocation. Problems arise in some cases with low dislocation when the upper half of the true acetabulum is overlapped by the false acetabulum (Hartofilakidis Type B2), some cases with high dislocation (Hartofilakidis Type C), and when there is posterior wall deficiency (Retroverted hips).

Most authors recommend placement of the acetabular component within the true acetabulum. This medial and inferior location diminishes joint contact forces, facilitates limb lengthening and improves abductor function. Furthermore, fixation of the cup in the false acetabulum can be difficult because bone stock in that area, where the iliac wing is thin, is insufficient.

In cases in which the reamed acetabulum can provide osseous cover of at least 80% (as it is estimated intraoperatively) an uncemented acetabular component is preferred [19, 45]. If the sagittal diameter is too small at this level, the cup can be placed more inferiorly (Fig. 6). The size of these components is often small, and in order to avoid problems with thin polyethylene liners [46], some authors currently advocate the use of monobloc components or alternative bearing surfaces such as ceramic-on-ceramic [47]. These techniques also have the advantage of using a bigger femoral head.

Excellent clinical results have been reported using standard or oversized hemispherical cups to reconstruct the acetabulum defects in revision hip arthroplasty by converting the deficient acetabulum back into a hemisphere with an intact rim of bone [48-50]. This method can be used in some cases of low dislocation where there is sufficient bone stock (Fig. 7).

However, if the acetabular defect is large and the bone stock is insufficient; small, standard or oversized hemispherical cups might not achieve adequate stability on host bone, and alternative methods of acetabular reconstruction are necessary. Several techniques are in use such as placement of the cup in a high hip center with or without lateralization, acetabular impaction grafting (cotyloplasty), acetabular augmentation with structural graft, and the use of oblong cups or acetabular reinforcement rings (Fig. 8).

One of the most popular reconstruction methods of a deficient acetabula involves structural graft from the femoral head. The use of a bulk structural autogenous graft from the femoral head to augment the superolateral aspect of the acetabular rim was initially proposed by Harris et al. [51] and is advocated by many authors. This technique can restore the bone stock for future revision surgery, the hip center, and the limb length [52, 53]. Excellent short to mid-term results have been published [54-60], while others reported marked resorption of the graft [61] and rates of loosening as high as 46% after 12-year follow-up [49, 62].

The reason for such a high failure rate may be the abnormal distribution of stresses combined with the unfavorable long-term biological behavior of structural grafts [61, 62]. Most of these reported long-term results have been in conjunction with cemented acetabular components. Theoretically, uncemented cups may have a better outcome than cemented cups because of better transmission of forces. It is likely that the success of the graft is owed in part to the quality of the initial fixation and the accurate apposition of the graft to the pelvis.

Some authors have recommended the placement of a small socket in a high but not a lateral position (high hip center) [49, 63, 64]. Although the effect of a high hip center on the durability of the arthroplasty remains controversial, there is enough evidence for increased rates of femoral and acetabular loosening with initial acetabular cup positioning outside of the true acetabular region. Other authors have argued that isolated superior placement of the cup, without concomitant lateral displacement, is not detrimental to prosthetic component longevity. The advantage of this technique is the ability to place a cementless cup against bleeding host bone. The disadvantages are less bone stock for subsequent revision surgery, and if there is great limb length discrepancy the lengthening of the leg must be done on the femoral side and there is always a higher risk of impingement and dislocation [65-68].

There are two techniques in order to place a small cup in a protrused position. The first is to ream the floor of the true acetabular fossa (medial protrusio technique). The other is an acetabuloplasty technique which involves the

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creation of a controlled comminuted fracture of the medial wall of the acetabulum, the placement autogenous cancellous morselized bone graft on the periosteum and between the fragments, and the insertion of a cemented cup. This technique was developed by K. Stamos and was named acetabular impaction grafting or cotyloplasty [15, 16, 45]. This technique can also be used with the placement of an uncemented cup. Hartofilakidis et al reported satisfactory mid- and long-term results of the original cotyloplasty technique [16, 45]. Comparable good long-term results have been reported by other series [69-71].

Both of these techniques re-establish the hip center. The first technique has yielded good results when an uncemented cup was used but poor when a cemented cup was inserted [63]. When the hip is placed in a protruded position better coverage of the cup superiorly, and also better coverage anteriorly and posteriorly can be achieved. The medial placement of the component also reduces the abductor force needed to balance the pelvis. Care must be taken to avoid excessive medialisation because of impingement. This is aggravated even more by the valgus deformity of the knee (Fig. 5). The intentional perforation of the medial wall and associated removal of bone stock may compromise later revision procedures.

The oblong type cups provide another alternative for acetabular reconstruction. These cups have been used mainly for revision arthroplasty of the acetabulum, and they have been advocated for primary replacement in hips with low and high dislocation. The oblong cup was designed to provide implant stability on host bone and to restore the anatomic hip center [72]. The primary disadvantage associated with the use of this device for treatment of hips with DDH is not only the failure to restore bone stock but the distraction of what valuable bone stock there is. In the published short-term results, complications such as acetabular stress fracture and loosening have been reported [73, 74].

Another option for the reconstruction of the defected acetabulum in DDH is the use of bone grafts and antiprotrusio cages along with cemented polyethylene cup. Some authors advocated the use of such cages with bone graft after the good results that these cages had in cases of revision arthroplasty in comparison with the use of bone graft alone [75]. These implants require an extensive exposure in order to secure the implant's iliac and ischial extensions. The results using this technique are controversial [75-81]. We reserve these last two techniques for revision surgery of DDH in older patients.

Finally, in cases with significant bone stock deficiency superiorly, where the structural graft will support almost entirely the cup or by using the medial protrusio technique the cup must be medialized too much, the combination of medial protrusio technique with minimal medial displacement and structural graft over the remaining uncovered acetabular component can avoid the disadvantages of both techniques and get good coverage and position of the cup (Fig. 9). The cup is not over-medialized, and the most of the cup is in contact with host bone. The defect that remains to be covered by the graft must be less than one-third of the weight-bearing surface of the cup. Combination of these techniques can also be used in revision cases of DDH (Fig. 10, 11, 12).

Special attention is needed in cases of retroverted hips. Retroverted hips are usually iatrogenic and result after pelvic osteotomy. Care must be taken during the reaming process not to destroy the posterior wall. If needed the resected femoral head and neck segment is used for reconstruction (Fig. 13). Pelvic osteotomy can help THA in the adult by providing a better bone stock of the weight-bearing area. However, in cases with misdirection of the osteotomy and posterior wall deficiency, THA is even more complicated than in hips, which receive no treatment at all.

Reconstruction of the femur

Because of the anatomical abnormalities of the dysplastic femur, it is widely believed that if THA is performed using conventional designs of femoral prostheses, the centre of the femoral head will not be restored to an acceptable position. This has led to the increased use of customised prostheses and

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the emergence of implants specifically designed for DDH. Since the anatomical abnormalities present are thought to increase with the severity of the deformity of the hip, difficulty in performing joint replacement and the use of appropriate design of a femoral prosthesis may be related to the severity of the disease and its effect on the morphology of the dysplastic femur.

In dysplastic hips, and in the majority of hips with low dislocation, the reconstruction of the femur is similar to that of conventional cases. Problems arise with the more hypoplastic types of low dislocation, in hips with high dislocation, and in hips where previous femoral osteotomies have been performed.

The neck cut must be made at the level of the lesser trochanter. It is necessary because cutting the neck short decreases the degree of neck anteversion allowing for easier insertion and fitting of the femoral component. Excessive femoral anteversion can also be corrected with a straight and narrow stem, a modular femoral component, or a cemented stem that can be rotated into any degree of version. A trial reduction is then attempted after release of the iliopsoas tendon and the small external rotators. If the reduction is not possible, additional shortening of the femur is needed (Fig. 14). Additional shortening of the femur can also be needed because the femur might be longer than the other especially in the unilateral cases.

Femoral shortening can be carried out by means of subtrochanteric osteotomy [43] or by resection of more bone from the proximal part of the femur [82]. Shortening can also be achieved by distal femoral osteotomy [83]. In this way, a valgus knee can be corrected at the same time, if needed.

A subtrochanteric shortening osteotomy offers maximal bone preservation and does not require an additional incision or hardware but is associated with the potential problem of nonunion. A long stem or a modular stem may be necessary to provide stable fixation of the osteotomy site. A step-cut, oblique or chevron osteotomy, cortical struts, or a plate can be used to obtain stability at the osteotomy site [84] [85] [86] [87] [88] [89] .

A step-cut, oblique, or chevron osteotomy is technically difficult and requires adjusting the version while allowing for the configuration of the osteotomy. Special design modular femoral components are easier to use if the femoral shortening is carried out by subtrochanteric osteotomy and an uncemented stem is used.

Shortening by resection of more proximal femoral bone avoids the problems associated with osteotomy but involves the resection of metaphyseal bone, which is needed for stabilisation of the implant and osseous ingrowth. However, proximal shortening is more simple and uneventful. Though, care must be taken to keep the resection proximal enough otherwise the narrow diameter of the femoral canal more distally may become a major problem. To overcome this problem, splitting of the femur both anteriorly and posteriorly before the medullary canal is prepared and filling the splits with cancellous bone has also been proposed but specially designed femoral components with very thin straight stems are now available, and there is no need for that technique [90].

Short cementless conical distal bearing components and custom-made femoral components have also been used. If a trochanteric osteotomy was advocated, the greater trochanter must be shaped concave to fit on the proximal diaphysis of the femur and advanced distally far enough. Rarely, in very dysplastic cases, a two-level osteotomy is required to reduce the joint and equalise leg-lengths.

Sciatic and femoral nerve

Although some authors prefer lengthening of the leg with the use of external fixation prior to THA, most authors prefer lengthening at the time of surgery. Lengthening of the leg can cause sciatic nerve damage. Although the lengthening of the leg is not directly proportioned with the possibility of damage to the nerve [91, 92], if the limb is to be lengthened by more than 2 cm, it is wise to identify the nerve in order to check its tension after trial reduction is done and protect it during surgery. Excessive dissection of the nerve should be avoided because of the danger of devascularization. Some authors proposed wake-up test [93] or monitoring of the nerve with somatosensory evoked potentials [94].

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The femoral nerve can also be damaged during surgery either by too much lengthening or more often by the correction of fixed flexion deformity. Care must be taken not to damage the nerve with the anterior retractor because the nerve is sometimes too close to the anterior wall of the false acetabulum.

The postoperative position of the leg should be with the hip flexed to relax the femoral nerve and the knee flexed to relax the sciatic nerve. Stretching of both hip and knee is then done gradually. Since we have been using this technique, neuropraxia was avoided. However, in cases of neuropraxia due to lengthening of the leg after THA, patients usually recover within 6 months postoperatively.

In conclusion, careful attention to the morphology of the acetabulum and femur in hip radiographs and CT scan, accurate classification of the deformity, selection of proper reconstruction method and implants, and surgical experience are essential in order to be effective in treating this condition.

Tips and tricks

Use both hip radiographs and CT scan preoperatively to accurately classify the deformity and predict the acetabulum bone deficiencies (Fig. 15). Perform transverse trochanteric osteotomy in most cases with low and high dislocation. Placement of the acetabular component within the true acetabulum diminishes joint contact forces, facilitates limp lengthening and it improves abduactor function. The use of small components can make the procedure easier (Fig. 16). If needed, cotyloplasty technique or Harris graft, is used to achieve adequate acetabular coverage (Fig. 8, 9).

Femoral shortening can be carried out by means of subtrochanteric osteotomy or by resection of bone from the proximal part of the femur. Unless there is a femoral curve that needs correction, proximal shortening is more simple and uneventful. The level of resection of the femur is estimated with x-ray templates. In dysplastic and low dislocated hips, an ordinary stem may be used. In high dislocation, the femoral component must be mounted below the intertrochanteric level. At this level, the diaphysis is straight and narrow. Therefore, a small straight DDH stem is required. Place a wire just below the intertrochateric area for two reasons: first to avoid the periprosthetic fracture when impacting the stem because the cortex is very thin, and second to hold the tension band wire for the great trochanter reattachment (Fig. 14c). Passing the tension band wire within the medullary canal with the stem in place may be impossible because the diaphysis at this level may be too narrow.

Full correction of the leg length discrepancy is indicated only in younger patients with mobile lumbar spine. After reduction and closure, a subcutaneous adductor tenotomy is required if there is too much tension. If significant leg-lengthening has been performed, it is wise to place the patient with the hip and knee flexed postoperatively in order to relax both femoral and sciatic nerve. Stretching of both hip and knee is done gradually. In difficult cases, full weight-bearing is restricted for three to six weeks postoperatively.

Conflict of interest disclosure

The author declared no conflicts of interest.

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