Total hip replacement for developmental hip dysplasia is challenging. The anatomical deformities on the acetabular and femoral sides are difficult to predict. The Crowe classification is usually used to describe these cases—however, it is not a very helpful tool for pre-operative planning. Small acetabular components, acetabular augments, and modular femoral components should be available for all cases. Regardless of the Crowe classification, the surgeon must be prepared to perform a femoral osteotomy for shortening, or to correct rotation, and/or angulation.

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In 1986, Harris speculated that 80% of routine total hip replacements (THR) performed in women, and 15% in men, encounter some dysplasia. Certain patient populations, such as those from around the Mediterranean and Japan, have reported higher incidences of dysplasia, suggesting some genetic predisposition. Severe arthritic joints as a result of developmental dysplasia of the hip (DDH) seems to be decreasing in the more developed areas of the world, perhaps due to improved infant screening programs. With earlier treatment, most hips with DDH sustain less arthritis, which can therefore be managed with standard total hip replacements.

Bony deformity

DDH can manifest with different anatomical abnormalities, including those to the abductors and the neurovascular structures, and the acetabulum is usually shallow and small. The more the hip subluxes, the fewer loads are transmitted, resulting in soft peri-acetabular bone. The acetabulum may be relatively retroverted with or without a high centre of the hip. On the femoral side, there can be increased femoral neck anteversion, lower head centres, higher neck shaft angles, and a lower femoral offset. The greater the anteversion of the neck, the more posteriorly positioned the greater trochanter. There can be metaphyseal and diaphyseal size mismatches and small femoral intramedullary canals.

Increased surgical risks. Performance of THR in hips with these different anatomical abnormalities is difficult including an associated increased risk of sciatic and femoral nerve injuries. Trying to restore the hip centre in Crowe III and IV deformities may excessively lengthen the leg, and risk neurovascular injury. Incidences of nerve injuries vary from 0.8% to 4.5% and are usually due to traction. Local trauma or haematoma may also be a contributory factor. There is also an increase in cases that have had multiple previous procedures. Between 2.5 cm and 4.5 cm is recommended to be the amount of lengthening that can be safely achieved.

There is an increased risk for femoral fractures due to the presence of narrow femoral canals and lack of a medial calcar flare. The risk of femoral fractures is higher with use of conventional shaped femoral stems and lower with straight or modular stems.

The risk for dislocation is greater than for standard THR. Dislocation can occur as a result of component impingement from use of short femoral necks, decreased femoral offset, and small head diameters. Bony impingement can occur due to a retroverted greater trochanter impinging against the posterior acetabulum or femoral component impingement on a protruding posterior acetabular wall or ischium, when the acetabular component is medialised.

Early component loosening can occur especially when using cemented components. DiFazio et al reported a 43% incidence of acetabular component loosening at a mean of 13.3 years and Hartofilakidis et al reported a 32% incidence of loosening at a range of 15 to 33 years. Woolson and Harris reported a 15% femoral component revision rate at five years. Cementing in a small femoral
stem may make it easier to adjust anteversion. However, there is less rotational control of the distal segment of diaphyseal osteotomy unless an oblique or step-cut osteotomy is performed. Cementless fixation is now preferred by most surgeons. It is difficult to press-fit a one-piece femoral stem when there is a severe metaphyseal or diaphyseal size mismatch. Use of cementless modular femoral stems has markedly changed our ability to manage these patients as they make it easier to adjust leg length and offset. The modular proximal body can be inserted independent of the femoral neck in order to deal with increased femoral neck anteversion. Available narrow modular stems can deal with a mismatch between the larger metaphysis and narrow diaphysis, and have flutes that provide torsional stability if a femoral osteotomy is performed.

Early polyethylene wear is predicted due to frequent need to use small components that may necessitate thinner polyethylene inserts. Most of these patients are young, so a highly cross-linked polyethylene acetabular lining or ceramic or metal bearing surfaces may be preferred.

Use of the Crowe classification for pre-operative planning

When describing a DDH, most orthopaedic surgeons commonly use the Crowe classification, which is based on the amount of subluxation of the femoral head that is present. Type I has < 50% subluxation, type II has between 50% and 74% subluxation, and type III has between 75% and 99% head subluxation. Crowe type IV is completely dislocated. The usefulness of a classification comes when one can use it to predict the types of deformities that one may encounter at surgery pre-operatively, so that proper instruments and implants will be available. One might assume that a higher Crowe class designation would imply the presence of a greater deformity than with a lower Crowe category. However, contrary to what one would expect, not every anatomical abnormality gets worse as the Crowe category increases. In a CT scan study by Robertson et al., advancing disease was shown to have only poor to good correlation with increasing femoral anteversion, decreasing femoral offset, decreasing femoral neck shaft angle, and increased distance from centre of head to tip of greater trochanter. There is also a wide variability of deformities present, even in patients within the same Crowe classification. Thus, the Crowe classification is frequently not a helpful tool for pre-operative treatment planning.

Some deformities do increase with a higher Crowe classification. For example, limb length inequality does increase with the degree of femoral head subluxation. Argenson et al. reported a mean shortening in patients with Crowe I classification of 16 mm, compared with 23 mm in Crowe type II and 33 mm in types III and IV. This same study demonstrated a progressive decrease in femoral offset with a higher Crowe classification, although these deformities are readily apparent on plain radiographs. A decreased acetabular anteversion appears to correlate with increased Crowe classification. A CT analysis by Bernasek et al. showed a mean anteversion of 17° in a normal hip, 15° in Crowe type I deformities, 10° in type II, 7° in type III and 4° in type IV. This knowledge is helpful when bony landmarks are used for the positioning of acetabular components.

Some deformities do not change much with increased Crowe classification. In the CT study by Argenson et al., the acetabular anteroposterior (AP) dimension was reported to be very similar across Crowe classifications (51 mm, 53 mm and 50 mm for types I, II and III and IV, respectively). This is significant when selecting the size of an acetabular component. This same study showed that the diaphyseal canal in all dysplastic hips is narrower in the mediolateral (ML) plane than the AP, the mean being between 8 mm and 10 mm across all classes. This creates a metaphyseal/diaphyseal mismatch and therefore smaller diameter components are usually needed, and in these situations the lateral radiograph is more useful for pre-operative templating.

Many anatomic deformities have been shown by CT analysis not to correlate with increased Crowe classification. The mean acetabular volume of a normal hip in a CT study by Bernasek et al. was 22 000 mm³. Crowe type I and type IV hips had lower mean volumes (18 000 mm³ and 16 000 mm³, respectively), whereas type II and type III hips had greater mean volumes (25 000 mm³ and 23 000 mm³, respectively). Mean femoral neck shaft angles are similar to primary osteoarthritic hips in Crowe I, III, and IV deformities, but Crowe II hips have more valgus. The same study showed large variations of the femoral neck shaft angles in cases with the same Crowe classification.

Not only is there a poor correlation of deformity prediction between Crowe classes, but there also appears to be differences between ethnic groups. A CT analysis of Japanese patients shows that those with Crowe I and III dysplasia have the highest femoral neck anteversion (normal hip: 25°, Crowe I: 42°, Crowe II: 30°, Crowe III: 43°; and Crowe IV: 27°). A similar study with European patients shows that Crowe II dysplastic patients have the greatest amount of femoral anteversion (normal hips: 23°, Crowe I: 36°, Crowe II: 44°, Crowe III and IV: 38°). This study again showed that there is a large variation of up to 8° difference in femoral anteversion within each category. In order to complicate our ability to predict what deformity will be present pre-operatively, the CT study by Robertson et al demonstrated that the increased anteversion actually extends to a level below the lesser trochanter.

Surgical exposure

Posterior, direct lateral, anterolateral, and transtrochanteric surgical approaches can be used, but the first two are the most popular. The advantages of a posterior approach are that it minimises damage to abductors, provides easier access to the diaphysis if a femoral osteotomy is needed, and facilitates direct visualisation of the sciatic nerve tension if release of the gluteus maximus is needed for decompression. The advantage of the direct lateral is that it gives...
the best view of the acetabulum, and this approach perhaps has a lower dislocation risk. With a direct lateral approach, a standard vastus lateralis split can be performed for Crowe I deformities, but it is better to take the entire vastus lateralis anterior with the anterior gluteal flap if a Crowe II to IV deformity is present, in case there is a need for a femoral osteotomy. A capsulectomy can be performed in Crowe I cases, and is usually needed for Crowe II to IV hips to improve exposure and allow lengthening. It is preferred to retain 15 mm to 20 mm of the medial neck above the lesser trochanter in order to maximise proximal contact and stability of the femoral component. If a femoral osteotomy is likely to be needed, it is better to prepare the femur first. This will allow retraction of the proximal and distal femur segments separately, and ease acetabular exposure.

Principles of acetabular reconstruction
In general, the goal of reconstruction of the acetabulum in hips with DDH is to try and restore the hip centre as close as possible to normal. Since most hips will have some degree of loss of the superior acetabulum, placing the acetabular component slightly more proximal will usually provide some superior coverage. But since the ilium becomes narrower as one goes more proximal to the superior acetabulum, the advantage of proximal acetabular component positioning eventually diminishes. If the acetabular component is placed more than 15 mm above the hip centre, there is a higher incidence of component loosening.15 Medialising the cup slightly through the medial wall may help to provide superior coverage. If proximal support is still lacking, a bulk allograft or a metal augment should be considered.

The first step in the acetabular preparation is to identify the inferior acetabulum at the distal cotyloid notch or transverse acetabular ligament. Ream medially with a small diameter reamer at the level of true acetabulum down to medial wall. Expand the reaming to contact the anterior and posterior acetabular walls. Consider further reaming to improve proximal coverage, even if it means sacrificing some anterior or medial wall. One’s goal is to obtain at least 80% proximal coverage. Be careful as over reaming may become counter-productive.

Acetabular reconstruction in Crowe I and II lesions is usually not that difficult. The acetabular component can usually be placed near the true acetabulum with at least 80% proximal coverage. Figure 1 shows a Crowe I acetabular defect with minimal superior lateral erosion. This is easily managed with just a slightly higher positioned acetabular component. A Crowe II defect, as shown in Figure 2, has more femoral head subluxation and a little bit more proximalateral bone loss. This can be managed by placing the acetabular component more proximally.

Crowe III acetabular defects usually necessitate utilising other techniques to obtain component coverage such as medialisation and/or using smaller acetabular components. These are the cases that may require the use of a bulk graft or metal augment. Figure 3 shows such a case managed with a bulk bone graft.

Crowe IV acetabular defects are somewhat easier to manage. The anatomic acetabulum has minimal proximal erosion as the femoral head was not located within the true acetabulum. In this situation, a smaller diameter acetabular component is placed in the true acetabulum. The Crowe IV hips present more of a problem on the femoral side, where an osteotomy is always required. One should not succumb to the temptation to put the acetabular component high in the false acetabulum, as shown in Figure 4. Lack of good circumferential bone support in the false acetabulum usually results in earlier component loosening.

Principles of femoral reconstruction
The surgeon must be prepared to perform a femoral diaphyseal osteotomy regardless of the Crowe classification of
the deformity. A rotational osteotomy may be required for Crowe II deformities and a shortening and rotational osteotomy is likely for type III and IV deformities. Occasionally even in Crowe I if there is a very proximal femoral bow, the smallest stem reamer may not pass without risk of penetrating the anterior diaphyseal cortex and necessitates an extension femoral diaphyseal osteotomy Pre-operative templating of the lateral femoral view may pre-empt this risk.

When preparing the femur, the femoral canal should be reamed first to obtain diaphyseal contact over 2 cm to 3 cm of length. The next step is to ream and broach the femoral metaphysis irrespective of rotation, in order to obtain the best fill and stability for the modular proximal sleeves. We recommend applying a circlage wire proximal to lesser trochanter if bone quality is poor. The trial proximal sleeve is then inserted, followed by the modular femoral neck/stem implant in 10° to 15° of femoral anteversion, following which a trial reduction is performed.

If the hip in not quite reduced, minor soft-tissue releases can be tried, such as resecting the iliopsoas tendon from lesser trochanter, the rectus femoris from anterior superior iliac spine, gluteus maximus tendon from the femur, or an adductor tenotomy. If the hip is still irreducible, a shortening femoral osteotomy will be necessary.

If the hip can be reduced, it is then manipulated through the expected normal range of movement. If impingement of the greater trochanter on the posterior acetabulum or ischium occurs in extension with minimal external rotation, the surgeon has two options. Either one can increase the femoral stem offset or more likely, a femoral rotational osteotomy will be required.

The technique for a rotational or shortening osteotomy is firstly to ream and broach the intact femur before performing the osteotomy. The osteotomy is placed in the subtrochanteric area about a centimetre below the distal end of the femoral sleeve. If the osteotomy is too proximal, the
femur can split when inserting the proximal sleeve. A transverse osteotomy can be used if good diaphyseal stability from the flutes on the stem is expected. This is much easier to orientate. An oblique osteotomy is performed if diaphyseal contact is questionable and in this situation an oblique osteotomy is made from lateral proximal to distal medial. After the osteotomy is performed, check to see that the stem will still have good diaphyseal stability. If the initial reamer was crossing the canal, the diaphysis may have to be reamed more. The proximal sleeve is inserted in the proximal fragment and the femoral stem is inserted with the proximal femur appropriately rotated. The hip is reduced. Traction is applied to the leg and the level of the proximal femur is marked on the overlapped diaphysis. In the case of an oblique osteotomy, the proximal and distal fragments are held in the appropriate rotation and the distal fragment is marked with a line parallel to the proximal oblique osteotomy line. The osteotomy is then made along the mark on the overlapped diaphyseal bone fragment. Circlage wires should be considered for the metaphyseal segment proximal to the lesser trochanter, and at the proximal end of the diaphyseal segment if the bone is thin in order to prevent vertical fractures. The two fragments are opposed in the desired rotation and the femoral stem is inserted with appropriate anteversion. If an oblique osteotomy was performed, a cerclage wire is placed around the osteotomy (Fig. 5).

**Post-operative management**

Between 10kg and 50% weight-bearing is initially allowed depending on the initial stability of the acetabular and femoral components. If a femoral osteotomy was not performed, a walking stick is encouraged at six weeks, and used until there is a negative trendelenburg gait. If a femoral osteotomy was performed, crutches or a walking frame...
with 10 kg weight bearing is used for six weeks, followed by 50% weight bearing until osteotomy healing is noted radiologically.

Our experience
The authors reported the Florida Orthopaedic Institute’s experience with DDH requiring femoral osteotomies.14 There were 23 cases with four Crowe I, three Crowe II, five Crowe III, and 11 Crowe IV deformities. This demonstrates that femoral osteotomies can be required through all Crowe classes. There was a five- to 14-year follow-up, with a mean age of 43 years. Hemispherical acetabular components with supplementary screw fixation were used. Of these five cases needed proximolateral structural acetabular allografts, all performed early in the series. In most cases we made use of small acetabular components, ranging from 40 mm to 55 mm in diameter with a mean of 46 mm, placed at or slightly through the medial wall. Three-piece modular femoral stems were used in all cases.

The femoral osteotomy resections ranged from 12 mm to 77 mm, with an average of 32 mm. All osteotomies healed. There were four dislocations (17%), and all were successfully managed without revising any components. Two were reduced closed and two required open reductions. There were no neurovascular injuries with a mean lengthening of 1.4 cm, and there were no femoral component revisions. One acetabular component was revised for loosening – it was a manufacturer’s recalled component. Three acetabular liners were revised for wear, and of these two were very small components with only 4.7 mm polyethylene thickness. Excluding revision for the recalled acetabular component, our series of DDH patients treated with a femoral osteotomy have an 80% ten-year survivorship.

Summary
When preparing to perform a THR for a DDH, the Crowe classification can be useful to classify the anatomical deformity. However the Crowe classification is usually not very helpful in predicting which anatomical defect that will be present, and the type of surgical reconstruction required. The surgeon needs to come to surgery with this degree of complexity well prepared, especially in terms of smaller acetabular components, acetabular augments for Crowe III deformities, and modular fluted stems for all. One must always be prepared to perform a femoral osteotomy as it is difficult to predict whether this procedure will be required.

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References