Techniques for DDH Cup and Femur

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INDICATIONS
Total hip replacement (THR) in the setting of developmental dysplasia of the hip (DDH) is indicated in symptomatic patients after failed conservative and nonarthroplasty options. Patients are counseled regarding pros and cons of the procedure.

CONTRAINDICATIONS
Severe neuromuscular disorders and inability for patients to follow postoperative rehabilitation are relative contraindications for any THR procedure. Absolute contraindications include active infection and neurovascular dysfunction precluding a satisfactory result.

PREOPERATIVE PREPARATION
THR in DDH involves detailed evaluation and preparation of patients including adequate history, physical examination, and relevant investigations. The purpose of this evaluation is to determine whether the patient is an appropriate candidate for surgical intervention.
HISTORY

History taking should adequately elucidate the patient’s main presenting symptoms. The impact of pain and stiffness on daily and recreational activities and relevant past medical and surgical history should be investigated. It is important to document any childhood hip disorders, previous hip surgeries (open/closed hip reductions and femoral or pelvic osteotomies), prior surgical complications (especially prior infection), as well as relevant medications and allergies. Consultation and collaboration with internal medicine or anesthesia colleagues should be undertaken prior to surgery.

EXAMINATION

A thorough examination should be undertaken including general patient features such as spinal deformity, gait analysis, hip range of motion and strength evaluation (making note particularly of any abductor weakness), and leg length discrepancy. Leg length discrepancy should be accurately measured using a tape measure and confirmed with blocks under the short limb. In addition, the neurovascular status of the limb, with particular attention to the sciatic nerve function, should be well documented. The hip should be examined for prior surgical scars, range of motion, and fixed deformities. Surgeries to the contralateral limb (e.g., epiphysiodesis) should also be noted.

INVESTIGATION

Every patient should be investigated with plain radiographs of anteroposterior (AP) projection pelvis and lateral x-rays of the involved hip. Radiographs should take into account the magnification of the images and be reviewed to look for deformities around the hip joint.

Although each DDH patient presents with varying degrees of deformities, the acetabulum is usually characterized by deficiencies in the anterior column and superior dome. Similarly, the common deformities of the proximal femur are increased anteversion, a metaphyseal/diaphyseal mismatch with a relatively reduced intramedullary canal size, and coxa valga. Special attention should be taken of thin cortical diameters, which combined with smaller canal width make the femur prone to intraoperative fractures.

The hip can be classified according to the Crowe classification (1). This system radiographically divides dysplastic hips into four categories based on the extent of proximal migration of the femoral head compared to the contralateral normal head (Table 19-1).

In addition to the radiographic assessment, adequate blood work and urinary cultures should be carried out to prepare patients for surgical intervention. Computed tomography (CT) scans are not usually required; however, they can be used to accurately define femoral anteversion and acetabular bone stock.

<table>
<thead>
<tr>
<th>Type</th>
<th>Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crowe I</td>
<td>Proximal migration of the head-neck junction from the ilioischial line of &lt; 50% of the vertical diameter of the femoral head</td>
</tr>
<tr>
<td>Crowe II</td>
<td>Proximal migration of 50% to 75% of femoral head diameter</td>
</tr>
<tr>
<td>Crowe III</td>
<td>75% to 100% of proximal migration</td>
</tr>
<tr>
<td>Crowe IV</td>
<td>&gt;100% of proximal migration</td>
</tr>
</tbody>
</table>

Surgery

Approach

Anterolateral, direct lateral, and posterior approaches can all be utilized for THR. However, for increased postoperative stability, the anterolateral approach is the preferred approach by this author. A posterior approach is recommended if the deformity is very severe and sciatic nerve monitoring is anticipated.

Position

The patient is positioned in the lateral decubitus position on a radiolucent table, with the affected side up. The underlying leg is flexed to reduce the degree of lumbar lordosis and secured in such a way as to allow leg length assessment during surgery through palpation of both heels and knees. All bony prominences are protected and the trunk and pelvis appropriately stabilized. The pelvis is squared and adequately secured with bolsters.
Incision

A longitudinal incision is centered over the greater trochanter (GT), 4 cm proximal to and 6 cm distal to the GT, in line with the midshaft of the femur. Dissection is carried down to the fascia lata, and fat is swept away both anteriorly and posteriorly.

Deep Dissection

Using the GT as a landmark, the iliobial band is incised beginning at the GT and extended distally. An index finger is then inserted under the fascia lata to separate it from the underlying tensor fascia lata fascia and the gluteus maximus fascia proximally. This internervous plane is utilized to dissect the fascia lata.

The dissected fascia lata layers are retracted using Charnley retractors, ensuring the sciatic nerve is not caught with posterior retractor. An abductor split is made at the level of GT 2/3 and 1/3 junction. The dissection is curved anteriorly over the GT and headed toward the vastus lateralis leaving a thick cuff of tissue over the GT for satisfactory closure later. The abductor muscles are lifted anteriorly off the GT and distally from the proximal femur.

The gluteus minimus is identified proximally after dissection through gluteus medius. A layer of fat helps to identify this layer. This fat layer is swept away, and an incision is made in this minimus layer in line with the neck toward the superior rim of the acetabulum. This dissection is connected distally to the gluteus medius dissection at the GT. The whole anterior layer of the capsule and muscles are dissected off the femoral neck to the level of the lesser trochanter. All the soft tissues are removed proximally and distally around the femoral head and neck to ensure femoral head dislocation.

Prior to dislocation, a leg length/offset guide is used to determine baseline measurements. A long Steinmann pin is inserted over the iliac crest, and a mark is made over GT with a Bovie and a marking pen. The offset guide is used to measure the length and limb offset from the iliac crest pin to this mark and fixed to compare the length and offset later.

Dislocation of the femoral head is then performed after ensuring adequate release of the capsule up to the acetabulum and proximal femoral neck. The femoral neck is cut as per preoperative templating, usually about 1 cm above the lesser trochanter. This neck cut can vary in dysplastic patients dependent upon reconstructive plans and proposed femoral component selection. The remainder of the surgery depends on the severity of the dysplasia and the deformities seen (Table 19-2).

### TABLE 19-2 Summary of Surgical Options as per Crowe Classification

<table>
<thead>
<tr>
<th>Type</th>
<th>Acetabulum: minor superolateral defect</th>
<th>Surgical Options Acetabulum</th>
<th>Surgical Options Femur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crowe I</td>
<td>Uncemented cup in true acetabulum</td>
<td>Narrow cemented or uncemented stem, based on patients age, bone quality, and bone geometry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medialization of the cup</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No bone graft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crowe II and III</td>
<td>May require small uncemented cup with superior bone graft or augment</td>
<td>As above</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medialization of the cup</td>
<td>May require modular stem</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High hip center</td>
<td>May require femoral shortening</td>
<td></td>
</tr>
<tr>
<td>Crowe IV</td>
<td>Small uncemented cup in anatomic center</td>
<td>Usually requires modular implant and femoral shortening</td>
<td></td>
</tr>
</tbody>
</table>

CROWE I

Acetabulum

The acetabulum is exposed using three Hohmann retractors: anteriorly at around the 3 o’clock position, posteriorly around 8 o’clock, and inferiorly around 6 o’clock (for a right hip). The inferior retractor is placed last after dissection down to the capsule, ensuring no dissection into the psoas tendon. A blunt Hohmann retractor is used with a sponge through a proximal hole, which is then tied around the Charnley retractor and snapped on to the leg drape. Further retractors may need to be placed superiorly to expose acetabulum.

All labrum is excised using a long handle knife, ensuring the knife is inside the acetabulum. Soft tissues from the floor are excised using diathermy.
Reaming is started with a small reamer to identify the true floor. This author’s preference is to begin with a reamer 6 mm less than the templated final acetabular component size. Progressive reaming is performed with larger reamers up to the largest reamer that produces adequate purchase of acetabular wall and bleeding subchondral bone. It is usually under reamed by 1 mm. An adequate fit is usually possible with a standard uncemented acetabular component. If the acetabulum is shallow, slight medialization of the cup (described below) may be required. Additional screw fixation may also be required for augmentation.

In a Crowe type 1 defect, there is minimal host acetabular bone stock loss. This is seen primarily superiorly and perhaps in the anterior wall. For these minimal defects, the acetabular preparation and component selection is essentially as it is for a standard total hip arthroplasty. Once the acetabular component is placed, there may be slight component uncoverage superiorly. In a Crowe 1 defect, bone grafting is not normally required.

Depending on individual preference, a trial cup and liner or a definite cup and trial liner can be placed. If placing a definite cup, it is advisable not to place screws until the final trial has been performed after preparing the femur. Placing screws will compromise changing the cup position later if required.

**Femur**

The femoral deformity associated with a Crowe 1 acetabulum is usually minimal and as such a standard preparation with a conventional press-fit stem is usually performed. A curved Woody retractor is placed under the GT to deliver the proximal femur out of the wound. The leg is then placed in a sterile bag.

Adequate exposure of the proximal femur is obtained by placing another sharp Hohmann retractor over the posterior calcar to retract the abductor muscles posteriorly. The proximal femoral canal is opened using a box chisel. The distal femoral canal is opened using a Wagner gouge. The femur is progressively reamed distally with straight reamers until adequate cortical purchase is obtained. Proximal preparation is then performed using broaches to the templated size and/or until a good press fit fixation is achieved. Then, the femur is prepared for trial reduction with trial implants.

**Trial Reduction**

The incidence of hip instability is greater in DDH cases compared to standard THRs, and as such, often the largest femoral head diameter available is used. That being said, this needs to be balanced against the risks associated with thinner polyethylene and the fact that many of these patients are younger than seen in a more conventional series. Additionally, the sockets themselves are commonly of smaller diameters in these dysplastic cases. Therefore, the surgeon is often using a 28 or 32 mm bearing diameter.

A trial reduction is performed checking for impingement, stability, and leg length and offset restoration. Definitive implants are then placed.

**Closure**

The closure is performed in layers. First the capsule is closed with thick absorbable sutures. This is followed by progressive closure of abductor layers, fascia lata, and subcutaneous tissues. The skin is usually closed with staples. A drain is not required.

**CROWE II, III**

The superolateral acetabular deficiency present in these cases prevents simply placing a standard hemispherical shell without further consideration. These hips are the most challenging for reconstruction. Special components including extra small cups and metal augments may be necessary to address inadequate osseous coverage of the acetabulum. The acetabular deficiency can be addressed using one of several methods:

1. Acetabular reconstruction at the anatomic hip center with possible augmentation using femoral head autograft or metal augmentation.
2. Medialization of the anatomic hip joint to obtain sufficient lateral coverage.
3. Acetabular reconstruction at a high hip center in a false acetabulum (not recommended).

**Femoral Head Autograft**

This technique originally described by Harris et al. (2) involves using a femoral head autograft to reconstruct a superior defect. After exposure of the acetabulum, the superior bone defect is prepared by reflecting glutaeus medius and minimus muscles as required. The underlying lateral cortex of ilium is then scored. The femoral head autograft is then decorticated and adequate fit on the ilium is determined. This is then temporarily fixed with 2 K wires.
The GT of the femur is then brought down to ensure that abductors are not shortened. The thickness of the graft may have to be reduced in that case. The graft is then secured with two or three screws. The acetabulum is then reamed with reamers to shape the graft into the final size. The trial and implantation of the cup is then performed in the usual manner (Fig. 19-1).

There have been reports of significant complications including bone graft resorption, nonunion, mechanical failure of the graft, and cup loosening with this technique. However, the latest results of this technique as reported by Abdel et al. (3) concluded that an uncemented porous-coated socket used in conjunction with a bulk femoral head autograft provides good long-term fixation and restores bone stock. This study reported on 35 hips with this technique followed for mean of 21.3 years. All of the bone grafts demonstrated union to the pelvis. Mulroy and Harris (4) have recommended at least 70% coverage of the acetabular component by host bone to provide adequate stability and bony ingrowth.
Medialization of the Anatomic Hip Joint

This technique can be utilized to improve superolateral host bone coverage of the acetabular component. After adequate exposure of the acetabulum, the defect is estimated. There is usually a superolateral defect of the acetabulum. The soft tissues are removed from the floor to expose the cotyloid notch. The smallest reamer is used to start reaming medially in a controlled manner. The direction of reaming is as per desired anteversion angle. The anterior wall is usually hypoplastic, and care should be taken not to overream anteriorly. The reaming is carried out medially to the desired depth to cover the cup (Fig. 19-2). The aim is to have less than 20% of uncoverage superiorly (5). After desired reaming, the rest of the procedure is carried out in the usual manner.

Dorr et al. (5) reported successful outcome with this technique. They followed 24 THR using this technique and a hemispherical metal shell for a minimum of 5 years. There were no revisions of these metal shells.

High Hip Center in a False Acetabulum

This is generally not recommended, and for the most part, it is a historical technique and describes placement of the acetabular component at a high hip center in a false acetabulum using a small cementless cup. The reaming is performed until adequate coverage is obtained. The center of rotation should not be lateralized, but in this technique, that almost always occurs. The cup stabilization generally requires an additional one or two screws for fixation. Delp et al. (6) reported that superolateral placement of hip center (2 cm superior and 2 cm lateral) decreases the abductor moment arm by 28%. The group also concluded that this force is increased by only 10% if only 2 cm superior displacement is obtained, and neck length is used to restore the abductor muscle length.

Kaneuji et al. (7) reported no acetabular component loosening in their series where they used this technique at 10-year follow-up. The same group later recommended that the high hip center of up to 30 mm from the teardrop line is feasible option if appropriate stem is used, which restores femoral offset and abductor lever arm (8).

CROWE IV

A small uncemented cup is usually used on the acetabular side in the true anatomic center as described above. The femur usually needs a shortening and derotational osteotomy as described below.

Femoral Shortening and Derotational Osteotomy

After femoral dislocation and femoral neck osteotomy, femoral preparation is performed prior to acetabular preparation. Both modular and nonmodular femoral implants can be used depending on the degree of bony deformities, in particular excessive anteversion.

In cases using modular femoral components (SROM, Depuy, Warsaw, IN), proximal reaming is performed for the modular metaphyseal sleeve. An appropriate proximal metaphyseal trial sleeve is introduced. A subtrochanteric transverse osteotomy is then performed 2 cm distal to the sleeve.
In cases using a nonmodular femoral component, an osteotomy is performed at the inferior border of the lesser trochanter (Fig. 19-3).

Following the osteotomy, the proximal fragment is mobilized and the acetabulum prepared. Trial implants are introduced into the acetabulum. On the femoral side, the trial implant is introduced into the proximal fragment only. Hip reduction is performed, and the amount of femoral overlap is determined. This overlapping fragment is then resected using a power saw (thereby shortening the femur).

The resected fragment is then split longitudinally to create napkin ring autografts that may be placed around the osteotomy site at the time of closure. The distal femoral fragment is then reduced over the trial implant, and rotation of the distal fragment is established. This requires distal reaming with an appropriate reamer. A prophylactic wire, or cable, may be placed around the distal fragment if risk of fracture is anticipated due to bone quality (Fig. 19-4).

The stability of the hip joint is then assessed. This is followed by definite implantation of the femoral stem (modular or nonmodular). The osteotomy site is reduced adequately ensuring minimal gap and appropriate rotation of the proximal and distal fragment. The site is then augmented with cortical fragments split earlier. Cerclage wires are utilized to stabilize these fragments. The site can be further augmented with morselized femoral head autograft. Strut allografts can also be utilized for additional rotational stability. The remaining surgery is then completed.

Our group has reported on the use of this technique on 21 hip arthroplasties for Crowe 3 and 4 DDH (9). Femoral osteotomies healed in 91% of cases at an average follow-up of 5.8 years. Two cases of osteotomy nonunion required revision. There were no neurologic complications. Similar successful results were also reported by Krych et al. (10). The group reported on 28 cementless THR with subtrochanteric osteotomy in the setting of Crowe 4 DDH. At a mean follow-up of 4.8 years, there were only 2 (7%) nonunions and no neurologic complications.
Postoperative Management

This is individualized based on the intraoperative findings, especially the amount of deformity and implants used. If no additional procedures such as an osteotomy and/or bone grafting are required, patients are allowed to follow a routine THR protocol. They are allowed to weight bear and perform range of motion as tolerated under a supervision of physiotherapist. If bone grafting or an osteotomy are required, weight bearing is protected for at least 6 weeks or longer depending on healing at the graft and osteotomy sites.

Perils, Pitfalls, and Complications

Arthroplasty in the setting of DDH can be quite challenging. As described above, the deformities and options for treatment vary depending on the severity of each individual case. As a result, it is very important to perform thorough preoperative planning. Appropriate implants, in particular...
small-sized cups, heads, liners, and stems (modular or nonmodular), need to be planned for. The need for additional equipment like cerclage wires, plates, and bone grafts should also be considered.

- Hip instability risk is high due to the small cup sizes and consequent smaller bearing diameters.
- In severe deformities, anatomy may be difficult to define and may require intraoperative imaging.
- Throughout the case, the risk of fractures should be remembered especially during hip dislocation and reduction maneuvers.
- Similarly, neurologic complications especially sciatic nerve damage should also be thought of throughout the case. Intermittent palpation of tension of the sciatic nerve is recommended.
- There is also an increased incidence of both acetabular and femoral component loosening. Adequate fixation of both components is required. Maintaining an anatomic hip center is helpful to minimize cup loosening.
- Nonunion at the acetabular graft sites and femoral osteotomy sites can occur. Attention should be directed toward adequate fixation of graft and osteotomy sites.

REFERENCES
