13 Developmental Dysplasia of the Hip

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Developmental dysplasia of the hip (DDH), one of the most common hip disorders, is a condition that acetabular defects at birth progress gradually during the growth and cause the abnormal biomechanical environment. Subsequently, the secondary pathological changes range from femoral head subluxation, degeneration of cartilage in weight-bearing area, focal necrosis of femoral head to severe osteoarthritis.

The occurrence of DDH varies significantly worldwide. There is no complete epidemiological data in China. It has been estimated that the incidence in neonates is about 1‰, and about 20% of the patients have a positive family history. Male to female prevalence ratio is 1: 4.75 in China. Furthermore, occurrence varies widely geographically and ethnically, which could be related to many genetic and environmental factors and different lifestyles.

The primary goals of surgical intervention are to relieve pain, to correct the acetabulum morphology, and to restore the normal anatomic relationships between acetabulum and proximal femur. Additionally, treatment of secondary lesions is also important, including repair of labrum tear or cartilage damage, removal of femoroacerabular impingement (FAI). All the interventions aim at improving the function of the hip joint and deterring the progress of osteoarthritis. Despite there are numerous hip-preserving surgeries, the Bernese periacetabular osteotomy (PAO) firstly reported by Ganz et al. from University of Bern has been performed worldwide, with favourable results. This procedure can effectively increase the acetabular coverage and restore the congruency of the hip joint, thus preventing or at least delaying the progression of osteoarthritis. Multiple medical centers worldwide reported satisfactory intermediate to long-term results. According to the reports from University of Bern, the original 63 patients with 75 hips who received the procedure had an average survival rate of 60% in mean 20-year followup and 29% in mean 30-year followup, respectively.

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13.1 Pathology and Classification

13.1.1 Pathology

The pathological changes of DDH are complicated, which include soft tissue and bony structure abnormalities, which manifest as superolateral and anterior defects of acetabulum, shallow acetabulum, lateral shift of the joint center, and incongruency of the joint. These changes can easily lead to joint instability, concentrated mechanical loads, and impingement, which will probably lead to premature degeneration of articular cartilage and osteoarthritis.

13.1.1.1 Acetabulum

Lesions of acetabulum include excessive anteversion or retroversion of acetabulum; the decreased tilt of acetabulum; lateral shift of the joint center; shallow acetabulum; and insufficient acetabular coverage. Due to insufficient coverage and joint instability, the labrum in adult DDH is commonly hypertrophic, sometimes with cysts. The labrum is often torn and inverted during weight bearing, resulting in degeneration of the articular cartilage under it, leading to hip pain, snapping, and degenerative changes. About 90% of DDH patients with symptoms have labrum injuries.

13.1.1.2 Proximal Femur

Femoral abnormalities mainly include the morphological changes of the femoral head; increased anteversion that could exceed 60 degrees; decreased femoral offset; increased neck-shaft angle and overgrowth of the great trochanter.

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13.1.2 Classification

The existing classification system is mainly suitable for surgical planning before total hip arthroplasty. Currently, there is no feasible classification system applicable to hip-preserving surgery, which requires further attention.

13.1.2.1 Crowe Classification

DDH is divided into four types according to the proportion of displacement of femoral head and height of femoral head and pelvis measured using pelvic AP film.

- Type I: Femoral head displacement accounts for less than 50% of femoral head height, or less than 10% of the pelvic height (Fig. 13.1).
- Type II: Femoral head displacement accounts for 50% ~ 75% of femoral head height, or 10% ~ 15% of pelvic height (Fig. 13.2).
- Type III: Femoral head displacement accounts for 75% ~ 100% of femoral head height, or 15% ~ 20% of the pelvic height (Fig. 13.3).
- Type IV: Femoral head displacement exceeding 100% of femoral head height, or 20% of the pelvic height (Fig. 13.4).

13.1.2.2 Hartofilakidis Classification

There are three types in this classification system, which is commonly used in clinical practice:

- Type I: Acetabular dysplasia, with varying degrees of incomplete dislocation, but the femoral head is still contained in the true acetabulum.

Fig. 13.1 Right DDH. Crowe type I

Fig. 13.2 Left DDH. Crowe type II

Fig. 13.3 Left DDH. Crowe type III

- Type II: Low dislocation, the femoral head has been located in the secondary acetabulum, and there are still parts of the secondary acetabulum connected with the true acetabulum, which is easy to be neglected during operation.
- Type III: High dislocation with posterior displacement of the femoral head, and the secondary acetabulum is located on the superoposterior ilium without connection with the true acetabulum.

Fig. 13.4 Right DDH. Crowe type IV

13.2 Clinical Features

13.2.1 Symptoms

Patients with DDH have no obvious symptoms in the early stage, and most patients will develop evident symptoms at the age of 20–40 years gradually. At the initial stage, sore and discomfort in the hip region are presented, which are aggravated after standing or walking for a long time and alleviated after rest. Subsequently, hip pain gradually appears, mainly in the upper thigh and the groin area. There is no significant limitation of joint activity in the early stage. Noteworthily, pain in the hip region often suggests that the articular cartilage has already been damaged. The severity of pain is related to the degree and extent of articular cartilage injury. As the condition progresses, the pain in the hip joint deteriorates, and the movement of the hip joint is significantly affected. Usually, patients can walk only with walking aids and analgesics.

13.2.2 Signs

Physical examination ought to be a comprehensive assessment of posture, gait, limb length, muscle strength, and range of motion. Intra-articular lesions will lead to hip flexion deformity and antalgic gait, manifesting as shortened stance phase and decreased step length. Increased femoral anteversion usually results in excessive internal rotation of the hip joint, whereas decreased internal rotation suggests the presentation of secondary osteoarthritis. Trendelenburg sign could be positive. The positive result of FAI test, indicates that there is bone abnormality with labral injuries. Typically, the pain is presented in the groin area. Positive result of hip rolling test indicates that the hip joint has intra-articular lesions.

13.3 Imaging Examinations

13.3.1 X-ray Imaging

13.3.1.1 Anteroposterior View

On pelvic anteroposterior (AP) film, the diagnosis can be made, and the severity of the condition can be evaluated (Fig. 13.5).

1. Center-edge angle (CE angle): It refers to the angle between the line connecting the center of the femoral head and the lateral margin of the acetabulum and the perpendicular line through the center of the femoral head. The normal CE angle is 25° or more. Values of 20-25° are considered borderline DDH. Values of less than 20° are diagnosed as DDH.
2. Tönnis angle: The Tönnis angle quantifies the slope of the sourcil (the sclerotic weight-bearing portion of the acetabulum). The normal Tonnis angle is 10° or less. Values of more than 10° are considered a risk factor for instability.
3. Anteversion and retroversion of the acetabulum: Observe the anterior and posterior wall of the acetabulum. When the anterior wall line overpasses the posterior wall line, it is called a crossover sign, which indicates excessive retroversion of the acetabulum.

Fig. 13.5 Pelvic AP film. Bilateral DDH

4. Shenton line: It is a continuous arc drawn from the inner edge of the femoral neck to the superior margin of the obturator foramen. This should be smooth and undisrupted; otherwise, it may indicate subluxation caused by DDH.
5. If there is a fracture on the margin of the acetabulum, it means stress is concentrated.
6. The joint gap can be used to assess the severity of cartilage degeneration.

13.3.1.2 Frog Lateral View

Patient is supine with no rotation of pelvis, the affected hip is abducted 45° with the knee flexed 30° to 40°. If it is a unilateral examination, the heel of the affected limb should rest against the medial side of the contralateral knee. If bilateral, both knees are to be resting on sponges, giving the appearances of frog legs. It is often used to observe the congruency, reduction, and coverage of hip joints, as well as the lesions of the femoral head, neck, and the presentation of developmental deformities (Fig. 13.6).

13.3.1.3 False-Profile View

Patient stands before the image intensifier. The 45° oblique projection is obtained with the affected hip adjoining the intensifier, and ipsilateral foot parallel to the intensifier. This view can be used to assess the anterior acetabular coverage. Anterior center-edge Lequesne's angle can be measured on this projection, which is between the line connecting the center of the femoral head and the anterior margin of the acetabulum and the perpendicular line through the center of the femoral head. Normal minimum value is 25°.

Fig. 13.6 Pelvic frog lateral film. Bilateral DDH

13.3.1.4 Abduction Functional View

The joint is placed at its maximum abduction, which can be used to simulate the correction angle during osteotomy and to observe the congruency, reduction, and acetabular coverage.

13.3.2 Computed Tomography

CT scanning makes it possible to observe the changes of the acetabulum and femoral head in the coronal, sagittal, and horizontal planes (Fig. 13.7). Measurement of femoral anteversion is simple and accurate using CT scanning. It is the angle between a line along with the femoral head and neck axis and a second line that is touching the posterior border of both femoral condyles. In adults, the normal value ranges from 10° to 15°. Three-dimensional reconstruction model can clearly show various pathological changes of the acetabulum, femoral head, and surrounding tissues, which is superior to other methods for preoperative planning and postoperative evaluation. It can even be used to conduct a surgical simulation in order to make personalized treatment plans.

13.3.3 Magnetic Resonance Imaging

Many pathological conditions of the hip are detected early by MRI due to its high soft-tissue resolution and sensitivity. MR has the capacity of multiparameter imaging, which has clear advantages for revealing the complex three-dimensional structure and types of tissues of joints. Currently, MRI and MR arthrography (MRA) are the best imaging methods for diagnosing articular cartilage injury and soft tissue lesions. The commonly used methods include native MR imaging, intravenous enhancement of MR arthrography (indirect contrast), and direct MR arthrography (direct contrast). A comparative study of these three methods showed that direct MR arthrography has clear advantages and possesses much higher reliability and accuracy. Therefore, in addition to native MR imaging, direct MR arthrography guided by ultrasound is often used in DDH patients to diagnose intra-articular lesions (Fig. 13.8). It is usually injected with 15–20 ml 0.8%–1% of gadopentetate dimeglumine. The presence of contrast agent makes the intra-articular structure clear and the diagnosis accurate and reliable.

Labrum and articular cartilage injuries are often secondary to DDH. The morphology of labrum and imaging characteristics related to abnormal stress distribution (such as cartilage lesions) can be detected and further analyzed by MR arthrography. The methods provide a clear clue for accurate diagnosis and important information for surgery and arthroscopy if necessary. It can also be used to evaluate the outcomes of the treatment and to predict the prognosis.

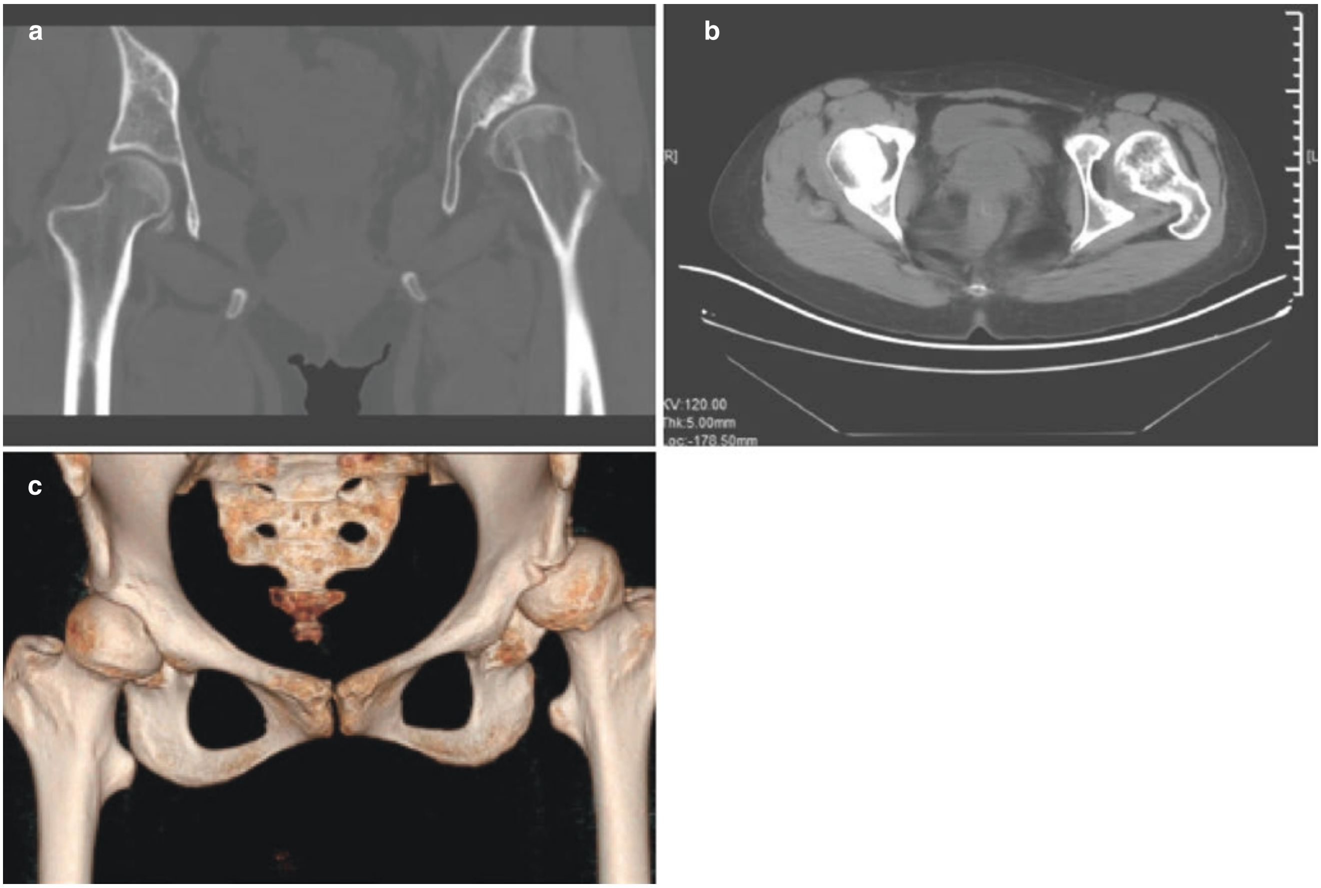

Fig. 13.7 Pelvic CT scanning. Left DDH. (**a**) Coronal plane; (**b**) horizontal plane; (**c**) three-dimensional reconstruction

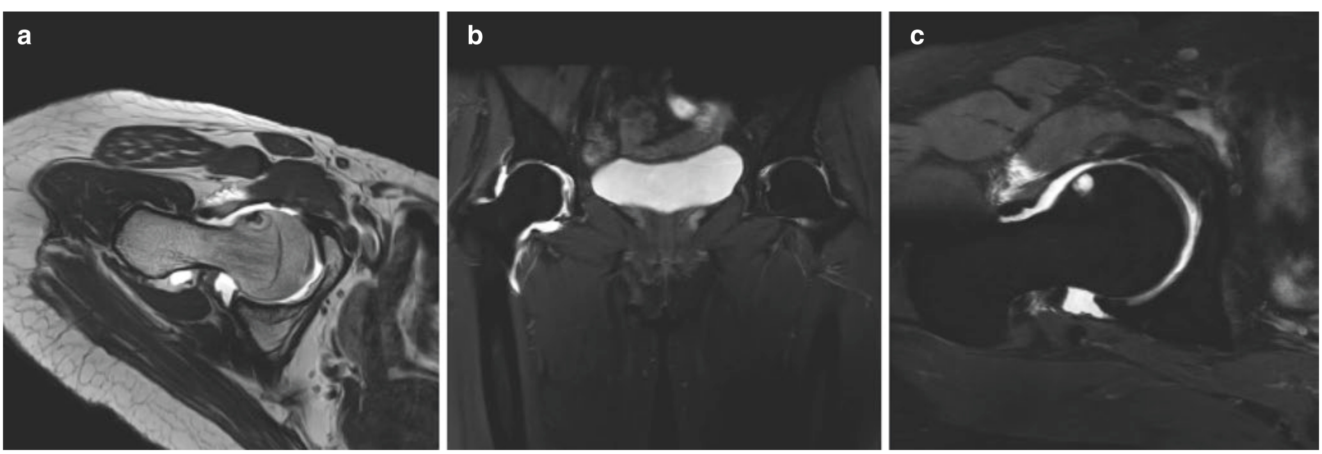

Fig. 13.8 Direct MR arthrography of the right hip joint. (**a**) Horizontal plane along the longitudinal axis of femoral neck; (**b**) coronal plane along the longitudinal axis of femoral neck; (**c**) radial scanning along the labrum

13.4 Treatment of DDH in Adults

It is not necessary to perform any procedure on patients with no pain in the hip region. However, regular follow-ups are needed to detect any obvious deterioration. Once the pain is presented, especially accompanied by limited joint activity, surgical intervention is required. The primary goals of surgical treatment are to relieve pain, to restore the joint morphology and congruency, to treat the diseases related to labrum tear and cartilage damage including FAI, and to improve joint function, preventing the development of osteoarthritis.

13.4.1 Treatment of DDH in Adults

Among the different surgical techniques available, the Bernese periacetabular osteotomy (PAO) is one of the most frequently and successfully used techniques and this section will focus on discussing this procedure. Spherical acetabular osteotomy (SAO) gains popularity in Japan. Better outcomes could be achieved in some patients after the procedure combined with a proximal femoral osteotomy (PFO). Total hip arthroplasty (THA), or hip resurfacing arthroplasty (HRA) is suitable for patients with severe osteoarthritis. Hip arthrodesis is now rarely performed.

13.4.2 Periacetabular Osteotomy

13.4.2.1 Indications

PAO is suitable for symptomatic DDH: (a) cases without osteoarthritis or with mild secondary osteoarthritis, such as grade 1 or 2 of Tönnis classification; (b) young and middle-aged patients; (c) cases with normal or basically normal range of motion; (d) cases with congruent joint on the functional view; and (e) cases with mild deformed femoral head. These can be restored by intra-articular surgery.

13.4.2.2 Contraindications

The procedure cannot be performed on cases with moderate secondary osteoarthritis or even worse, which is grade 3 of Tönnis classification; elderly patients; cases with severely deformed joint; obese patients; cases with significantly limited ROM; cases with the severe accompanying disease; patients with poor compliance.

13.4.2.3 Preoperative Planning

Imaging examination can be used to measure angles describing the characteristics of the conditions. Then, according to the results, the details of the procedure are designed, including the correction angle and direction of the acetabular fragments, aiming at restoring normal Tönnis angle, reducing the femoral head and improving the stability of the joint. Developmental abnormalities of the proximal femur may also require treatment during the process of PAO. In order to improve long-term effects, treatment for injuries of the joint surface or labrum should also be considered in the surgical planning. Hip arthroscopy (before PAO) or limited capsulotomy during PAO can be effective methods. It is contraindicated to treat the labrum injury of DDH patients separately. The torn labrum is often associated with other abnormalities of the hip joint, such as FAI or DDH, so it also requires correction for optimal treatment outcomes. In order to prepare for early rehabilitation after the procedure, training of exercise techniques for patients are necessary.

13.4.2.4 Surgical Techniques

13.4.2.4.1 Position

The patient is positioned supine on a radiolucent table, and the involved limb is disinfected and draped to the costal margin; posteriorly, to the least posterior third of the ilium; medially, to the umbilicus.

13.4.2.4.2 Approach

The standard Smith-Peterson incision is usually used (Fig. 13.9). The incision adopted by the authors' team is slightly different, which is the ilioinguinal incision (Bikini) (Fig. 13.10). This incision is cosmetic, however, with the disadvantage of insufficient anterior ischial exposure. Therefore, an auxiliary longitudinal incision at the medial part of the upper thigh is routinely made in order to expose the ischium thoroughly (Fig. 13.11).

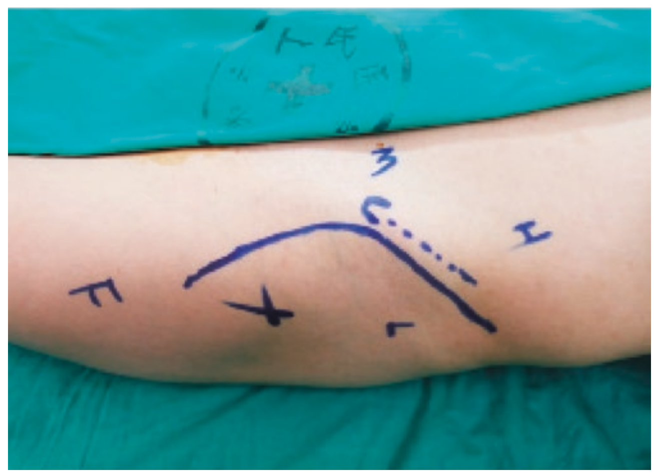

Fig. 13.9 Smith-Peterson incision on left hip

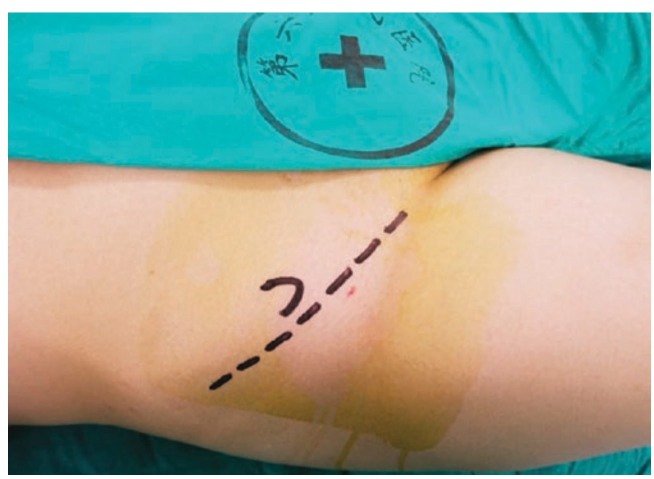

Fig. 13.10 Bikini incision on right hip

Fig. 13.11 Auxiliary longitudinal incision at the medial part of the upper thigh on right hip

Fig. 13.12 Expose ramus of ischium through the auxiliary longitudinal incision at the medial part of the upper thigh

13.4.2.4.3 Exposure and Osteotomy of the Anterior Portion of the Ischium

An auxiliary longitudinal incision is an optional approach for ischial osteotomy in those larger and more muscular patients, which is made at the medial part of the upper thigh. It can make the exposure of the anterior portion of the ischium easy and provide a better cosmetic result. The adductor longus is an important anatomic landmark. Through the medial margin of this muscle, there is interspace between adductor longus and gracilis muscle. Then, the interspace formed by adductor brevis, adductor magnus, and pectineus can be seen. Through the deeper interspace, the operation site can be reached. Use Hohmann retractor to expose the ramus of the ischium (Fig. 13.12). After locating the osteotomy site by inserting K-wires (Fig. 13.13), use the osteotome to perform the osteotomy of the anterior portion of the ischium (Fig. 13.14). The proper position of the osteotome is 1 cm below the inferior lip of the acetabulum with the tip of the osteotome aimed at the ischial spine. Using fluoroscopy to evaluate the location and the depth of the osteotomy (Fig. 13.15). After confirming that the osteotomy is performed correctly, the incision is temporarily packed with gauze.

13.4.2.4.4 Superficial Dissection of the Ilioinguinal Approach

This approach can provide a better cosmetic result but can limit access for the anterior ischial osteotomy. Therefore, it is not an appropriate choice for larger and more muscular patients. For those patients, an auxiliary longitudinal incision at the medial part of the upper thigh for anterior ischial osteotomy mentioned before, and the standard anterior incision may be the proper option. Incise the skin and subcutaneous fat, exposing the fascia on the surface of the obliquus externus abdominis and gluteus medius which is incised posterior to the anterior superior iliac spine, through the inter-

Fig. 13.13 Locate the osteotomy site of the ischium by inserting K-wires

Fig. 13.14 Osteotomy of the anterior portion of the ischium

Fig. 13.15 Image from intraoperative fluoroscopy of the osteotomy of the anterior portion of the ischium

space between the two muscles. Use a scalpel to divide the iliac crest periosteum. Perform subperiosteal dissection of the inner table of the ilium, using gauze packing hemostasis. The iliac periosteum is exposed between the tensor fascia latae and sartorius to avoid injury of the lateral femoral cutaneous nerve. The tensor fascia latae is separated from the intermuscular septum bluntly until ilium can be palpated.

Sartorius is detached with a thin wafer of bone from the anterior superior iliac spine with intact insertion. Alternatively, a 2.5-mm drill may also be used to pre-drill holes around the anterior superior iliac spine, and a 1 × 1 × 1 cm bone mass is osteomized, facilitating medial exposure and later repair.

13.4.2.4.5 Deep Dissection of the Ilioinguinal Approach

Flexion and adduction of the hip joint make it easy to expose the deep structure and superior ramus of the pubis. The reflected head of rectus femoris is divided at its junction with the straight head, and, along with iliacus, are reflected distally and medially, exposing the superior and anterior hip capsule. The iliacus, sartorius, and abdominal contents are together reflected medially. The sheath of psoas is cut open longitudinally, and the psoas is also retracted medially, exposing superior ramus of the pubis medial to iliopectineal eminence.

13.4.2.4.6 Osteotomy

Osteotomy is usually performed in the following order: anterior portion of the ischium, superior ramus of the pubis, Supra-acetabular ilium, and posterior column of the acetabulum.

1. Anterior ischial osteotomy: If the osteotomy was not performed through auxiliary longitudinal incision at the medial part of the upper thigh, it could be performed with following methods. The interval between the medial joint capsule and the iliopsoas tendon is created and then dilated with a long Mayo scissors. Insert the tip of the Lane retractor at the anterior aspect of the ischium. The proper position of scissor and retractor should be confirmed with intraoperative fluoroscopy.

   With hip flexed 45° and slightly adducted, a 30° forked, angled bone chisel (20 mm) is carefully inserted in the space between psoas muscle tendon and medial capsule, and its tip is placed at the upper part of infracotyloid groove, anterior to the ischium, just superior to the obturator externus tendon. The medial and lateral surfaces of the ischium are gently palpated using the chisel, and image intensification in both the anteroposterior and the iliac oblique projections are used to confirm the position of the chisel (about 1-cm below the inferior acetabular lip with the tip of the chisel aimed at the ischial spine) (Fig. 13.16). The chisel is impacted to a depth of 15 ~ 20 mm through the medial and lateral cortex of the ischium. When performing osteotomy of the lateral cortices of ischium, do not drive the chisel too deeply because the sciatic nerve can be injured due to careless operation.
2. Osteotomy of superior ramus of pubis: The hip joint is flexed and adducted to relax the anterior soft tissue. The iliopsoas tendon and structures are gently retracted medially. The periosteum over the superior pubic ramus is incised along its axis, and careful circumferential subperiosteal dissection is performed. Two Hohmann retractors are inserted into at least 1 cm medial to iliopectineal eminence and the anterior and posterior surface of superior ramus of the pubis (Fig. 13.17) to protect the obturator nerve and artery. Inserting K-wires (Fig. 13.18), the position and direction of osteotomy are determined by intraoperative fluoroscopy with AP view (Fig. 13.19).

   The superior pubic ramus is osteotomized perpendicular to its long axis when viewed from above and oblique from proximal-lateral to distal-medial when viewed from the front. The osteotomy can be performed either by passing a Gigli saw around the ramus and sawing upward, away from the retractors, or by impacting a straight osteotome just medial to the iliopectineal eminence. It must be made medial to the iliopectineal eminence to avoid intra-articular extension.

3. Supra-acetabular iliac osteotomy: Initially, the abductors were stripped from the iliac wing. The bone cuts were performed from both sides of the iliac wing (Fig. 13.20).

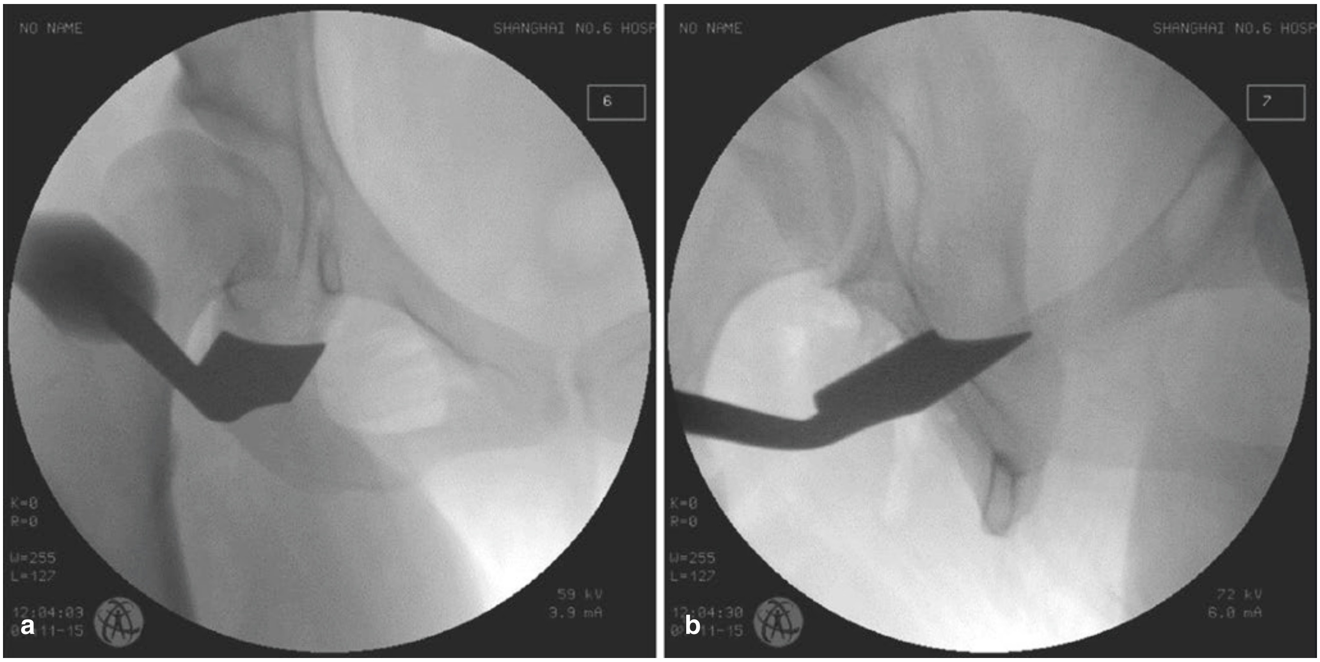

Fig. 13.16 Image from intraoperative fluoroscopy of anterior ischial osteotomy. Confirm the location and direction of the osteotomy. (**a**) AP view; (**b**) iliac oblique view

Fig. 13.17 Expose superior ramus of the pubis

Fig. 13.18 Expose superior ramus of the pubis and locate the position with K-wires

However, to preserve the abductors, this has evolved such that the abductors are tunneled only at the level of the osteotomy. A 2-cm subperiosteal window is created beneath the anterior abductors, just distal to the anterior superior iliac spine without disturbing the origin of abductor. The leg is extended and slightly abducted. The subperiosteal dissection is made with use of a blunt Hohman retractor that is placed posteriorly toward the apex of the greater sciatic notch. The iliacus is retracted medially with a reverse Hohmann retractor. Before beginning the cuts, K-wire is inserted into 1 cm lateral to the pelvic brim often in line with the apex of the sciatic notch, and the position is confirmed with image intensification (Fig. 13.21). The iliac osteotomy should be performed using oscillating saw under direct vision (Fig. 13.22). Saline irrigation is used for cooling. The osteotomy ends at 1 cm above the iliopectineal line (well anterior to the sciatic notch) (Fig. 13.23). The end point of the iliac

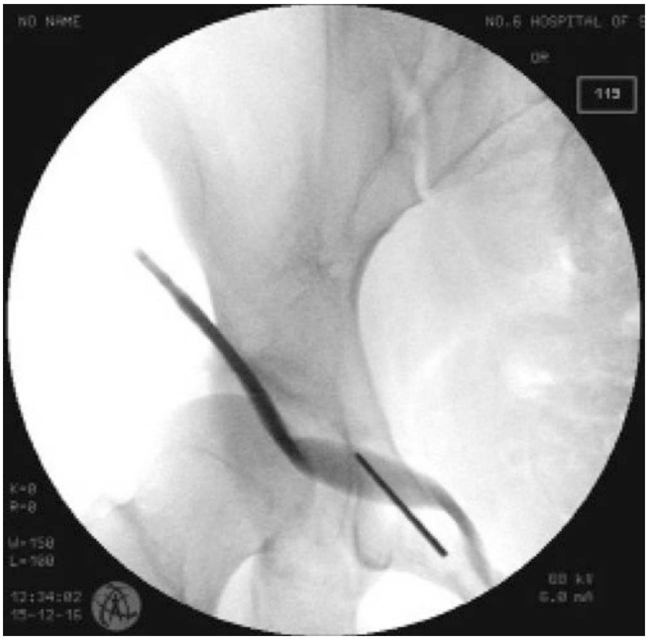

Fig. 13.19 Image from intraoperative fluoroscopy to confirm the position and direction of the osteotomy of the superior pubic ramus

Fig. 13.20 Expose the ilium and locate the position with K-wires

saw-cut represents the posterosuperior corner of the periacetabular osteotomy, which is also the starting corner of the posterior-column osteotomy.

4. Osteotomy of posterior column: The hip is once again maintained in flexion and adduction to relax the anterior and medial soft tissue. A reverse blunt Hohmann retractor is placed medially on the ischial spine. A long, straight 1.5-cm osteotome is used to make the osteotomy through the medial cortex (Fig. 13.24). The osteotomy begins from the posterior end of iliac saw-cut, passes over the iliopectineal line, through the medial quadrilateral plate. The direction is parallel to the anterior edge of the sciatic notch on the iliac oblique view, aiming at ischial spine (Fig. 13.25).

Fig. 13.21 Image from intraoperative fluoroscopy to comfirm the position of 1 cm lateral to the pelvic brim with K-wires

Fig. 13.22 Supra-acetabular iliac osteotomy. Hohmann retractor is used to widen the incision and to protect the tissue around the osteotomy

The osteotomy must be performed at least 4-cm below the iliopectineal line to avoid joint penetration when performing the posterior–inferior osteotomy. The osteotomy of the posterior column begins at the medial side and is completed through the lateral ischial wall. The posterior

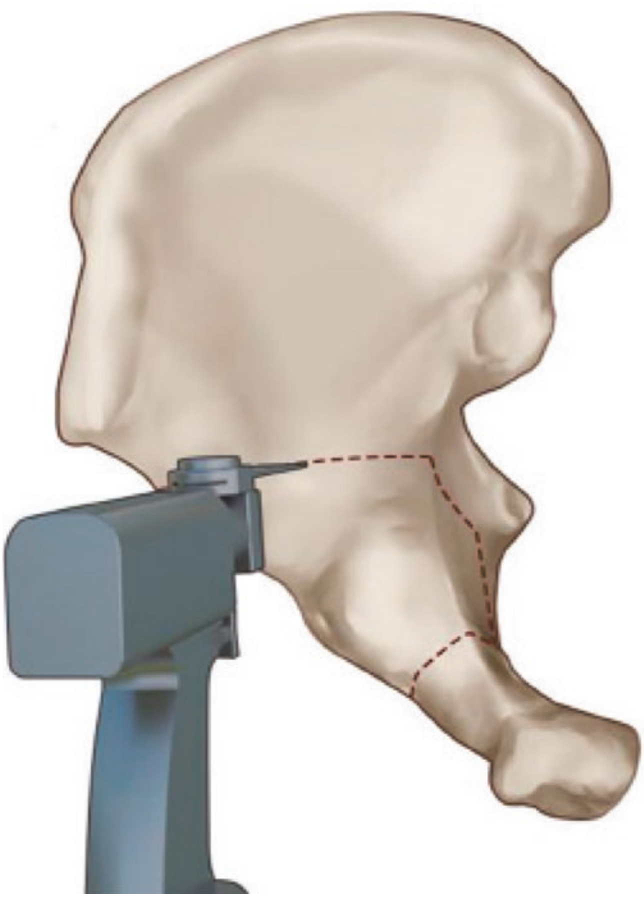

Fig. 13.23 Supra-acetabular iliac osteotomy using oscillating saw under direct vision

ischium is wider than the anterior ischium. If viewed from the top, the ischium resembles a triangular prism, with the narrowest tip at the anterior edge of the sciatic notch. Therefore, the osteotome should not be perpendicular to the medial quadrilateral. Instead, the medial edge of the osteotome should be tipped 10°–15° away from sciatic notch. On a coronal plane, the cut is completed perpendicular to the lateral cortex of posterior column. Again, the direction and position of the osteotomy are confirmed by intraoperative fluoroscopy.

The final step is a complete osteotomy of the posterior–inferior–medial corner of the quadrilateral plate connecting the anterior and posterior ischial cuts. A 30° angled, the long-handled chisel is used to make the two osteotomies become one. The crux of the step is to put the blade on the connecting part. The angle between the chisel and quadrilateral plate should be less than 50° to avoid anterior joint penetration.

13.4.2.4.7 Acetabular Fragment Displacement

When all of the cuts have been made, a Schanz screw is placed in the acetabular fragment at the anterior inferior iliac spine. This facilitates fragment mobilization and control of

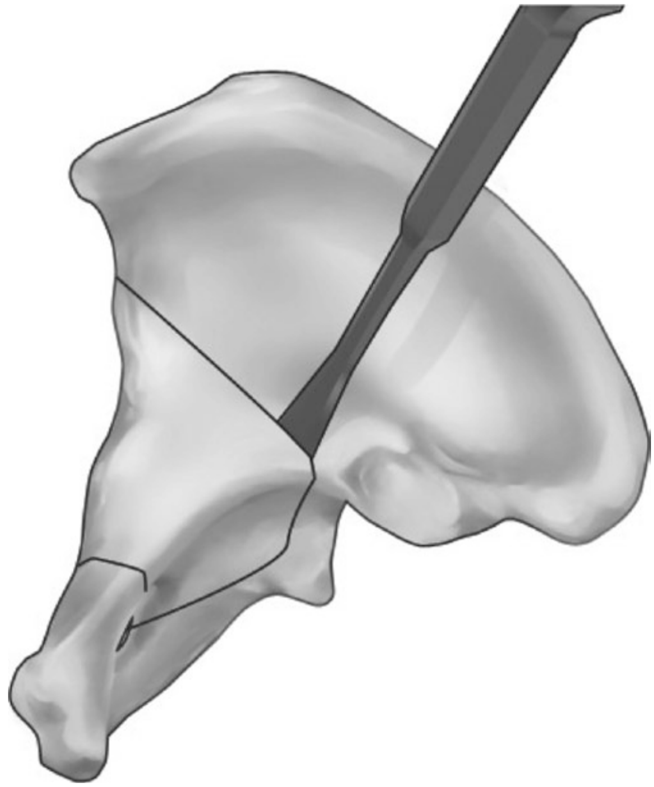

Fig. 13.24 Osteotomy of posterior column of the acetabulum

Fig. 13.25 Image from intraoperative fluoroscopy of osteotomy of posterior column of the acetabulum. The position and direction of the osteotomy are observed on 45° iliac wing oblique view

the fragment during correction. A straight Lambotte chisel is placed into the supra-acetabular iliac saw-cut to confirm the completion of lateral cortex osteotomy. The tines of the

Fig. 13.26 Place the Schanz screw on the acetabular fragment in order to displace the fragment later

Fig. 13.27 Hold the Schanz screw and displace the acetabular fragment to the proper position

Weber bone clamp are placed on the upper part of the acetabular fragment screw (Fig. 13.26). A lamina spreader is placed between the complete osteotomy of the superior posterior part of the ilium and Lambotte chisel anteriorly. While gently opening the lamina spreader, the surgeon moblilizes the acetabular fragment with Weber clamp and Schanz screw (Fig. 13.27). It is important to confirm whether the posterior and anterior osteotomy is complete; otherwise, the soft tissue or bony hinging hinders the correction and limits medialization of the joint. These cuts can be palpated with a narrow or broad 30° chisel and completed, if necessary.

Once the fragment is completely free, it can be placed at the desired position and direction. For classic DDH, the most common developmental defects of the acetabulum are an anterior and lateral part.

Therefore, it is preferable to start the correction with anterior rotation of the fragment; this movement normally produces additional lateral coverage. If more lateral coverage is needed, it is easier to correct this with the use of a second Schanz screw. Adjustment of version is always the last correction. Nonetheless, the correction should be individualized for each patient and based on the anatomy and the preoperative radiographs.

13.4.2.4.8 Acetabular Fragment Fixation

After the completion of acetabular displacement, the 2.5-mm K-wires are placed from proximal to distal through the ilium to the bifurcation of the acetabular fragment, and the position of the acetabular fragment is evaluated fluoroscopically (Fig. 13.28). Several parameters are assessed intraoperatively. The sourcil should be horizontal but not negative. The CE angle should be between 25-35°. The hip center should be slightly medialized to improve joint reactive forces. The teardrop should be more medial than previously. The anterior and posterior walls should meet at the lateral edge of the joint (Fig. 13.29). With stress radiograph, move the hip joint from full extension to 100° flexion to evaluate whether there is excessive anterior coverage or FAI. If the hip flexion is less than 90°, it is necessary to reposition the fragment or deal with femoral deformities.

Once a satisfactory correction has been obtained, measure the depth of the K-wires and fix the fragment with 3.5-mm or 4.5-mm screws. Intraoperatively, AP view of the pelvis, obturator oblique view and iliac oblique view are obtained to confirm the position and length of the screws and to ensure that the screws do not penetrate the joint (Fig. 13.30). For patients with ligamentous laxity, neuromuscular condition, or poor bone quality, a so-called home-run screw can be placed from the point posterior to the anterior inferior iliac spine to the lower part of the ilium in order to increase the stability. Author's team prefer to use a small plate for further fixation after screw fixation. After fixation with the acetabu-

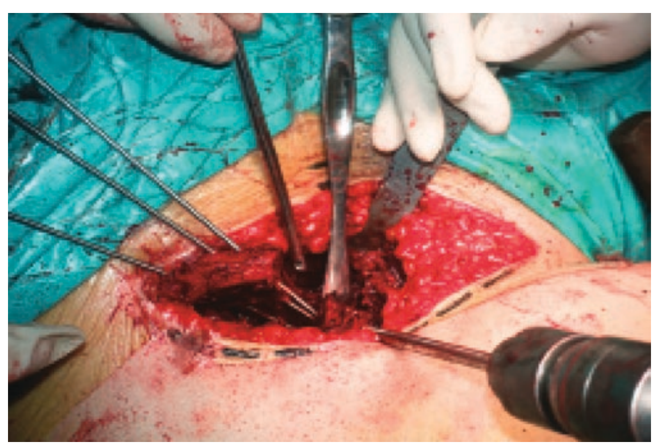

Fig. 13.28 Provisional fixation with K-wires after the designed position of the fragment is achieved

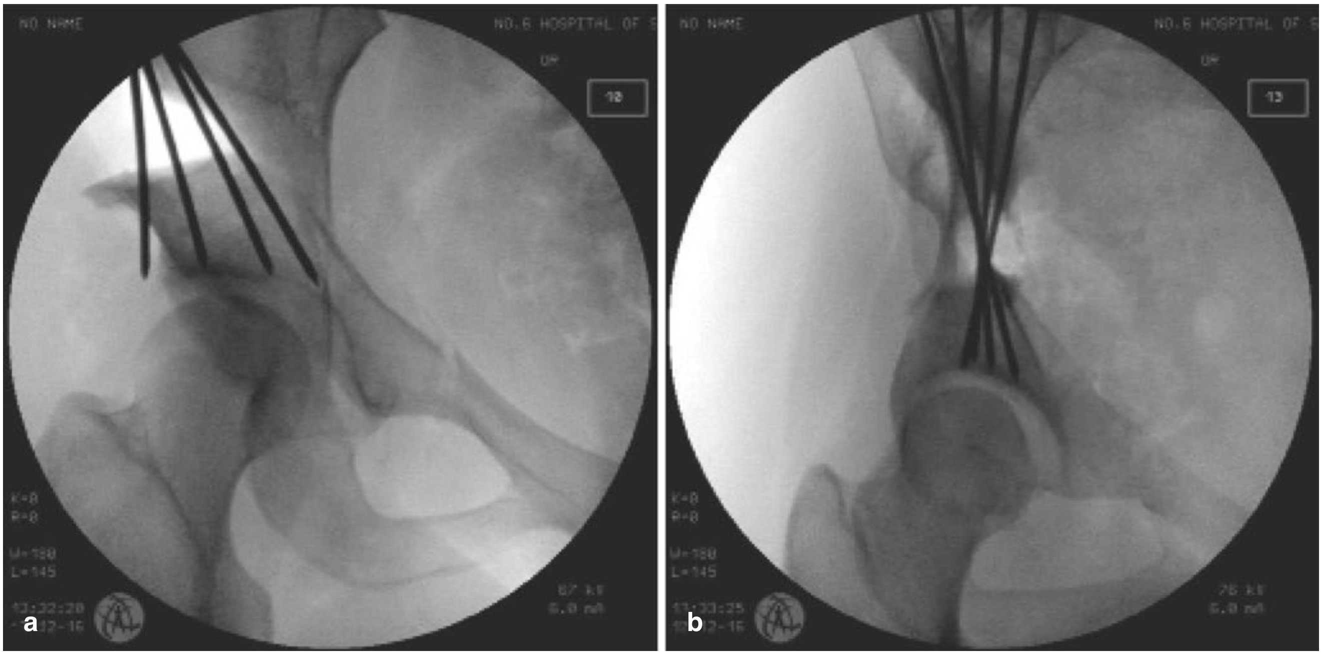

Fig. 13.29 Image from intraoperative fluoroscopy of provisional fixation with K-wires of an acetabular fragment. Sufficient acetabular coverage is achieved after the correction. (**a**) AP view; (**b**) 45° oblique view

lar fragment screw (Fig. 13.31), a bone graft can be harvested from the anterior iliac prominence of the acetabular fragment. Gelatin sponge can be used for hemostasis of the osteotomy surface.

13.4.2.4.9 Closure of the Incision

Remove packing gauze from the lower medial incision. Irrigate the incision copiously. A vacuum drainage tube is placed under the iliac muscle. Thin bone fragment of sartorius insertion is sutured to the anterior superior iliac spine, using thick, absorbable suture. The incision must be sutured with proper tension. The insertion of the abductor, iliac muscle, and obliquus externus abdominis should be fixed using thick absorbable suture through drill-holes in the ilium. Close the incision in layers (Fig. 13.32).

13.4.2.5 Postoperative Management

Multimode analgesia management is conducted postoperatively. On the day after surgery, guide the patient to do ankle pump and quadriceps exercise on the bed in order to avoid deep vein thrombosis. Prevent the occurrence of ectopic ossification. Two to three days after the operation, the patient is allowed to walk using crutches without weight-bearing and to exercise lower limb function. Six weeks after the operation, partial weight-bearing should be carried out. Straight leg raise, side-lying, and side-lying hip abduction should be performed gradually to improve the muscle strength around the hip joint and restore gait. According to the evaluation during follow-ups and bone healing, the crutches could be abandoned at 10–12 weeks after the operation, and the gait exercise ought to be conducted.

13.4.2.6 Complications

The occurrence of complications is closely related to the severity of the disease and steepness of the learning curve as well as the surgeon's experience. Ganz et al. reported the early experience of treating 63 patients (75 hips) with this procedure, with a total of 28 early complications, and severe complications in the first 18 cases. Davey et al. studied 70 cases that underwent Bernese PAO performed by the same surgeon. They found that the incidence of serious complications decreased from 17% in the former 35 cases to 2.9% in the latter 35 cases. Common complications include nerve and vascular injuries; malrotation of an acetabular fragment; secondary FAI; limited hip motion; failure of internal fixation; joint penetration; nonunion; heterotopic ossification; hematoma formation; and so on.

13.4.2.7 Outcomes

The outcome of the young patients (<35 years old) with mild hip osteoarthritis (>2 mm interarticular space, no obvious subluxation) were significantly improved postoperatively; and satisfying joint function can be maintained for at least 20 years. Postoperative symptoms can be significantly improved in elderly patients with moderate to severe hip osteoarthritis, but the relief of these symptoms is temporary. These cases may eventually require hip resurfacing arthroplasty or total hip arthroplasty (THA).

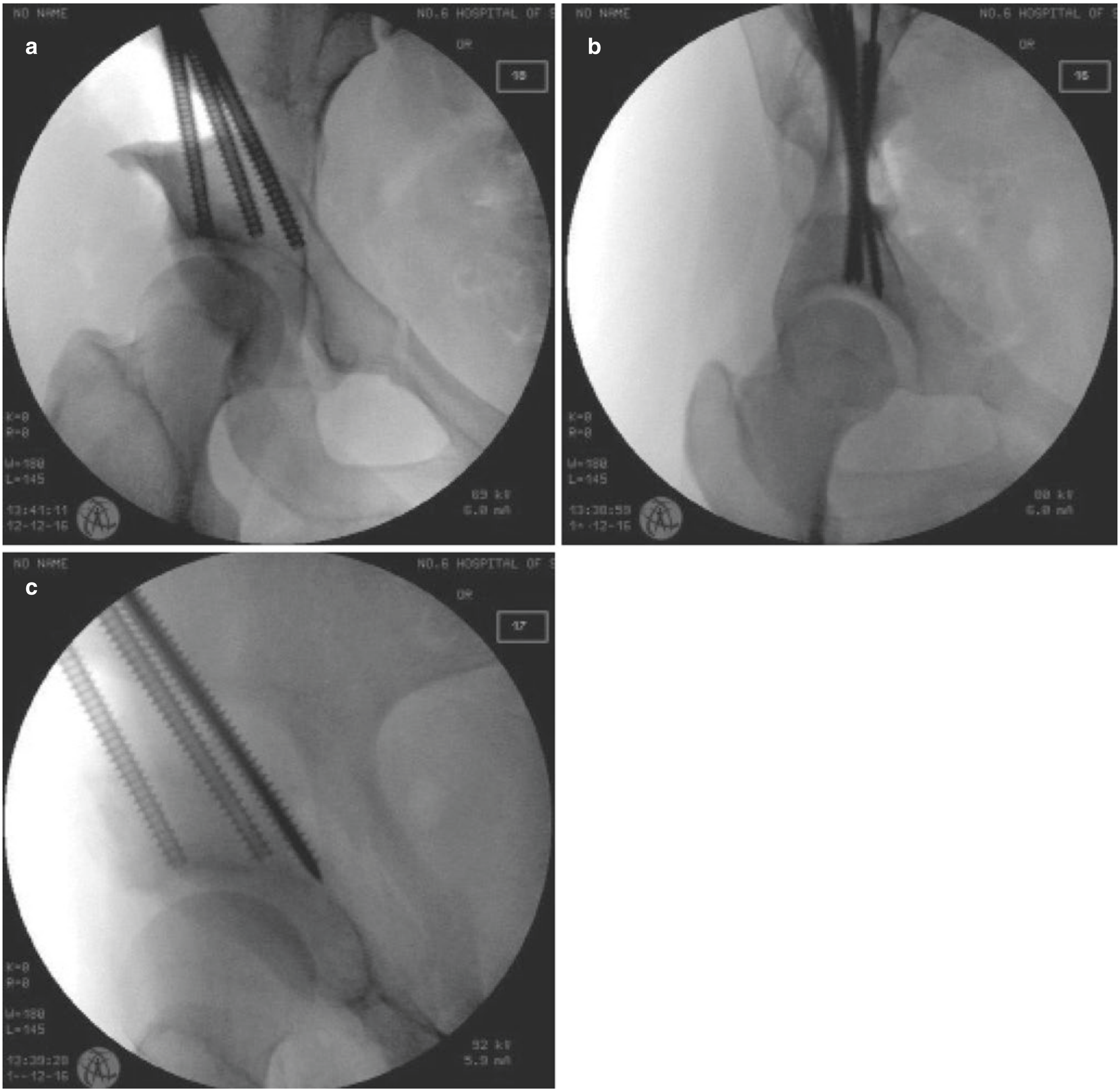

Fig. 13.30 Image from intraoperative fluoroscopy of screws fixation of an acetabular fragment. Confirm the position and length of the screws and ensure that the screws do not penetrate the joint. (**a**) AP view; (**b**) obturator oblique view; (**c**) iliac wing oblique view

13.4.2.8 Treatment of Intra-Articular Abnormalities

DDH could be accompanied by hip impingement syndrome in some cases, which causes persistent pain. The 10-year follow-up study after the PAO found almost 30% of the patients developing impingement symptoms over time. Further studies revealed that the anterior head-neck junction in patients with DDH frequently has no waisting contour, eventually leading to impingement after the PAO. Comprehensive physical and imaging examinations can improve the detection rate of acetabular deformities, cam deformities of the femoral neck, and labral injuries. These intra-articular abnormalities can be treated simultaneously with PAO or by staging operations, which can improve the outcomes of PAO. Commonly used surgical procedures include surgical hip dislocation, anterior capsulotomy, or hip arthroscopy.

Fig. 13.31 Screw fixation

Fig. 13.32 Closure of the incision of the right hip

13.4.3 Spherical Acetabular Osteotomy

13.4.3.1 Indications and Contraindications

The procedure, spherical acetabular osteotomy (SAO), shares the same indications and contraindications with PAO.

13.4.3.2 Surgical Techniques

Basic theory and principle of this procedure are the same as that of PAO, but some detailed techniques are different (Fig. 13.33). This procedure is mainly popular in Japan, and the intermediate to long-term results are satisfactory. It is a curved osteotomy with a spherical chisel along the osseous part of the acetabulum. The distance between the osteotomy plane and the articular surface is kept between 15 and 20 mm. After the osteotomy, the blood supply of the acetabular fragment comes from the branch of the acetabular artery and the

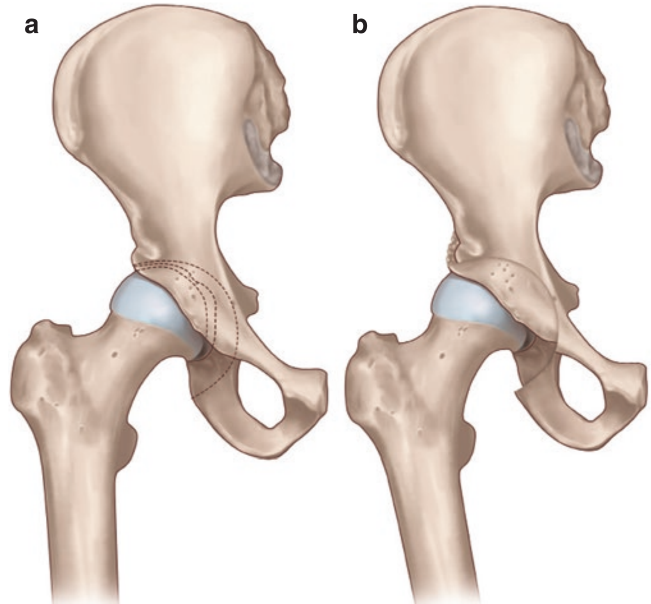

Fig. 13.33 Spherical acetabular osteotomy. (**a**) preoperative hip joint; (**b**) postoperative hip joint

blood supply of the capsule that remains intact, for this reason, the capsule should be not cut open. Rotate the acetabulum fragments forward, outward, and downward to increase the acetabular coverage of the femoral head and increase the stability of the hip joint. Standard fixation consisted of two large modified AO bifurcated tubular plates. Then, the bifurcations are inserted into the osteotomy surface of the acetabular fragments, and each plate is fixed on the lateral wall of the ilium by two bicortical screws.

13.4.3.3 Postoperative Management and Complications

The procedure requires the same postoperative management and has the similar complications with PAO.

13.4.4 Proximal Femoral Osteotomy

13.4.4.1 Indications

The procedure is suitable for DDH with excessive neck-shaft angle and anteversion; incongruency of the joint; and insufficient acetabular coverage.

13.4.4.2 Contraindications

The joint activity is significantly limited, and the treatment goal cannot be achieved by any corrective operation.

13.4.4.3 Preoperative Planning

Fluoroscopy must be performed that the congruency and biomechanical environment of the affected joint can be improved by the procedure. Quantify the femoral anteversion to determine correction angle and direction of the rotation of the acetabular fragments. Preoperative mapping should enable the surgeon to determine the level and position of the osteotomy, the point and direction of implants insertion according to the reference points that can be recognized during the surgery.

13.4.4.4 Surgical Techniques

Proximal femoral osteotomy (PFO) includes varus, valgus, and derotational osteotomy, aiming at restoring the congruency of the hip joint and normal biomechanical environment.

13.4.4.4.1 Approach and Exposure

The patient is placed in a supine position. The standard lateral approach on the proximal femur is adopted. A longitudinal incision of 10–12 cm, from the level of the great trochanter, along the lateral side of femur is made. The fascia latae is cut open to expose the vastus lateralis and the bursa located in the greater trochanter. The vastus lateralis is severed at its origin, where the lower margin of the insertion of gluteus medius locates anteriorly. The vastus lateralis is dissected with an L-shaped incision along the posterior margin. Anterior to the insertion of the gluteus medius, dissect the vastus lateralis downward. Carefully identifying the perforating branch and electrocoagulation is performed to control the bleeding. The femur is dissected subperiosteally to expose sufficient bone surface for plate insertion.

13.4.4.4.2 Osteotomy and Fixation

In some patients with DDH, PAO needs to be combined with a proximal femoral osteotomy to correct the deformities. However, for some DDH patients, a proximal femoral osteotomy can be performed separately which is suitable for cases of DDH with coxa valga and mild acetabular deformities (intertrochanteric) to restore the congruency of the joint. For cases of the flattened femoral head with massive osteophytes on the medial part, it is feasible to perform a valgus osteotomy to improve the coverage, which makes the center of the femoral head shift medially. It can restore the strength of the abductors. Furthermore, a derotational osteotomy is required when dealing with excessive acetabular anteversion.

A curved narrow periosteum elevator is used to strip the periosteum from the planned osteotomy site (above the lesser trochanter). A Steinmann pin is inserted at the proximal end of the osteotomy. Adjust the direction and angle of osteotomy by controlling the Steinmann pin after the osteotomy. For patients with excessive anteversion, before the osteotomy, two K-wires (2.5 mm) parallel to each other and perpendicular to the long axis of the femur can be inserted at the proximal and distal side of designed osteotomy line. When the derotation is performed, the angle between the two pins can accurately show the correction angle and maintain the position during plate fixation. The K-wires are temporarily used. After the designed position is achieved on fluoroscopy, the steel plate is used for fixation and the second fluoroscopy is conducted to confirm the position. If the position and the length of the screw are appropriate, the K-wires can be removed. Irrigate the incision copiously. Reattach the insertion of the vastus lateralis. Close the incision in layers.

13.4.4.5 Complications

Surgical complications include nonunion or delayed union due to inappropriate osteotomy, implants failure, and external rotation deformity of the lower limb caused by neglect of rotational alignment of the femur during the operation.

13.5 Prognosis

Usually, acetabular osteotomy can relieve pain and claudication, but the degree of relief is related to the severity of osteoarthritis before surgery. For patients with acetabular dysplasia who have spherical femoral head and acetabulum, the procedure is expected to provide permanent pain relief and prevent osteoarthritis. The intermediate to long-term follow-up study have confirmed that Bernese PAO can significantly improve the postoperative joint function, with an exceedingly low rate of severe complications, effectively preventing the occurrence and progression of osteoarthritis. Most patients are satisfied with the postoperative joint function. According to the report from University of Bern, the birthplace of the procedure, sixth factors predicting poor prognosis include age at the time of surgery, preoperative Merle d'Aubigne and Postel hip score, the presence of anterior acetabular impingement, limp, grade of osteoarthritis, and postoperative extrusion index. The scholars from Boston Children's Hospital reported that the factors associated with long-term poor prognosis of DDH include an age of more than thirty-five years and poor or fair joint-space congruency.

13.5.1 Case1

13.5.1.1 Medical History

A 42-year-old female was admitted for "bilateral hip discomfort, fatigue after walking for 4 years, right hip pain and progressive aggravation for 1 year." The symptoms of the right hip are severe, and the pain is mild when walking within 20 min or during rest. After 20 min of exercise or when the exercise is strenuous, obvious pain will be presented, and fatigue and limping will occur in the right lower limb. Symptoms of the left hip are relatively mild.

13.5.1.2 Physical Examinations

As for right hip joint, slightly limited ROM with normal flexion and extension was detected. External or internal rotation can induce pain in the hip region. Patrick sign was positive. Trendelenburg sign was negative and straight leg raise test showed negative. As for left hip, ROM was slightly restricted. Patrick sign was positive. Trendelenburg sign and straight leg raise test were negative.

13.5.1.3 X-ray Examination

Pelvic AP view and frog lateral view were obtained, which showed bilateral DDH with right CE angle of 11 degrees and 15 degrees on the left side (Fig. 13.34).

13.5.1.4 Diagnosis

Bilateral DDH.

13.5.1.5 Treatment

After admission, preoperative routine examinations were performed to ensure the absence of surgical contraindications. Because the pain in the right hip joint was more obvious, right PAO was performed which turned out successful. Pelvic AP film taken on the first day after the procedure showed that the right CE angle is 30 degrees (Fig. 13.35).

13.5.1.6 Follow-Ups

The patient's right hip pain disappeared, only with a little discomfort in this region. Daily life remains unaffected. The pelvic AP film and frog lateral film showed the osteotomies had already healed reliably (Fig. 13.36).

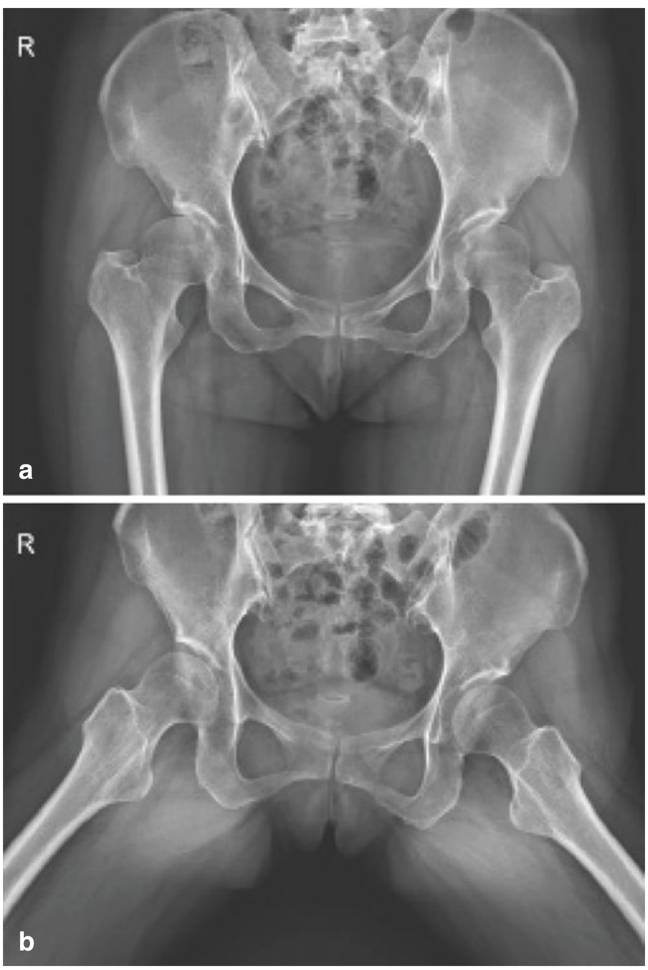

Fig. 13.34 Preoperative pelvic X-ray examination. Bilateral DDH. The right CE angle is 11 degrees. (**a**) AP view; (**b**) frog lateral view

Fig. 13.35 Pelvic AP film after PAO. The radiograph showed significantly improved acetabular coverage. The right CE angle is 30 degrees

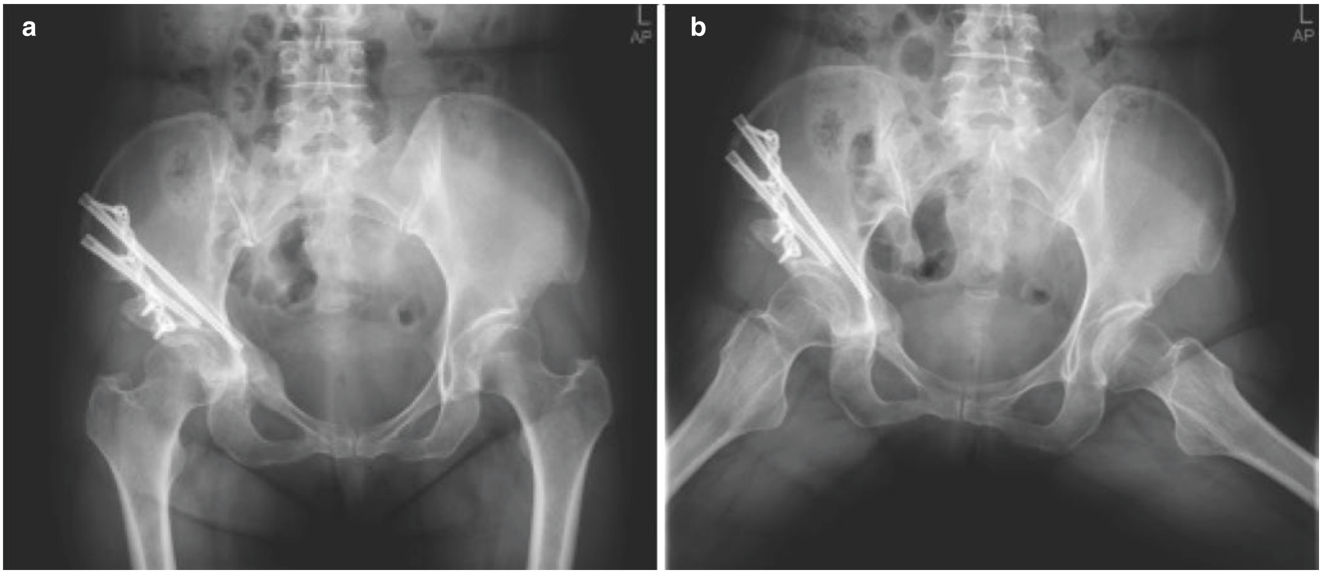

Fig. 13.36 Pelvic film during follow-up. Improved acetabular coverage and healed osteotomies can be observed. (**a**) AP view; (**b**) frog lateral view

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