2 Pelvic Osteotomy for Adult Patients with Hip Dysplasia

Szu-Yuan Chen, Pang-Hsin Hsieh, Wen-E Yang, and Ting-Ming Wang

Abstract

For a DDH patient under age of 40 or an older patient without advanced degenerative arthritis, pelvic osteotomies may be a better choice than a hip replacement. Periacetabular osteotomy (PAO) is indicated for a patient with a relatively congruent hip. Hsieh's periacetabular osteotomy is modified from Ninomiya rotational osteotomy and Ganz Bernese PAO. Trochanter osteotomy provides a better vision to the surgical field and capsulotomy can be done for assessment and debridement for the intra-articular lesions. Round-shaped osteotomy makes rotation of the segment easier and changes the shape of pelvic cavity less than a diagonal osteotomy. Salvage osteotomies with or without a proximal femoral osteotomy are indicated for a patient with an incongruent joint which is not to be restored by a PAO. Chiari osteotomy osteotomizes the pelvis above the acetabulum, medializes the distal fragment, and uses the joint capsule for interposition between the head and the proximal fragment for a better coverage. Shelf acetabuloplasty creates a slot at the pelvis above the femoral head and uses a bone graft to cover the femoral head. Chiari osteotomy has the advantage of a better coverage of the femoral head and better abduction of the hip, while shelf acetabuloplasty is easier to perform and may have fewer complications.

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K.-A. Lai (ed.), *Developmental Dysplasia and Dislocation of the Hip in Adults*,
https://doi.org/10.1007/978-981-13-0414-9_2

Keywords
Developmental dysplasia of the hip · Periacetabular osteotomy (PAO) · Hsieh's modification of PAO · Chiari osteotomy · Shelf acetabuloplasty

Developmental dysplasia is a common cause of osteoarthritis (OA) of the hip [1–3]. Although good long-term results have been recorded following total hip replacement in patients below the age of 50 years [4, 5], disappointing long-term results have been described in patients under 40 years of age [5, 6]. The rationale for performing a pelvic osteotomy in the treatment of adult hip dysplasia is to reposition the dysplastic acetabulum into a more anatomically correct orientation, to provide a better coverage of the femoral head, and thus prevent or deter the need for total hip arthroplasty in these relatively young patients.

Periacetabular Osteotomy (PAO)

PAO was developed to reduce the consequences of hip dysplasia by surgical reorientation of the acetabulum. Growing evidence suggests that timely correction of the deformity may prevent progressive destruction of the hip [7–11]. However, a periacetabular osteotomy is technically demanding, and patients require a long period of rehabilitation.

Evolution of PAO

The Bernese PAO has become popular since it was first described by Ganz et al. [8] in 1988, and several authors have reported encouraging results [12–15]. The Bernese PAO is a major progression from previously described triple innominate osteotomies (TIO). The TIO was originally described by Le Coeur [16] in 1965. In his technique, the pubis and ischium are osteotomized through a single incision near the symphysis. The ilium is then osteotomized just above the sourcil through a Smith-Petersen approach. In 1973, Steel described his technique for the TIO, in which an incision is made just proximal to the gluteal crease and the ischium is divided at the tubercle [17]. In 1981, Tonnis modified Steel's TIO by changing the location of the ischial cut so that it runs immediately inferior to the acetabulum and ends proximally to the sacrotuberous and sacrospinous ligaments, thereby improving acetabular mobility [18]. The ischial osteotomy is performed in the prone position, requiring an intraoperative flip to the supine position, where the pubic and iliac osteotomies are performed in a manner similar to those described by Steel. In 1982, Carlioz introduced a modification to Steel's technique in which the ischial osteotomy starts just below the acetabulum and runs horizontally, ending between the sacrospinous and sacrotuberous ligaments, leaving the sacrospinous ligaments attached to the mobile fragment and sacrotuberous ligament attached to stable fragment. The benefit of the Carlioz technique is that it does not require an intraoperative flip [19].

PAO is a general term that describes a series of bony cuts involved in mobilizing the acetabulum from the surrounding innominate bone to allow reorientation, but it is often used eponymously in reference to the Ganz technique for Bernese PAO. In 1975, Eppright described a barrel-shaped PAO oriented along the anteroposterior axis [20]. This osteotomy allows for increased lateral coverage, but limits the amount of achievable anterior coverage. In 1976, Wagner described three separated types of PAO [21]. In a type I PAO, a hemispherical cut is made around the acetabulum down to the obturator foramen using a specifically designed chisel. The loosened acetabular fragment is then redirected to allow anterolateral coverage of the femoral head. In a type II PAO, a cut is made similar to the cut made in a type I PAO and an autologous bone graft is inserted between the ilium and the acetabular osseous fragment to distalize the acetabular fragment. Type III PAO combines a type I osteotomy with a Chiari-like innominate osteotomy to allow realignment and medialization. In 1984, Ninomiya and Tagawa reported their experience with rotational acetabular osteotomy in skeletally mature patients with symptomatic hip dysplasia [22]. Their procedure was a modification of the circumacetabular osteotomies described by Eppright [20] and Wagner [23]. While the results reported by Ninomiya and Tagawa were satisfactory, the design of the osteotomy tended to leave the teardrop in its original position and technical errors, such as intra-articular penetration or osteonecrosis of the acetabular fragment, have raised concerns about the difficulty of performing this procedure well and in a consistent manner [24].

The Bernese PAO, originally described by Ganz, uses four or five straight osteotomies to separate the acetabulum from the surrounding innominate bone [8]. It has a number of benefits over other techniques. For example, it can be performed through a single incision in the supine position. The posterior column of the innominate bone remains intact, greatly improving stability and allowing for immediate postoperative mobilization without protection by a cast or brace. The bone cuts are performed close to the acetabular center of rotation, thereby facilitating correction of the acetabular fragment. The Bernese PAO reliably results in medialization of the acetabular center, which improves the biomechanics when compared with previously described techniques. The vascularity of the acetabular fragment is preserved via the inferior gluteal artery, which allows simultaneous hip arthrotomy without concern of devascularing the mobile fragment.

Surgical Anatomy

The hip differs from most other joints in the body in that it is deep and nonpalpable from the surface. This highlights the importance of understanding surface anatomy when planning the surgical intervention. During childhood, the articular cartilage of the acetabulum is continuous medially with the triradiate cartilage, lying between the ilium (superiorly), ischium (inferiorly), and pubis (anteriorly) [25]. Closure of the triradiate cartilage occurs at the halfway point of the ascending limb of the pubertal growth curve, corresponding to an approximate bone age of 12 years for girls and 14 years for boys [26]. The hip joint is a highly constrained and inherently stable ball and socket synovial joint formed by the confluence of the acetabulum with the femoral head.

The articular capsule consists of strong and dense collagen fibers arranged in a cylindrical sleeve, connecting the margins of the acetabulum to the proximal femur [27]. Distinct thickening of the articular capsule forms four reinforcing ligaments. The iliofemoral ligament, also known as the Y-ligament or the ligament of Bigelow, lies anteriorly and has an inverted Y shape. The lateral limb restricts internal and external rotation in extension. The medial limb restricts external rotation in extension. The pubofemoral ligament resembles a sling covering the inferior and medial aspect of the hip joint capsule and tightens with hip extension and abduction. The pubofemoral ligament's main restriction is external rotation in extension. The ischiofemoral ligament lies posteriorly. Its two horizontal bands spiral upward to blend with the zona orbicularis. The ischiofemoral ligament's major contribution to the stability of the hip is internal rotation. The zona orbicularis is a circumferential ligament surrounding the femoral neck at the lateral edge of the capsule. The fibers of the zona orbicularis are most abundant at the inferoposterior aspect of the capsule and anteriorly blend with the deep surface of iliofemoral ligament. The zona orbicularis contributes to stability in distraction.

The hip joint is surrounded by 23 muscles divided into five groups based on function: the flexors (iliacus, psoas, iliocapsularis, pecteneus, rectus femoris, and sartorius muscles), the extensors (gluteus maximus, semimembranosus, semitendinosus, biceps femoris long head, and posterior part of the adductor magnus muscles), the abductors (gluteus medius, gluteus minimus, and tensor fascia lata muscles), the adductors (adductor brevis, adductor longus, gracilis, and posterior part of the adductor magnus muscles), and external rotators (piriformis, quadratus femoris, superior gemellus, inferior gemellus, obturator internus, and obturator externus muscles).

The acetabulum receives its blood supply from the superior gluteal, inferior gluteal, and obturator arteries [28]. The obturator artery, a branch of the internal iliac artery, passes anteroinferiorly across the inner table of the pelvis, where pubic branches supply the quadrilateral plate. After exiting through the upper border of the obturator foramen, the artery splits into anterior and posterior branches. The posterior branch gives off an acetabular branch, which supplies the acetabulum ascending through the cotyloid fossa. The largest branch of the internal iliac artery, the superior gluteal artery, heads posteriorly between the lumbosacral trunk and the first sacral nerve before passing above the superior edge of the piriformis as it exits the greater sciatic notch and then dividing into superior and deep branches. The deep branches descend to supply the superior rim of the acetabulum. The inferior gluteal artery descends on the sacral plexus before passing below the inferior border of the piriformis, exiting the inferior portion of the greater sciatic notch. Outside the pelvis, a transverse branch runs inferiorly to supply the inferior and posterior region of the acetabulum. The corona mortis, an anastomosis between the obturator and external iliac vascular system traversing cranial to the superior ramus, is present in 83–84% of patients with a hemipelvis, according to two cadaveric studies [29, 30]. The anastomosis is found, on average, 6.5 cm lateral to the symphysis (range, 3.0–9.0 cm). Thirty-four to 36% of patients with a hemipelvis have an arterial connection, whereas 60–70% of such patients have a venous connection and 20–27.5% have both.

The major pelvis innervation of the lumbar plexus originates from the L1, L2, L3, and L4 roots. The femoral nerve (L2–L4) courses through the psoas and emerges on the inferolateral aspect of the psoas. It then travels between the psoas and iliacus, behind the iliac fascia until it passes under the inguinal ligament, before bifurcating into anterior and posterior branches. The lateral femoral cutaneous nerve (LCFN) (L2–L3) emerges from the lateral border of the psoas major and crosses the iliacus toward the antero-superior iliac spine (ASIS). It then passes under the inguinal ligament medial to the ASIS and over the sartorius in the thigh, where it divides into an anterior and a posterior branch. In two cadaveric studies of a total of 63 limbs, the LCFN was always found to be medial to the ASIS and deep to the inguinal ligament [31, 32]. On average, the LCFN was 3.25 cm medial to the ASIS (range, 0.6–9.2 cm). The obturator nerve (L2–L4) pierces the psoas major, emerging from its medial border near the brim of the true pelvis. It travels posteriorly to the common iliac artery before it descends laterally to the internal iliac artery and ureter. It then travels along the lateral wall of the lesser pelvis and superoanterior to the obturator artery, before exiting through the superior edge of the obturator foramen. Major pelvic innervation of the lumbosacral plexus originates from the L4, L5, S1, S2, and S3 roots. The sciatic nerve (L4–S3) exits the greater sciatic foramen and most commonly courses anteriorly (deep) to the piriformis before crossing posteriorly (superficial) to the superior gemellus, inferior gemellus, and obturator internus. It then travels down the posterior thigh, crossing below the long head of biceps femoris. The superior gluteal nerve leaves the pelvis through the greater sciatic notch above the piriformis, accompanied by the superior gluteal artery and the superior gluteal vein. The superior gluteal nerve provides innervation to the gluteus medius, gluteus minimus, and tensor fascia lata muscles. The inferior gluteal nerve exits through the greater sciatic notch below the piriformis accompanied by the inferior gluteal artery and the inferior gluteal vein. Then, the inferior gluteal nerve provides innervation to the gluteus maximus.

Surgical Indications and Approaches

Indications for the performance of a PAO include closed triradiate cartilage and symptomatic acetabular dysplasia without preexisting arthrosis. Although there is an apparent association between dysplasia and secondary arthritis, there is potential, but no strong evidence, that the correction of dysplasia will decrease the development of future arthritis [8–10]. Thus, a PAO should be a pain-relieving surgery first and a joint-preserving surgery second, not vice versa. Although the lower age limit for a PAO is dictated by the closure of the triradiate cartilage, the upper age limit is more ambiguous. Any patient with dysplasia without arthritis may be considered, but in North America, most patients are younger than the age of 40–45 years, as those with significant dysplasia will often show signs of significant arthritis by the fifth or sixth decade and may be better served by a total hip arthroplasty. However, Hsieh et al. found that a PAO could provide a favorable clinical outcome comparable to that of a total hip arthroplasty in the matched-pair analysis in young active patients [33]. Despite its increased surgical difficulty and longer recovery time, more patients preferred the outcome of the PAO to that of the THR at 2 to 10 years after surgery.

Several types of PAO have been developed in the past decades, and most are considered technically demanding [8, 10, 22]. Difficulties arise not only from the complex anatomical structures of the pelvis but also from the limited visualization provided by various surgical approaches in which some of the bony cuts have to be performed beyond the surgeon's field of view [10]. Opening of the joint offers an opportunity to directly assess intra-articular pathology. However, with a thin fragment created in the rotational acetabular osteotomy [22], capsulotomy is contraindicated because this may alter blood supply to the osteotomized fragment and lead to osteonecrosis. The design of the modified PAO proposed by Hsieh et al. creates a thick fragment with its vascular supply from the inner side of the pelvis; thus, the performance of a capsulotomy is permissible [10].

The PAO procedure can be undertaken through various approaches, including the Smith-Petersen, ilioinguinal, direct anterior, two-incision, and transtrochanteric methods. The classic Smith-Petersen exposure originally used by Ganz et al. carries a high risk of postoperative abductor weakness [34]. Although the use of the modified Smith-Petersen exposure, the ilioinguinal exposure, and recently, the direct anterior exposure to spare abductor dissection have been proposed, we believe that these approaches are still difficult and that surgical exposure can be improved with an alternative approach [24]. A high rate of damaging the lateral femoral cutaneous nerve and a cosmetically unacceptable scar are common problems with the Smith-Petersen approach [34]. Alternatively, the ilioinguinal exposure has been used to decrease abductor morbidity. However, this exposure is associated with other problems (e.g., it makes the assessment of intra-articular disease difficult, increases the likelihood of vascular injury, requires a longer operative time, and makes manipulation of the fragment difficult). The direct anterior exposure advocated by Murphy and Millis is also an abductor-sparing approach [35]. The main concern, however, is the vulnerability of the femoral nerve when dissection proceeds medially to the iliopsoas muscle. In one report two out of five patients, with whom the direct anterior exposure was used, sustained femoral nerve palsies [34]. Importantly, these surgical exposures were all anterior approaches so that the ischial osteotomy had to be performed blindly with special osteotomies, thereby requiring extensive anatomic knowledge and experience [35].

Hsieh's Modification of PAO

To improve exposure, Hsieh et al. [10] modified the techniques described by Ninomiya and Tagawa [22] and Ganz et al. [8]. The use of the transtrochanteric approach provides a sufficiently wide exposure to the osteotomy sites, and it is also a familiar approach used by most orthopedic surgeons.

Surgical Technique

After general anesthesia, the patient is placed in the lateral decubitus position. The leg involved is prepared and draped for easy mobilization during the procedure. A lateral skin incision is made 10 cm proximally to the tip of the greater trochanter and is carried distally along the longitudinal axis of the femur, ending at the base of the greater trochanter. After dividing the fascia lata using a straight midlateral line along the entire length of the skin incision, the anterior and posterior borders of the gluteus medius are identified at its insertion into the greater trochanter. A periosteal elevator is placed between the gluteus medius, minimus muscles, and the joint capsule to allow extracapsular dissection. The greater trochanter is osteotomized with the use of a Gigli saw and is reflected upward with the attached gluteus medius and minimus muscles. The osteotomy should end 0.5 cm proximal to the vastus lateralis ridge so that detachment of the vastus muscle is not required.

To free the joint capsule from the osteotomized trochanter, the piriformis and the proximal part of the conjoined tendon of the short external rotators are divided. Only the proximal part of the short external rotators should be dissected to prevent injury to the medial femoral circumflex artery, which is the main blood supply to the femoral head. The anterior, superior, and posterosuperior aspects of the capsule are then visualized. At this time, a T-shaped capsulotomy can be made, first, by a longitudinal incision to the anterolateral aspect of the joint capsule and, second, by a transverse incision along the acetabular rim. The flaps are retracted for direct inspection of the joint.

To proceed with the anterior exposure, the reflected head of the rectus femoris muscle is detached form the joint capsule to expose the anterior rim of the acetabulum. Through the plane between the iliocapsularis muscle, which is adherent to the anterior part of the capsule, and the psoas muscle, one can palpate bone medially and distally to the level of the base of the superior pubic ramus. Blunt dissection is performed deep to the rectus femoris and iliopsoas muscles to avoid injury to the neurovascular bundle that lies anterior to the iliopsoas. This dissection is made easier if the hip is flexed.

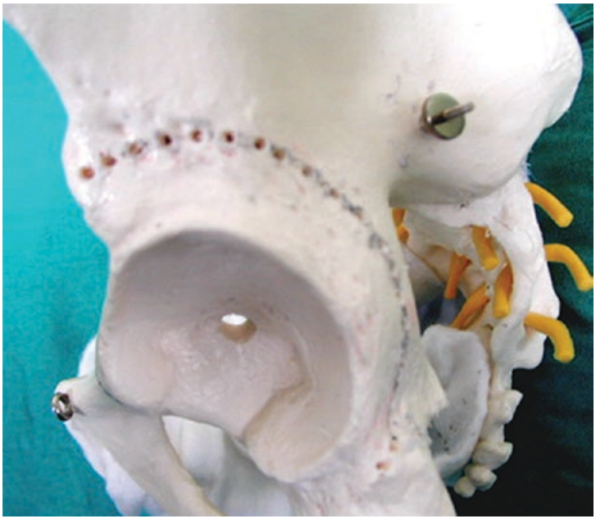

Fig. 2.1 The osteotomy is spherical in shape around the circumference of the acetabulum and is approximately 1.5 cm from the acetabular ridge

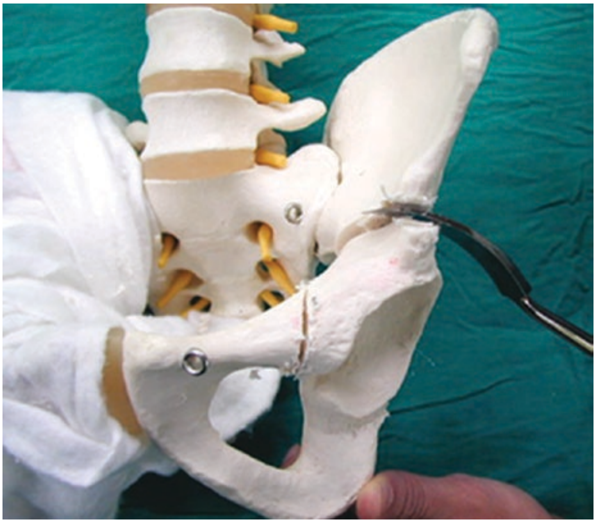

Fig. 2.2 The osteotomy penetrates the inner pelvic table rather than the medial part of the acetabular wall. Thus, the risk of creating an intra-articular osteotomy is minimized

With the use of a curved osteotome, the osteotomy is begun at the superolateral portion of the ilium, 1.5 cm from the acetabular ridge. We extend the osteotomy anteriorly and posteriorly around the circumference of the acetabulum (Fig. 2.1). Our method differs from the rotational acetabular osteotomy described by Ninomiya and Tagawa [22], in that it penetrates the inner pelvic table rather than the medial part of the acetabular wall (Fig. 2.2). Thus, the risk of creating an intra-articular osteotomy is virtually eliminated. In addition, we create a larger acetabular

Figs. 2.3 and 2.4 The correction is made by anterior and lateral rotation of the fragment. Because the fragment is smooth and round, the displacement is usually obtained without creating large gaps at the osteotomy site

fragment that includes the inner pelvic table, decreasing the potential complications of osteonecrosis.

After the osteotomy of the ilium and the ischium is completed, the fragment is connected to the pelvis only at the pubis. The osteotomy at the base of the superior pubic ramus is made easier with the leg flexed. It is safe to perform the pubic osteotomy through the plane between the flexor muscles and the joint capsule, and the location and the direction of the pubic osteotomy can be confirmed with an intraoperative anteroposterior radiograph.

When the osteotomy is completed, the surgeon controls the fragment with a bone hook to redirect the acetabulum. The main corrective displacement is by anterior and lateral rotation, but the fragment can also be shifted more medially. Because the fragment is smooth and round, the correction is usually obtained without creating gaps at the osteotomy site (Figs. 2.3 and 2.4).

After temporary fixation of the osteotomy with two Kirschner wires, the range of motion of the hip is tested. A radiograph is performed to confirm the amount of correction. The fragment is fixed to the ilium with three or four 3.5 mm cortical screws. The freed greater trochanter is then reduced and stabilized with two 6.5 mm cancellous screws. The joint capsule, the origin of the rectus femoris muscle, and short external rotators are repaired. Suction drains are placed anterior and posterior to the capsule.

Postoperative Care

No cast is required. Early active range of motion is encouraged. The patient is instructed to walk with crutches and partial weight bearing after the pain has subsided, usually on the fourth or fifth postoperative day. After 6 weeks, the patient is allowed to walk with one cane. The cane is usually discarded 3 months postoperatively when osseous healing is evident radiographically (Fig. 2.5a–f). We do not prescribe indomethacin for prophylaxis against heterotopic bone formation nor pharmaceutical prophylaxis for deep vein thrombosis because these complications are rare in our population.

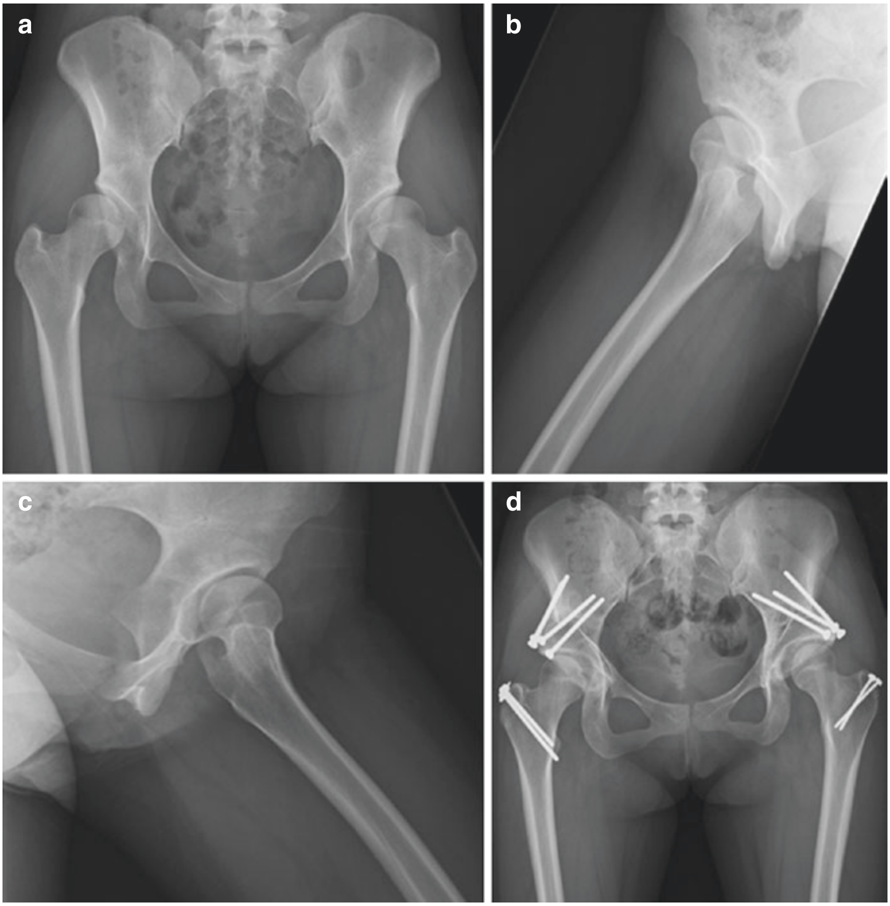

Fig. 2.5 The radiographs of a 19-year-old girl who had bilateral hip dysplasia. Anteroposterior (**a**) and lateral (**b** and **c**) views show the deformity before surgery. Five years after bilateral periacetabular osteotomy, the radiographs show good correction, healed osteotomy, and adequate joint spaces (**d**–**f**) (These pictures were agreed by the patient for publication)

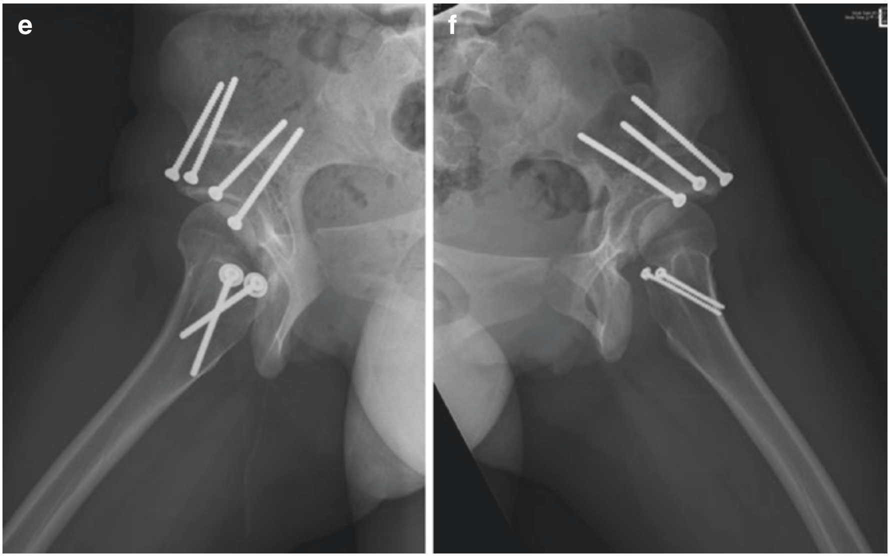

Fig. 2.5 (continued)

Outcomes of PAO

Management of young active patients with symptomatic OA secondary to hip dysplasia is a major challenge. PAO is usually considered for early OA (Tonnis grade 0–2) to arrest or delay its progression [8–10], and total hip arthroplasty is often required for advanced changes (Tonnis grade 3). Hsieh et al. found that, at the time of a follow-up at 2 to 10 years postoperatively, PAO led to similar functional results as did a total hip arthroplasty. Both groups of patients showed marked improvement in the Merle d'Aubigne and Postel hip scores, and most patients had high WOMAC scores in both hips. More patients preferred the outcome in the hips treated with a PAO to those treated with a total hip arthroplasty. Joint-preserving PAO can provide favorable clinical outcomes comparable to that of a total hip arthroplasty in the matched-pair analysis in young active patients (Fig. 2.6a–f). Despite its increased surgical difficulty and longer recovery time, more patients preferred the outcomes of a PAO to that of a total hip arthroplasty at 2 to 10 years after surgery. In the treatment of young adults with symptomatic developmental dysplasia of the hip, these findings should be considered during clinical decision-making.

With the osteotomy proposed by Hsieh et al. [10], the osseous cuts are near the acetabulum so that a large correction in the acetabular orientation is achieved

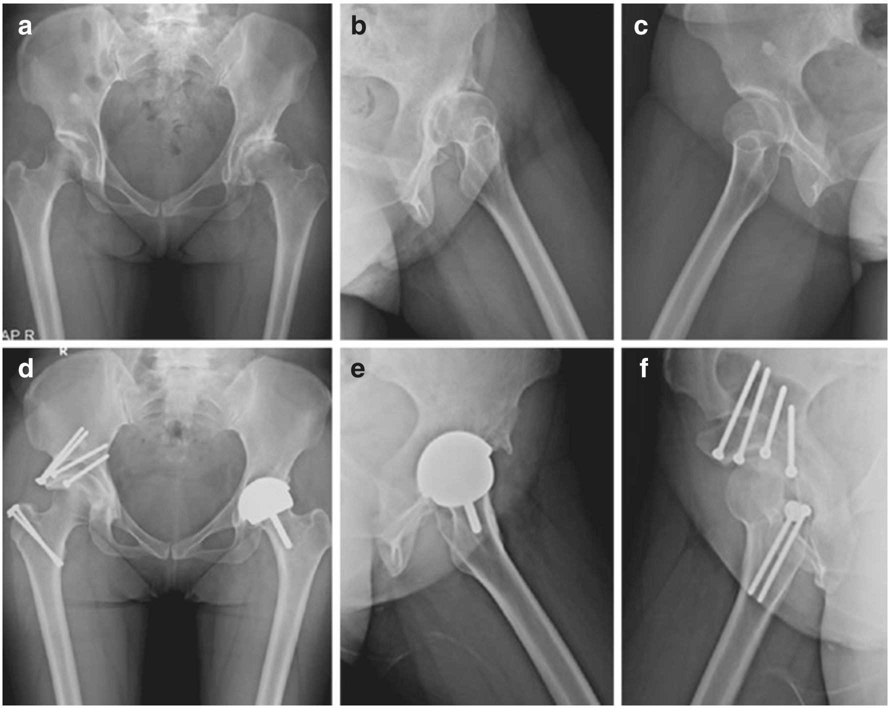

Fig. 2.6 The radiographs of a 35-year-old woman with bilateral dysplastic hips. Preoperative anteroposterior (**a**) and lateral (**b** and **c**) radiographs show advanced osteoarthritic changes in the left hip and mild osteoarthritis in the right hip. The postoperative radiographs (**d**–**f**), performed 9 years after resurfacing hip arthroplasty and 6 years after PAO, show well-fixed prosthesis in the left hip and solid bony union with good joint congruity in the right hip (These pictures were agreed by the patient for publication)

without altering the shape of the true pelvis, a benefit that allows young female patients to give birth naturally. In addition, maintaining the continuity of the posterior column offers the reliable stability of the pelvis for fixation of the fragment. Therefore, early postoperative mobilization is allowed without adverse effects on the osseous union.

Our osteotomy is spherical in shape, which is similar to the design of the rotational acetabular osteotomy [22]. The smooth, rounded surface allows easy mobilization of the fragment in all directions without impingement, and it provides a large area of contact, which results in rapid and predictable bone healing. In contrast, the polygonal shape of the Bernese osteotomy can result in large gaps, especially when a large corrective displacement is required. Furthermore, nonunion or delayed unions have been reported in other studies involving the Bernese osteotomy [8, 13, 34, 35].

The transtrochanteric approach through a single lateral incision has several advantages. Firstly, it is a familiar technique for most orthopedic surgeons and provides sufficient exposure, including the posterior column of the hemipelvis.

Secondly, the PAO can be performed outside the pelvis with minimal dissection of important structures. Thirdly, there is no change in the length of the abductors, and the abductor mechanism can be securely restored by bone-to-bone healing. Finally, this approach allows a surgeon to perform arthrotomy of the hip joint to directly assess intra-articular disease, which has been considered an important cause of residual symptoms [36].

Complications of trochanteric osteotomy include increased operative trauma, blood loss, and bursitis, with the most commonly noted serious complication being nonunion [37–39]. This complication is frequently seen in patients following a total hip replacement when the blood supply in the trochanteric area has been altered by the insertion of a femoral stem and the osteotomized trochanter can only be fixed by cables or wires [40]. In the series proposed by Hsieh et al., however, fixation was performed with two cancellous screws and bone healing was uneventful in all cases [10].

Computer-Assisted PAO

Computer-assisted image-guided surgeries, also called navigation surgeries, have recently been introduced to improve the accuracy and safety of hip, knee, and spine surgeries [41]. These technologies provide real-time, three-dimensional images of the position and orientation of surgical instruments with respect to the patient's anatomy. Hsieh et al. compared computer-assisted navigation and conventional techniques for PAO and found that the CT-based navigation effectively reduced the need for intraoperative radiographs and surgical time by a surgeon experienced with PAO surgery, although no differences with regard to the operative blood loss, transfusion requirement, radiographic correction of the deformity, and the functional outcomes between the groups were found [42]. A surgeon less experienced with PAO may benefit from application of the computer-assisted system more than an experienced surgeon.

In conclusion, an ideal technique of PAO for the treatment of hip dysplasia in adults should be safe and easy to perform and provide reliable stability and predictable correction with minimal use of postoperative external support. In addition, it should also allow the surgeon to address the intra-articular abnormality and have a low prevalence of complications.

Salvage Osteotomy of the Pelvis

Because the application of a PAO restores a nearly normal anatomy for most adult dysplastic hips, other pelvic osteotomies have been performed less often recently. However, some of the osteotomies may still be useful when PAO is not expected to be successful. These osteotomies that aim at providing a better coverage of the femoral head instead of restoring the congruity are referred to as "salvage" osteotomies. Among them, the most often mentioned are Chiari osteotomy [43–49] and shelf acetabuloplasty [49–54].

Indications for Salvage Osteotomy

Young patients with dysplasia of the hip and poor congruity between the femoral head and the acetabulum can be considered for salvage pelvic osteotomy, because a PAO cannot restore the congruity and an arthroplasty at a very young age is known to have poor long-term results.

The differences between Chiari osteotomy and shelf acetabuloplasty are that the Chiari osteotomy osteotomizes the pelvis above the acetabulum, medializes the distal fragment, and uses the joint capsule for interposition between the head and the proximal fragment for a better coverage, while shelf acetabuloplasty only creates a slot at the pelvis above the femoral head and uses a bone graft to cover the femoral head. Chiari osteotomy has the advantage of a better coverage of the femoral head and better abduction of the hip, while shelf acetabuloplasty is easier to perform and may have fewer complications.

The Chiari Osteotomy

The level and angle of the osteotomy is very important for the success of the surgery. The patient is placed supine on a radiolucent operation table to allow for the usage of an image intensifier during surgery. An anterior approach, usually the Smith-Petersen approach, is applied to expose the joint capsule, outer and inner tables of the pelvis, and the sciatic notch. A greater trochanter osteotomy may improve the exposure. The pelvic osteotomy is guided by an image intensifier, started at the brim of the acetabular insertion of the joint capsule, slightly curved to contain the joint capsule, and aimed at about 10° superiorly toward the inner table. After completion of the osteotomy, the distal fragment is translated medially until the joint capsule and the femoral head is well covered by the proximal fragment. The proximal and distal fragments are then fixed with screws or threaded pins (Fig. 2.7a–c).

Partial weight bearing can be allowed if the fixation is stable. Full weight bearing is allowed after the union of the osteotomy, and muscle strengthening exercise is started.

Although the Chiari osteotomy is referred to as a salvage surgery, it is technically demanding. If the osteotomy level is too low, the pressure on the medialized joint capsule might be too large and could cause necrosis of the joint capsule and prevent its metaplastic change into fibrocartilage. If the osteotomy level is too high, the transfer of the load for coverage of the femoral head is not achieved. The angle of the osteotomy and displacement of the distal fragment must be done meticulously to prevent damaging the sciatic nerve and poor coverage or impingement of the fragments.

Reported results of Chiari osteotomies varied widely because they usually contained mixed patient selection [47–49]. Major complications such as sciatic nerve palsy, nonunion and ectopic ossification were reported. Conversion to a surface replacement arthroplasty may be difficult due to difficult dislocation of

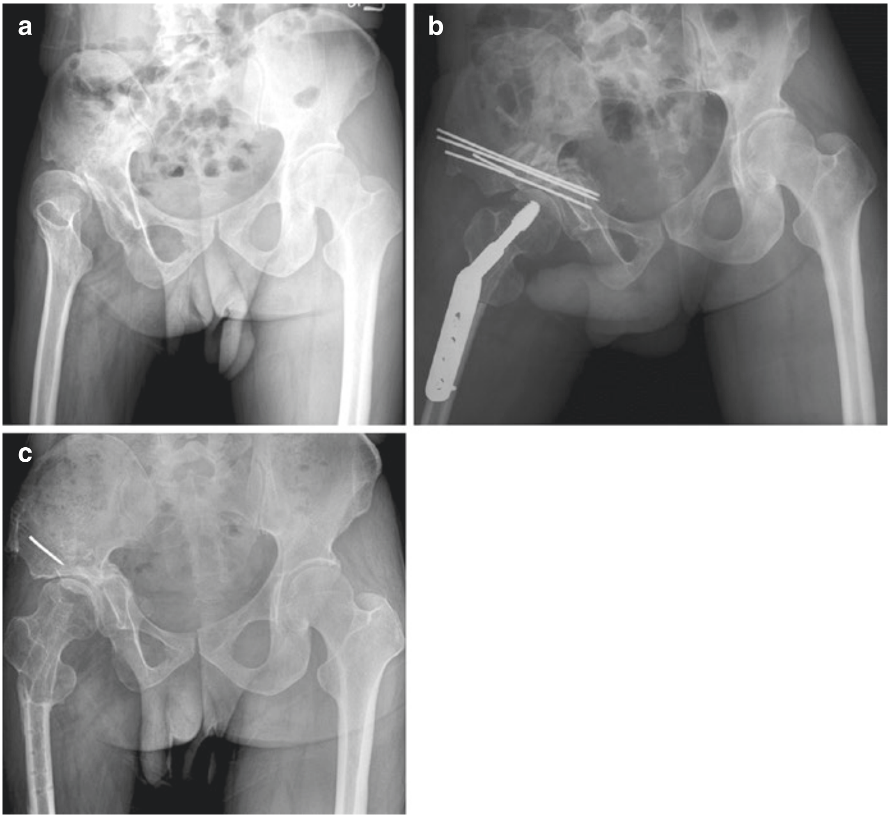

Fig. 2.7 (**a**) The anteroposterior X-ray of a 53-year-old male patient showing dysplasia and Hartofilakidis' low dislocation of the right hip. (**b**) A Chiari pelvic osteotomy with shortening-derotation osteotomy of the proximal femur was done. (**c**) After the removal of the fixation devices, acceptable coverage of the femoral head was observed 6 years after surgery (These pictures were agreed by the patient for publication)

the femoral head. However, conversion to total hip may be benefited by a deeper and larger acetabulum [50].

Shelf Acetabuloplasty

Shelf acetabuloplasty provides acetabular augmentation and extends acetabular size for aspheric congruity. It is a capsular arthroplasty based on the transformation of a fibrous capsule into fibrous cartilage.

The shelf procedure was first described by Konig [51] in 1891, and many modifications have been reported since. It can be used alone or in combination with other reconstructive procedures. Staheli's modification [52] of the shelf procedure—the slotted acetabular augmentation (SAA)—is done usually with the anterior approach

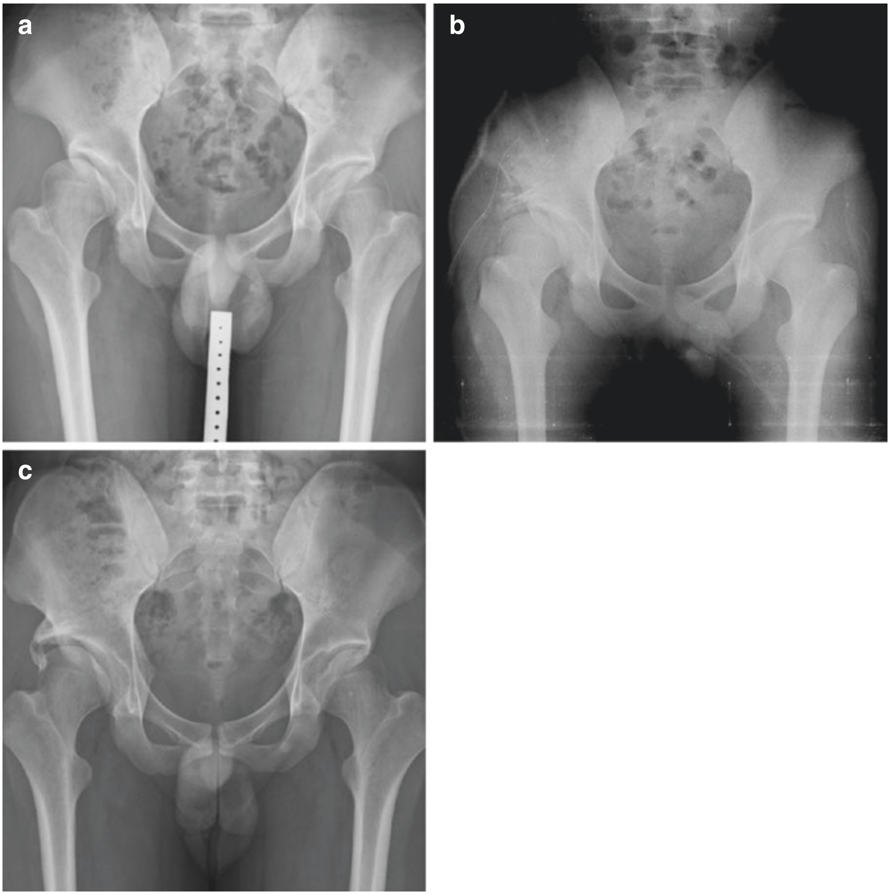

Fig. 2.8 (**a**) An anteroposterior X-ray of a 16-year-old boy shows the right hip dysplasia with an aspherical femoral head. (**b**) A shelf acetabuloplasty with SAA modification was performed. (**c**) Acetabular new saucer formation with acceptable coverage of the femoral head was observed 4 years after the operation (These pictures were agreed by the patient for publication)

of the hip. After lifting the rectus femoris tendon, a row of holes is drilled along the edge of the acetabulum. A slot is created along the holes. Strips of corticocancellous bone are harvested from the outer table of the ilium and inserted into the slot. The second layer of bone strips is paved. The reflected rectus tendon is sutured and more bone graft is added (Fig. 2.8a–c).

Partial weight bearing and external protection are necessary before consolidation of the bone graft.

The main complication of the SAA is the absorption of bone graft if it is placed too high from the joint. Other minor complications such as fracture and lateral femoral cutaneous nerve dysesthesia are reported.

Compared with other pelvic osteotomies, the shelf procedure is simpler and safer; there's no need for internal fixation, no interfering with the birth canal, and no risk of sciatic nerve injury; and it can be performed in both hips at one stage. The disadvantages are that the hip is not medialized and that it needs a long period of protection.

The long-term survival of the shelf procedure was around 60% at 15 years and 40% at 20 years [53, 54]. It also provides a better socket for total hip replacement when it becomes necessary.

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