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Human hip dysplasia: evolution of current treatment concepts

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Abstract Developmental dysplasia of the hip is best treated during infancy. Residual dysplasia is a major cause of disability and should be corrected surgically at an early age. Children 3–8 years of age are usually treated with an acetabular reshaping osteotomy, such as the Pemberton procedure or the San Diego osteotomy. Children over age 8–10 years are best treated using triple innominate osteotomy. After age 14–15 years, when the triradiate cartilage is closed, the Ganz periacetabular osteotomy provides effective correction of residual dysplasia. Surgical intervention during childhood or teenage years can alter the natural history of hip dysplasia and greatly improve hip-joint longevity.

Key words Hip dysplasia · Childhood · Osteotomies

Introduction

Developmental dysplasia of the hip, a common orthopedic disorder, is ideally diagnosed and treated during infancy.[16] Infantile cases can be treated with a Pavlik harness or some other abduction device. In most cases this is successful, with the child not requiring subsequent hip surgery. In some cases, however, acetabular growth[12] is inadequate, and the child requires a subsequent acetabular osteotomy to avoid premature hip arthritis.

In other cases of hip dysplasia, the child does not have a true dislocation but, instead, has a partial form of the disease with a poorly formed, inadequate hip socket that eventually will develop premature arthritic symptoms.[6,18,19] In some cases onset of symptoms is as early as 6–8 years of age, but they appear more commonly during the teenage years; even more commonly they are seen during young adult life. Thus, previously undiagnosed and untreated hip dysplasia is an important orthopedic problem. Harris[6] noted that the most cases of hip arthritis in adults, previously thought to be idiopathic, are actually the sequelae of a prior developmental abnormality. The most common of these is residual hip dysplasia (Fig. 1).

The purpose of this paper is to define our approach to hip dysplasia during childhood, as seen at Children's Hospital, San Diego.[2,5,8] Diagnostic and therapeutic concepts are presented. The content of this paper represents a review rather than a study documenting results in individual treatment groups.

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Diagnosis and treatment according to age

Young children with complete dislocation of the hip

Modern treatment of the child with a completely dislocated hip has become standardized. Children under age 18–24 months are treated with an initial attempt at closed reduction plus cast immobilization, which is often successful. The value of preliminary traction to decrease the risk for avascular necrosis (AVN) remains controversial.[16] Once the child is more than 1.5–2.0 years of age, the best treatment is primary open reduction with a capsulorrhaphy and acetabuloplasty performed at the time of open reduction (Fig. 2). Capsulorrhaphy is an important component of the procedure, with careful suturing to prevent redislocation. Others have suggested a circumferential capsulotomy/capsulectomy to achieve the same goal. We use the Salter acetabuloplasty[14] in this type of patient because it redirects the acetabulum without changing the acetabular shape or volume.

The Salter procedure is the best known of all acetabular osteotomies used in children, and its principles have been clearly defined.[14] The benefits of osteotomy

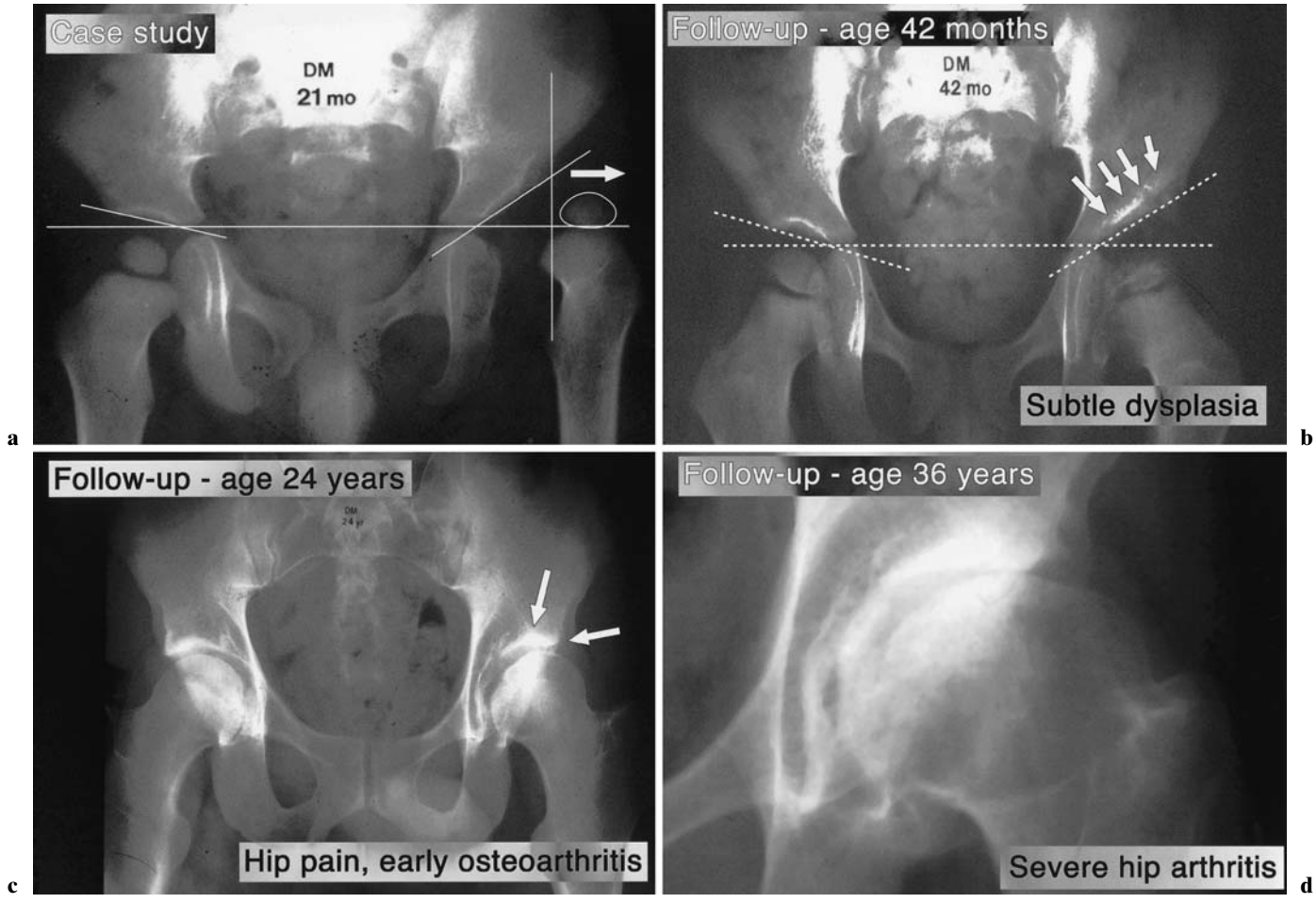

Fig. 1. **a** Radiograph of a 21-month-old girl with complete dislocation of the left hip. The child was treated by a closed reduction followed by spica cast immobilization in a Lorenz-type hip spica cast for 4 months. **b** Follow-up radiograph at age 42 months. The hip was thought to be adequately reduced. There is no break in Shenton's line. Despite significant residual dysplasia the surgeon thought that the child should be followed conservatively. **c** Patient at age 24 years. Anteroposterior (AP) radiograph demonstrates continued residual hip dysplasia, and the patient now has pain and early osteoarthritis. **d** Follow-up at age 36 years. The patient now has severe painful arthritis in the left hip. She required total hip replacement at this time. (Radiographs courtesy of Dr. Stuart Weinstein)

are that it is a widely understood procedure and is relatively easy to perform once one learns the principles. Care must be taken to rotate the acetabulum properly, place the triangular bone graft, and correctly place the threaded K-wires required for fixation.

The procedure provides improved anterolateral coverage and nearly full correction of residual dysplasia at the time of the primary open reduction. The smaller than normal acetabulum is simply redirected, with no risk that a bending maneuver will decrease the size or volume of the socket. Because the osteotomy is complete, fixation with threaded K-wires is required, which is a disadvantage in that one must later remove them, requiring a second exposure to general anesthesia. This is one of the reasons we do not use the Salter procedure in older children with residual dysplasia (without complete dislocation) and, instead, perform the Pemberton procedure or the San Diego-type procedure.

When a child with a complete dislocation is more than age 2–3 years, we combine the open reduction and Salter osteotomy with a derotational femoral shortening osteotomy (Fig. 3). This allows stable, safe reduction of the femoral head without preliminary traction.[20]

Residual hip dysplasia in children 2–8 years of age

Most busy pediatric orthopedic surgeons see a relatively large number of patients 2–8 years of age with residual dysplasia who require treatment. The child may have been in the clinic system since infancy with an acetabulum that has not fully developed despite treatment with a cast, Pavlik harness, or abduction brace. Occa-

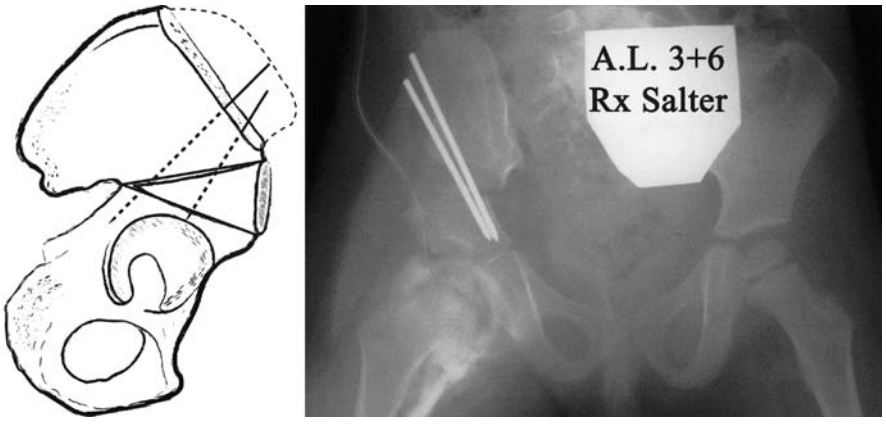

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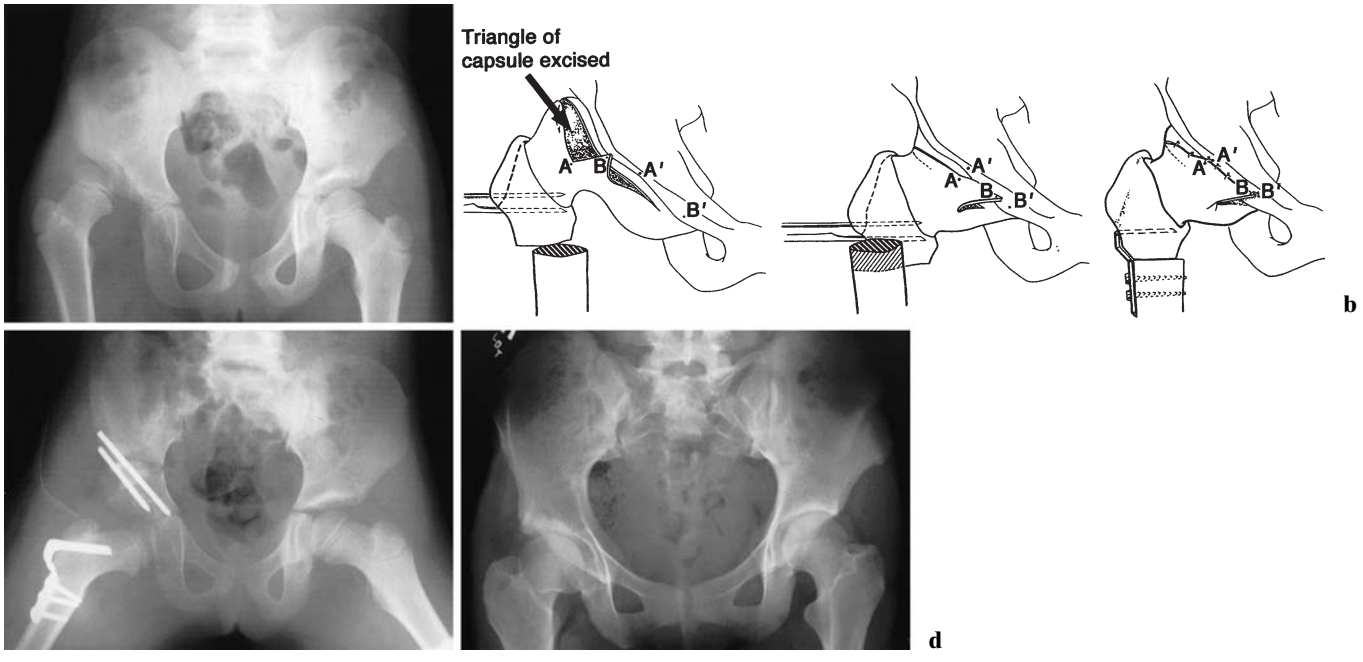
Fig. 2. a Salter innominate osteotomy. **b** Postoperative radiograph of a child treated by open reduction plus Salter innominate osteotomy



a b c d

Fig. 3. Open reduction plus Salter plus femoral osteotomy. **a** Preoperative AP radiograph of the pelvis of a 6-year-old child with a completely dislocated right hip. **b** Principle of open reduction plus femoral shortening plus capsulorrhaphy.[19] Salter-type capsulorrhaphy includes excision of a superolateral triangle of capsule (*arrow*). After excising this triangle, point *A* is an area on the anterior capsule at about the center of the femoral head. Point *B* is an area on the capsule just below the anteroinferior spine at the anterior rim of the acetabulum. This capsulorrhaphy method involves internal rotation of the femoral head, with the capsule being stretched medially. *A* is then sutured to the edge of the acetabulum near the anterosuperior spine (*A′*). *B* is sutured to the periosteum of the pubis (*B′*). **c** Immediate postoperative radiograph after open reduction plus femoral shortening plus capsulorrhaphy plus Salter innominate osteotomy. **d** AP radiograph of the pelvis 9 years later. The right femoral head remains well covered

sionally, a child without known prior hip disease presents with symptoms or perhaps has undergone radiography for other purposes that revealed occult hip dysplasia. It is now widely recognized that such patients should be treated surgically rather than waiting to see if they develop symptoms or if symptoms are present until they become severe.[3,8] Hip symptoms can be attributed to shear stress on the acetabular cartilage in the presence of hip dysplasia (compared to compression forces in the normal, nondysplastic hip). The goal of surgery designed to correct hip dysplasia is to convert pathologic shear forces to more normal compressive forces by an acetabular osteotomy that repositions the acetabulum.

A wide variety of acetabular osteotomies can be used to correct dysplasia in this age group, with addition of a

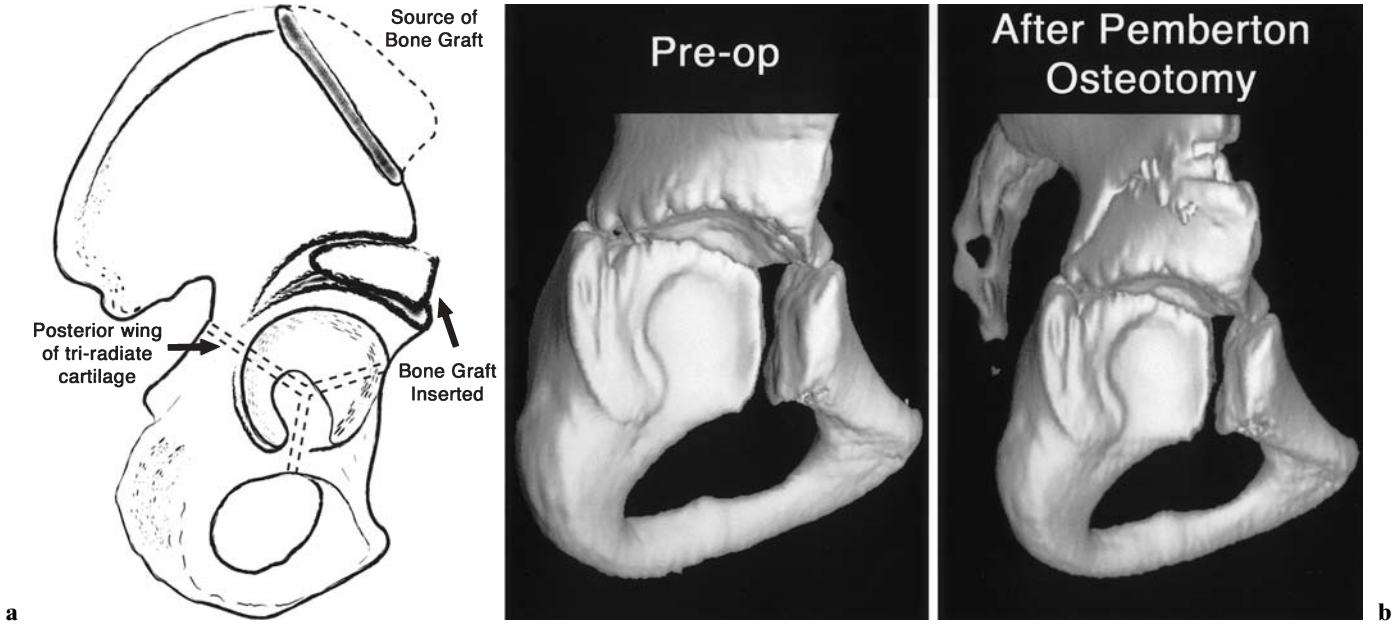


Fig. 4. Pemberton acetabuloplasty. **a** Nature of the Pemberton acetabuloplasty. **b** Preoperative and postoperative three-dimensional computed tomography (3D CT) scan of a child who had undergone a Pemberton acetabuloplasty to correct subtle hip dysplasia

femoral osteotomy in the most severe cases. Traditionally, most North American surgeons have used the Salter acetabular procedure, which is highly effective in this age group. On the other hand, because internal fixation using threaded pins is required for the Salter procedure, a second operation is required for pin removal. For this reason, at Children's Hospital – San Diego we use the Pemberton osteotomy[11] to treat residual dysplasia in this age group.

Pemberton osteotomy

The Pemberton osteotomy cut is directed toward the posterior wing of the triradiate cartilage and hinges on this posterior wing in the area behind the acetabulum. This angular hinging changes the acetabular shape and is commonly used for a child who has a sloping, migrating acetabulum where it may be desirable to correct the acetabular shape (Fig. 4).

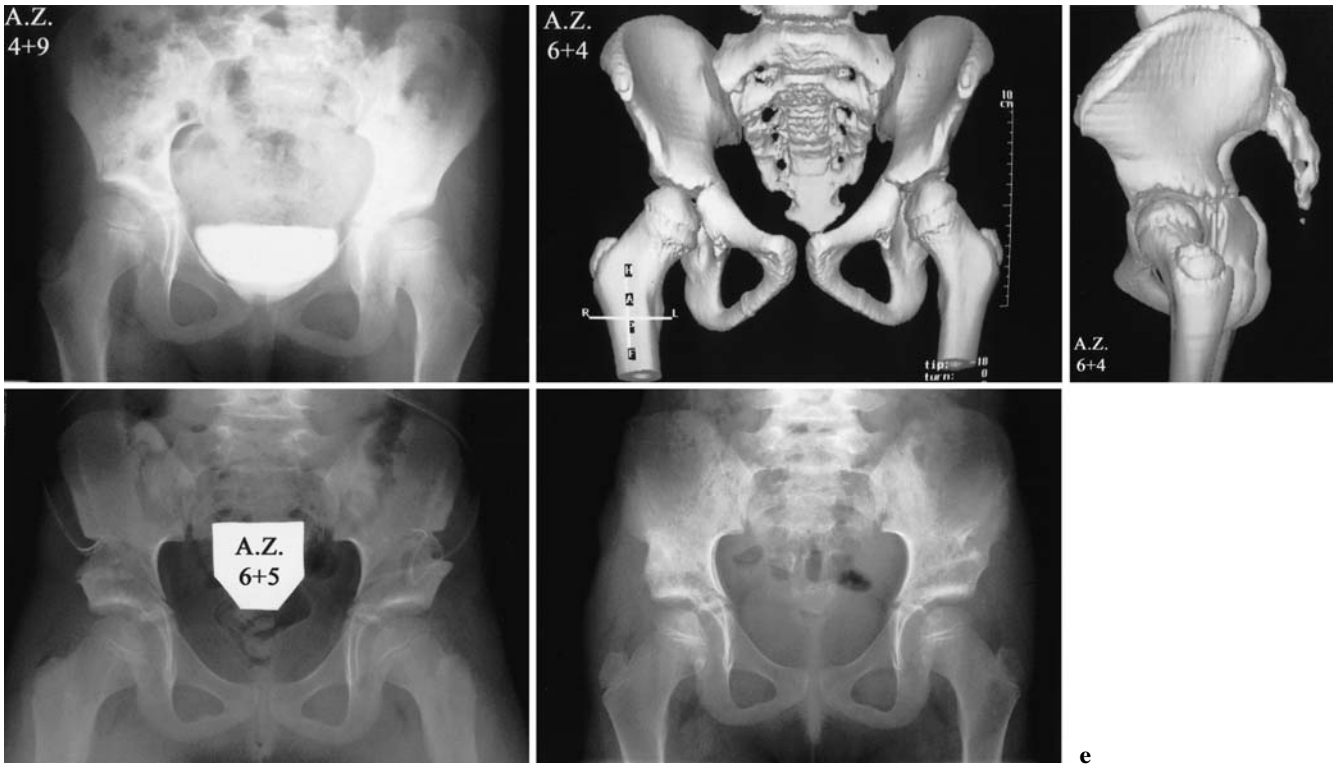
The Pemberton osteotomy technique has been widely described in both the original publication[11] and subsequent orthopedic texts. Briefly, an anterolateral approach is made to the hip, with the wing of the ilium exposed medially and laterally. A series of cuts are made on the inner and outer wall of the acetabulum, extending posteriorly and down to the posterior wing of the triradiate cartilage. The acetabulum can then be hinged and rotated anterolaterally with a slightly curved triangular graft taken from the iliac crest and placed in the osteotomy. This provides secure stability in most cases, and internal fixation is not required.

In our experience, the results of the Pemberton osteotomy are similar to those achieved by the Salter operation for correcting dysplasia and is the desired procedure in this age group because subsequent surgery to remove pins is not required (Fig. 5). Also, the osteotomy is innately more stable than the Salter procedure because the cut through the ilium is incomplete. Thus, bilateral surgery can easily be performed on the same day.

San Diego acetabuloplasty

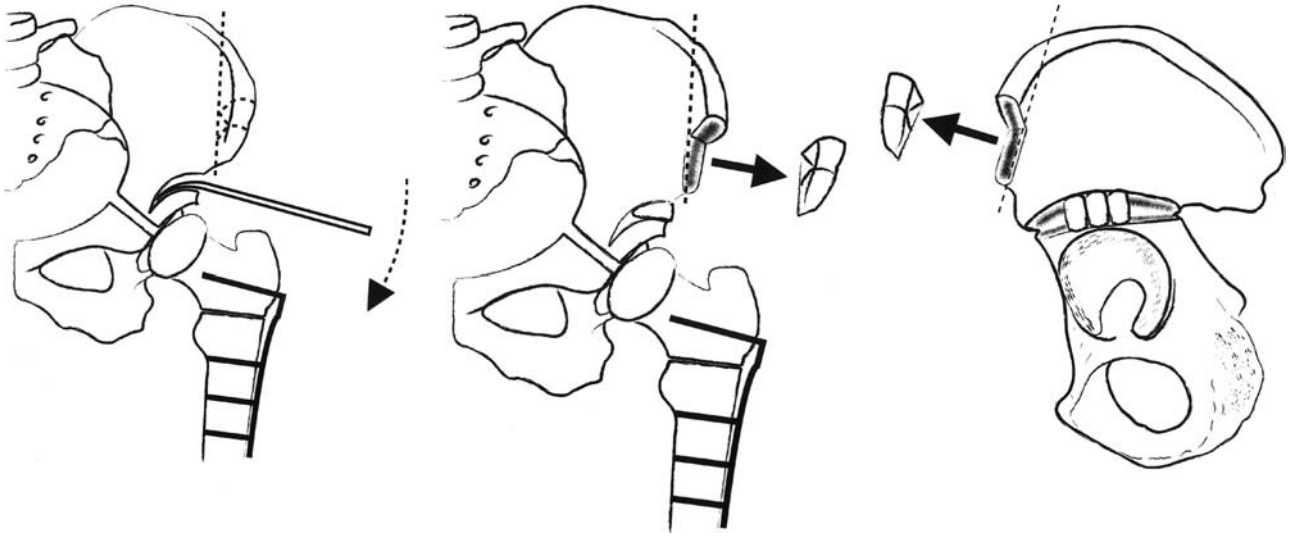
Although this paper is primarily directed toward normal children who do not have neurologic conditions, it is appropriate to mention the San Diego acetabuloplasty,[9] which we designed for children with neuromuscular hip dysplasia. We often perform three-dimensional computed tomography (3D CT) to analyze the nature and degree of acetabular deficiency. In neuromuscular hip dysplasia patients the deficiency is usually superior and posterior,[7] so acetabuloplasty should improve coverage in this area.[9] Using the San Diego method, one can place the triangular bone grafts laterally to maximize this coverage (Fig. 6) with symmetrical triangular grafts placed in a manner that ensures improved posterior coverage.

This procedure is primarily used in children with cerebral palsy. On the other hand, if one sees a normal



a,b c d e

Fig. 5. Pemberton acetabuloplasty. **a** AP radiograph of a child with bilateral subtle residual acetabular dysplasia. **b** AP 3D CT scan depicting dysplasia. **c** Focal 3D CT view of the left hip clarifying the subtle anterolateral deficiency. **d** After bilateral Pemberton acetabuloplasty. **e** Follow-up AP radiograph of the pelvis



a,b c

Fig. 6. San Diego acetabuloplasty. **a** Position of the osteotome as noted on the frontal view using an image intensifier. **b** Origin and placement of bone graft. Note also the proximal femoral derotational shortening osteotomy. **c** Direct lateral view of acetabulum demonstrating placement of grafts. The posterior graft is at least as large as the anterior graft for improving posterolateral coverage

child who has dysplasia and a straight lateral acetabular deficiency (or the occasional superior and posterior deficiency), one may elect to use the San Diego acetabuloplasty to correct hip dysplasia in a normal child age 2–8 years.

Triple innominate osteotomy

Once the child is over age 8–10 years, it becomes difficult to hinge on the triradiate cartilage, as it nears closure. One can still perform a Salter procedure in this age group, but the acetabulum becomes more difficult to rotate and dysplasia correction may be incomplete. With a single cut in the ilium (Salter), one may obtain temporarily improved coverage of the femoral head; however, upward migration or rotation through the sacroiliac joint may cause loss of correction and coverage over time. Rab[13] noted that one can achieve only modestly improved acetabular coverage using the Salter procedure.

Therefore at Children's Hospital – San Diego children over age 8–10 years of age with residual dysplasia are treated with a triple innominate osteotomy.[3] In children over age 14 years, spherical[10] and other acetabuloplasties that cross the triradiate cartilage can be used, although these operations are not appropriate until the triradiate cartilage is closed or nearly closed. We use the Ganz periacetabular osteotomy in skeletally mature adolescents in whom postoperative hip spica casting would be undesirable (e.g., obese patients). The Ganz procedure is more difficult to perform than the triple innominate osteotomy and should be selected only by surgeons with appropriate training.

The triple innominate osteotomy has many variations, with the earliest descriptions by Steel,[15] Tonnis et al.,[17] and Carlioz.[1] At first, we used the Steel procedure in our institution, but after learning the benefits of making the cuts closer to the acetabulum we began to use a modification of the Carlioz procedure (Fig. 7).

Our technique involves making three separate incisions. The anterolateral incision is identical to that used for the Salter and Pemberton procedures. A Gigli braided wire saw is used to make the acetabular cut. A separate small skin incision is made over the symphysis pubis so a single cut can be made through the superior pubic ramus. The ischium can be approached by extending the same medial incision posteriorly and laterally or by making a separate longitudinal incision over the tip of the ischium. After a careful, somewhat

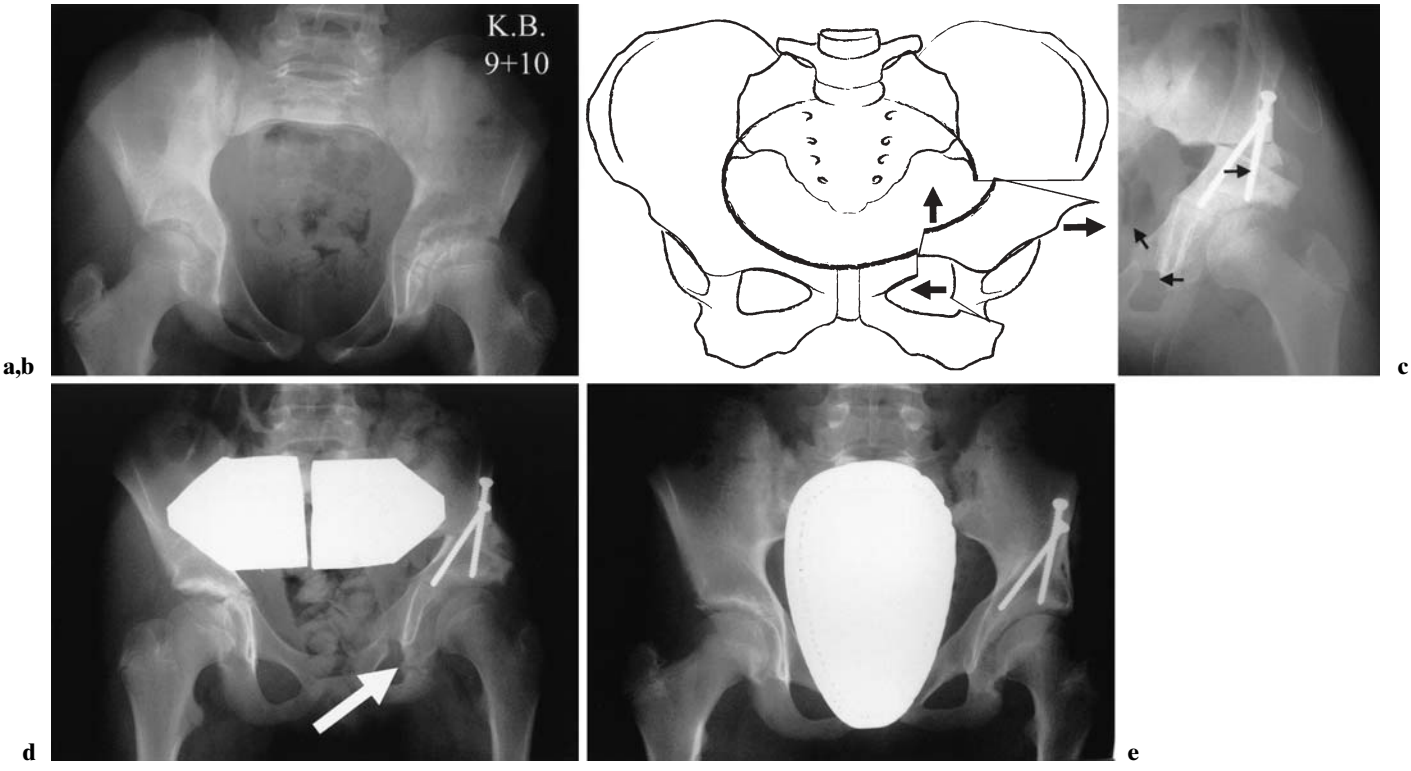


Fig. 7. Triple innominate osteotomy. **a** Preoperative AP view of the pelvis in a child with hip pain and residual left hip dysplasia. **b** Nature of a triple innominate osteotomy. **c** Immediate postoperative radiograph after triple innominate osteotomy. Note the rotation of the acetabulum in the frontal plane. **d** Later follow-up radiograph. **e** Radiograph 3 years after corrective osteotomy. Patient is now asymptomatic

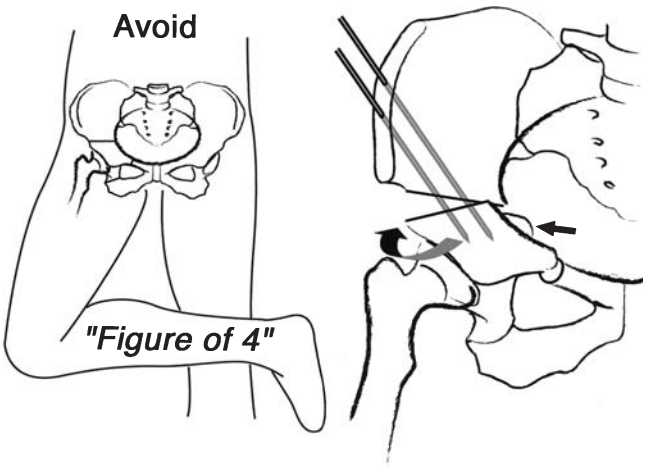


Fig. 8. Avoiding iatrogenic external rotation with triple innominate osteotomy. Salter originally described this "figure-of-four" maneuver used during surgery to improve acetabular mobility. We believe this maneuver should not be used when performing triple innominate osteotomy. The greater acetabular freedom achieved with a triple osteotomy may cause excess external rotation. The drawing of the acetabulum depicts excessive external rotation (*curved arrow*) documented by a prominent ischial spine (*straight arrow*)

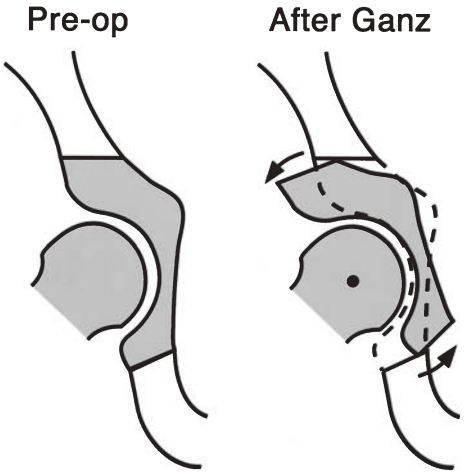


Fig. 9. Bernese acetabular osteotomy. These diagrams clarify the nature of acetabular rotation using the Bernese procedure (Ganz)

difficult dissection (good tissue retraction is required), the ischium just below the acetabulum is identified. An oblique cut is made through this bone.

We then insert a Schanz screw into the acetabular fragment to use as a guide (a technique adapted from Ganz). Great care must be used to bring the acetabulum forward and to rotate it in the frontal plane, avoiding external rotation.[3] A retroverted acetabulum has been associated with premature hip arthritis, and the surgeon must avoid creating this deformity. Acetabular rotation and femoral head coverage are documented using an image intensifier. Fixation is achieved with three fully threaded 4.5 mm diameter A-O screws. Occasionally, we add wire fixation to the superior pubic ramus, as described by Tonnis et al.[17] This provides additional stability and minimizes the risk for iatrogenic acetabular retroversion.

Postoperative care in most cases includes a hip spica for 6 weeks followed by touch-down weight bearing for an additional 6 weeks. Complications include pseudarthrosis and inadvertent external rotation of the acetabular segment (Fig. 8). One can decrease the tendency toward external rotation by not using the figure-of-four procedure described by Salter to mobilize his osteotomy. This maneuver can be used for the Salter procedure,[14] although with the greater instability produced by three cuts around the acetabulum, using the maneuver after a triple osteotomy may cause undesirable external rotation.

Bernese acetabular osteotomy (Ganz)

Because the pelvis is somewhat unstable after triple innominate osteotomy, Ganz et al.[4] developed a procedure for correcting acetabular dysplasia that makes appropriate cuts around the acetabulum but does not completely cut through the posterior column of the ischium. There are many circular and periacetabular osteotomies (Tagawa)[10] that achieve the same orientation, but all are somewhat difficult to perform. Ganz carefully studied the acetabular fragment size to determine if it would be large enough to avoid avascular necrosis of the acetabular segment yet would be close enough to the acetabulum to allow ideal rotation. The Ganz procedure is appropriate once the triradiate cartilage has closed. The great advantage of the procedure is that after fixation with several threaded A-O screws the osteotomy is innately stable owing to the design of the osteotomy cuts (Fig. 9).

The Ganz procedure is indicated in a child or teenager who has significant dysplasia with a triradiate cartilage that is closed or nearly closed. Prerequisites include proper training, as the procedure is initially somewhat difficult to perform. Once mastered, the Ganz procedure provides excellent acetabular mobility and femoral head coverage.

Salvage procedures for hip dysplasia

If the femoral head is flattened, asymmetrical, or deformed, one may still choose to improve acetabular coverage, but the typical osteotomies noted above are generally contraindicated. In these cases one may

consider a shelf acetabuloplasty (Staheli) or the Chiari osteotomy. This paper does not cover these procedures.

Femoral osteotomy and hip dysplasia

In the past, a proximal varus osteotomy was commonly performed to correct hip dysplasia, particularly in young children. It is now widely accepted that this is rarely used as a primary procedure to correct hip dysplasia. In our review we found the varus osteotomy to be unpredictable for correcting hip dysplasia, even in children as young as age 4 years.[8] Accordingly, we do not perform a varus osteotomy alone to correct residual hip dysplasia during childhood. In some cases of severe dysplasia, however, we perform minimal varus femoral osteotomy in conjunction with an acetabular rotation procedure to be certain we obtain complete femoral head coverage. This is particularly important in a child with significant residual coxa valga and anteversion.

Conclusions

Residual hip dysplasia during childhood is a common condition. Leaving it partially treated or untreated is a major cause of disability. Surgical intervention during childhood or the teenage years can alter this natural history and greatly improve the longevity of the hip joint.

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