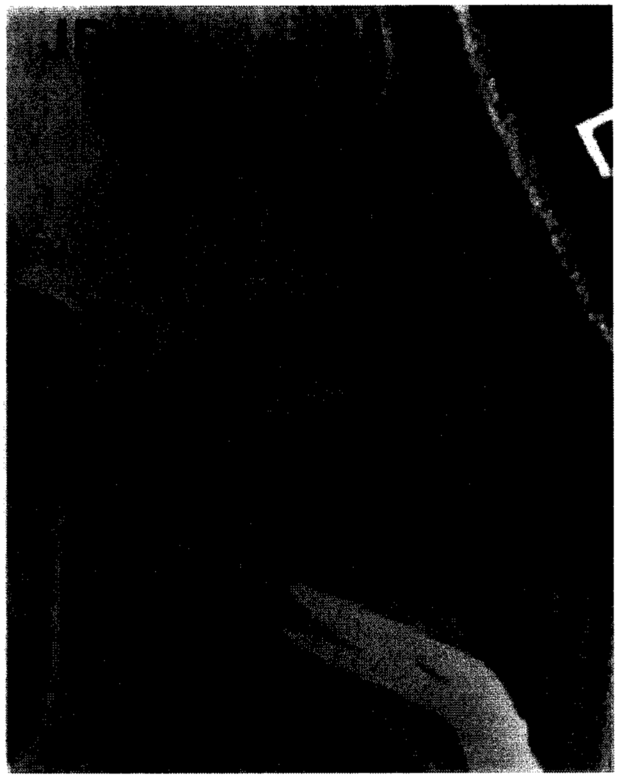
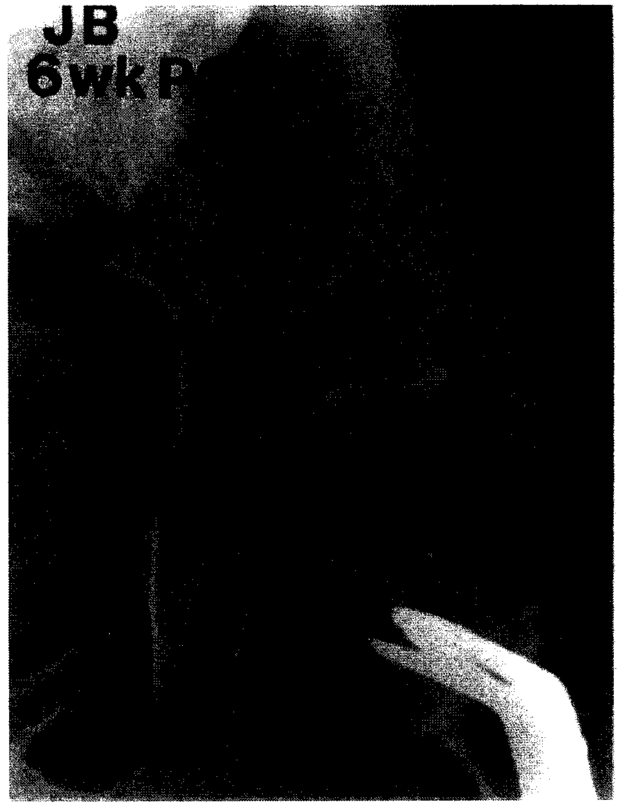


A



B

FIGURE 23-105. JB is a 4-year-old boy who had an open reduction, femoral shortening and rotation, and a Pemberton osteotomy for spastic dislocation. A radiograph immediately after surgery **(A)** demonstrates the osteotomy extending into the triradiate cartilage and not breaking into the sciatic notch. Radiographs at 6 weeks **(B)** and 6 months **(C)** demonstrate the rapid healing and the excellent coverage of the femoral head.

C

Pericapsular Pelvic Osteotomy of Dega (Figs. 23-106 to 23-109)

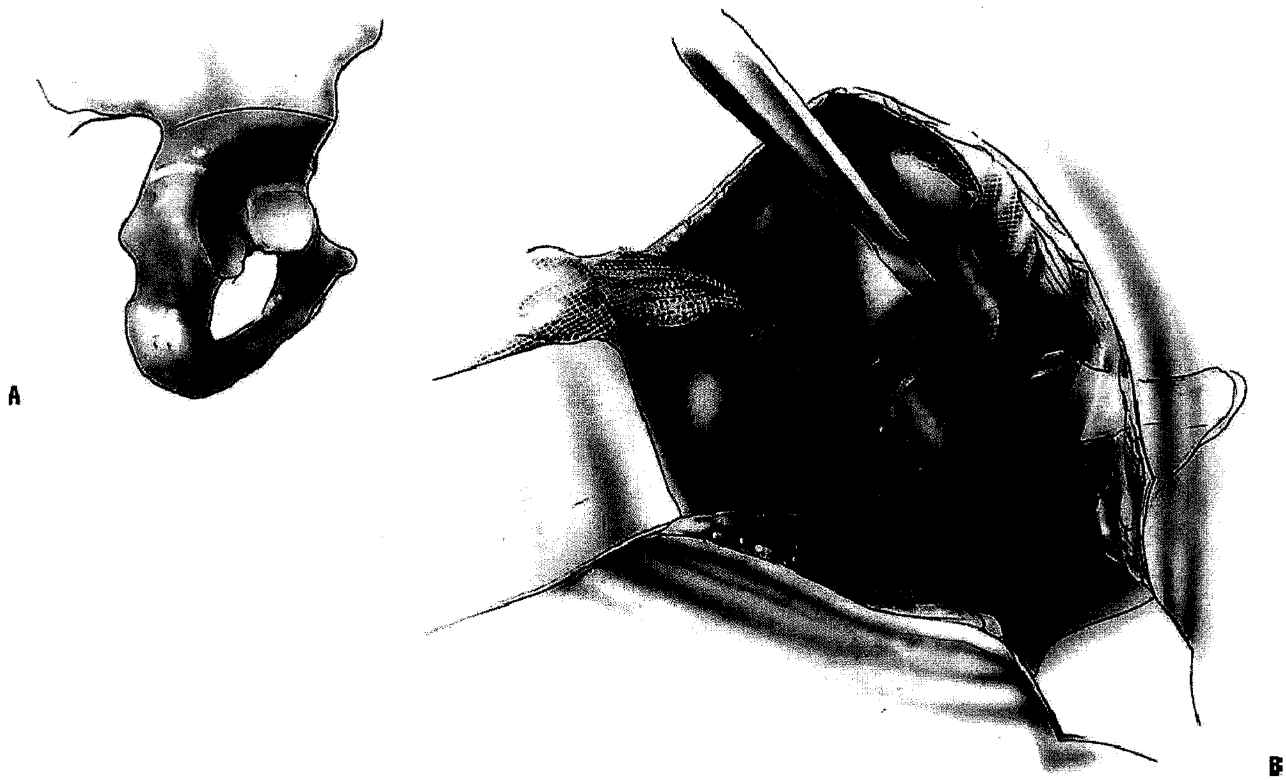


FIGURE 23-106. Pericapsular Pelvic Osteotomy of Dega. The positioning and exposure for the Dega osteotomy are the same as for the other pelvic osteotomies. The sciatic notch should be clearly visualized posteriorly **(A)**, the false acetabulum identified, if present, and the true acetabular edge identified. As described, it is not necessary to expose the inner aspect of the ilium. Because this takes only a minute and adds little to the morbidity of the case, the additional exposure might be advisable until experience is gained.

The osteotomy **(B)** begins on the lateral cortex along a curvilinear line, which starts just above the anteroinferior iliac spine, continues to arch posteriorly, staying above the acetabulum, and ends posteriorly 1 to 1.5 cm before reaching the sciatic notch. If the surgeon desires, guide pins may be used. These pins can be helpful if the surgeon is not sure of the location of the correct exit point on the medial side. Because of the difficulty in viewing such a complex three-dimensional structure as the acetabulum in two dimensions on a radiographic screen, three pins should be used. One pin is placed anteriorly, one at the highest point above the acetabulum, and one posteriorly.

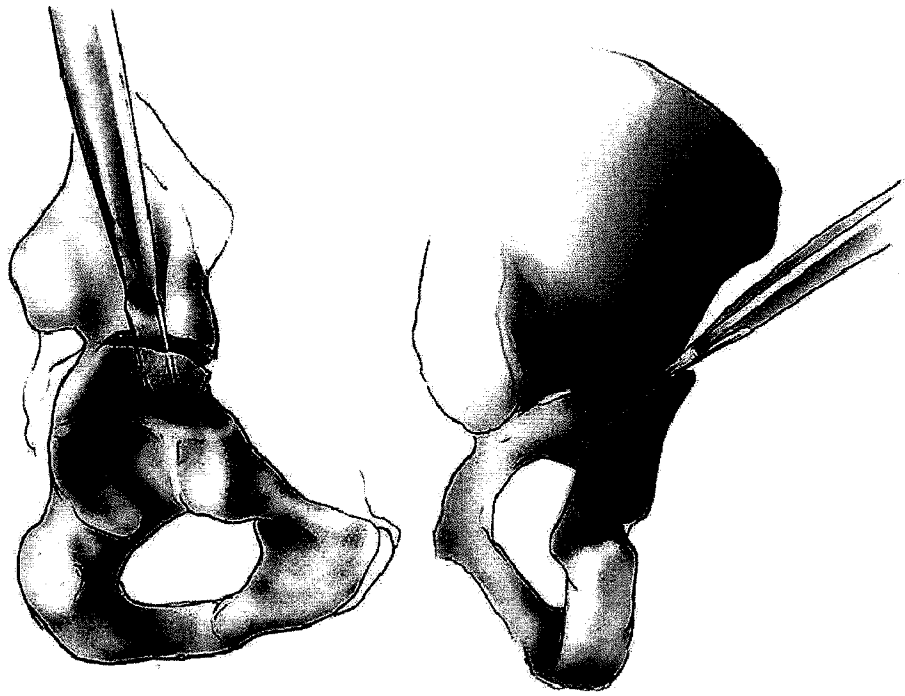


FIGURE 23-107. After the outer cortex is cut, a straight osteotome is directed medially and caudally. The steeper the acetabular slope, the higher the starting point is above the acetabulum, so that the medial cut always emerges above the horizontal portion of the triradiate cartilage. The osteotome should exit medially, just above the horizontal limb of the triradiate cartilage, which is composed of the ilioischial and iliopubic portions.

A B

FIGURE 23-108. The direction of the rotation is determined by the extent of division of the inner cortex on the inner wall of the ilium. If more anterior coverage is needed, the inner wall is divided, except for the 1-cm posterior hinge just anterior to the sciatic notch. This **(A)** permits the distal fragment to be rotated anteriorly. If more lateral coverage is needed, however, about one-third of the inner cortex is left intact. This **(B)** now moves the hinge to the medial wall of the ilium and determines that the rotation is anterior and lateral. The rotation becomes more anterior as more of the inner wall is divided, and the rotation becomes more lateral as more of the inner wall is left intact.

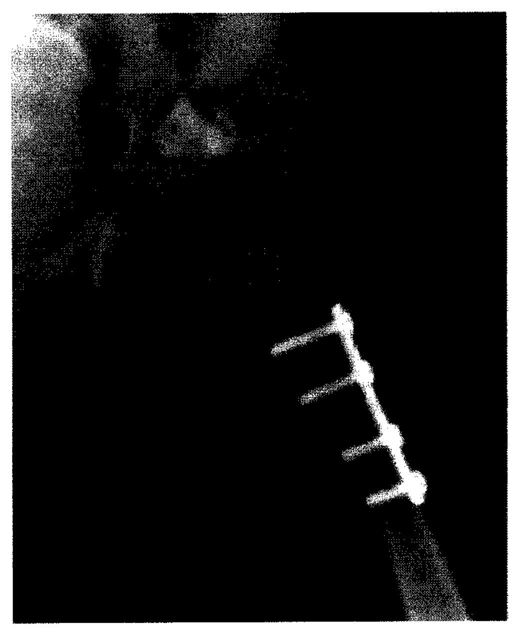
FIGURE 23-109. The osteotomy is pried open with the osteotome. The osteotomy can be held open with a lamina spreader while the bone graft is inserted. As in the Pemberton osteotomy, if a femoral shortening has been performed at the same time, the resected bone segment can usually be used. If not, tricortical bone from the iliac crest is used. The larger graft is anterior and the smaller graft is posterior. The graft should be stable, and no internal fixation is required. The wound is closed over drains in the routine fashion.

Postoperatively, because of the usual age and reasons for performing this operation, the patient requires a spica cast. Healing of the pelvic osteotomy should usually be sufficient after 6 weeks to permit motion and weight bearing. Dega removed the anterior portion of the cast after 6 weeks to start motion, and then the entire cast was removed at 12 weeks.

As mentioned above, Mubarak and colleagues (471) have clarified their understanding of the differences between the osteotomy they described and that actually performed by Dega, and they describe their osteotomy as a modification of Dega osteotomy. In actuality, the operation described by Mubarak and colleagues is more a modification of the shelf procedure described by Albee (472) than it is of the Dega osteotomy (Figs. 23-109 and 23-110).

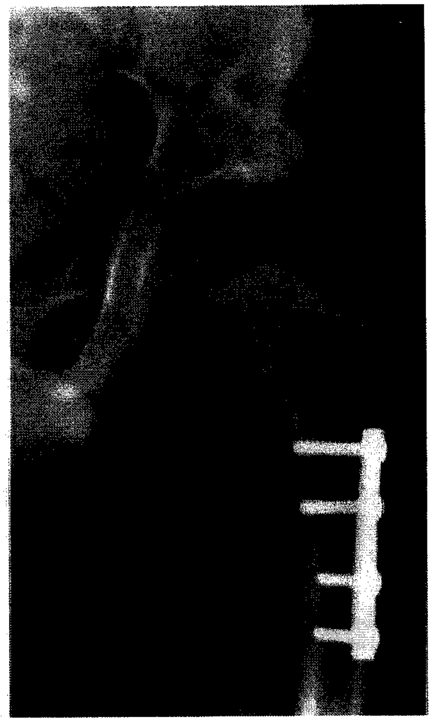
Albee performed his osteotomy at a time of limited surgery and no intraoperative radiographic control. During this period, shelf procedures were the only procedures used to add coverage to an acetabulum. Much of the subsequent discussion about the differences between Albee osteotomy and those of others concerned how deep and exactly where the osteotomy went. Trevor and colleagues (473) described a procedure that they attributed to A. O. Parker. Albee is not credited with it, although the description is strikingly similar. For several years, Mubarak and colleagues (471) reported on the use of an osteotomy similar to that of Albee in the treatment of the hip in cerebral palsy. Their report provides the first useful description of this osteotomy, along with modifications, which have popularized this procedure (Figs. 23-111 to 23-115). In a recent report on the use of this osteotomy in the one-stage correction of the dysplastic hip

A



B

FIGURE 23-110. A: Left hip dislocation in an 18-month-old boy. **B:** The radiograph taken after a femoral shortening, an open reduction of the hip, and a Dega osteotomy. The bone that was removed from the femur is used to hold the osteotomy in position. It is difficult from this radiograph to tell the difference between this osteotomy and a Pemberton osteotomy, although they are performed in an entirely different manner. **C, D:** The remodeling of the acetabulum 1 year, and 2 years and 3 months, respectively, after surgery. (Courtesy of W. Timothy Ward, M.D., Pittsburgh Children's Hospital, Pittsburgh, PA.)



C

FIGURE 23-110. (*continued*)

in cerebral palsy, it was referred to as the *San Diego acetabuloplasty* (474). It is often used by surgeons to correct hip dysplasia in young patients.

After wound closure, a hip spica cast is applied—one leg or one-and-one-half leg, depending on the surgeon's preference. This should be maintained until radiographic healing occurs, which usually lasts 6 to 8 weeks, depending on the patient's age.

Although seemingly obvious, it should be pointed out that osteotomies that depend on the triradiate cartilage as the fulcrum must be done in patients with open triradiate cartilage. Procedures that involve hinging on the triradiate cartilage, such as the Pemberton osteotomy, have the potential to injure the triradiate cartilage and cause premature closure, but these complications are not common (462, 464). Procedures that must cross the triradiate cartilage and that would definitely induce closure, such as the Ganz osteotomy, cannot be done in patients with open triradiate cartilage.

A third group of acetabular reconstructive procedures involves placing bone over the hip joint capsule on the uncovered portion of the femoral head. These procedures provide coverage of the femoral head by capsular fibrous metaplasia (472, 475, 476). They include the various shelf procedures (477–483) and the medial displacement osteotomy described by Chiari (414–416, 475, 484–490). In 1981, Staheli and Chew introduced a modification of a previously described shelf arthroplasty, and this gained widespread acceptance for use on its own in significant anatomic dysplasia, and also in conjunction with various rotational procedures as an augmentation to provide increased femoral head coverage (483) (Figs. 23-81 and 23-116).

The shelf arthroplasty (Fig. 23-116) and the Chiari osteotomy (Figs. 23-117 to 23-120) may be performed in well-reduced hips, but they are usually reserved for hips that lack significant femoral head coverage because of inability to acquire such coverage with articular cartilage by means of one of the other procedures mentioned in the preceding text (461, 462). Many of these procedures can be performed in patients with early degenerative changes in the hope of delaying the necessity for arthroplasty or fusion. Further discussion of these issues is beyond the scope of this chapter.

The Chiari medial displacement osteotomy hinges on the symphysis pubica, with the distal fragment displacing medially and upward (Figs. 23-119 to 23-123). This medialization results in reduction of the lever arm in order to reduce joint loading. Abductor muscle function is theoretically improved.

Unlike operations that redirect the acetabular cartilage and the subchondral bone and are called *reconstructive* procedures, the Chiari medial displacement osteotomy is a *salvage* procedure that uses the cancellous bone of the ilium with interposed hip joint capsule to contain the femoral head and bear weight. It accomplishes this by a single osteotomy through the ilium just above the hip joint capsule with medial displacement of the hip joint and its capsule under the superior iliac fragment.

The operation is primarily indicated in the older patient with a subluxated hip who is experiencing pain and in whom one of the reconstructive procedures that redirect the acetabulum is not possible. It is not necessary to achieve a concentric reduction of the femoral head to perform this procedure, and it can be used in the presence of a persistently subluxated hip. If the hip is subluxated too far cephalad, however, the Chiari osteotomy does not produce sufficient coverage. This is based on the anatomy of the pelvis. The cross-sectional area of the pelvis decreases the more cephalad from the acetabulum that it is measured.

There is insufficient width to the proximal fragment to provide adequate coverage. The same anatomic consideration makes this osteotomy less successful in young children, especially those with myelomeningocele and other paralytic conditions that result in a small, thin pelvis. In addition, most young children are good candidates for one of the reconstructive procedures.

Study of an anatomic model of the pelvis demonstrates that the Chiari osteotomy is unable to give much coverage to the posterior part of the femoral head. This has been demonstrated on three-dimensional computed tomographic reconstruction (491). The recognition that the width of the proximal fragment may be insufficient to produce adequate coverage has led to the use of bone graft to augment the lateral coverage (492–494).

Because so much of the anterior femoral head is generally uncovered by the ilium, a strong case can be made for always augmenting a Chiari osteotomy in this fashion.

Long-term follow-up of patients treated in adulthood for residual acetabular dysplasia has been reported (495–497). These and similar reports have made the operation popular for the adolescent and young adult with subluxation of the hip because it does not require reduction of the hip and gives

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The Albee Shelf Arthroplasty (Figs. 23-111 to 23-114)

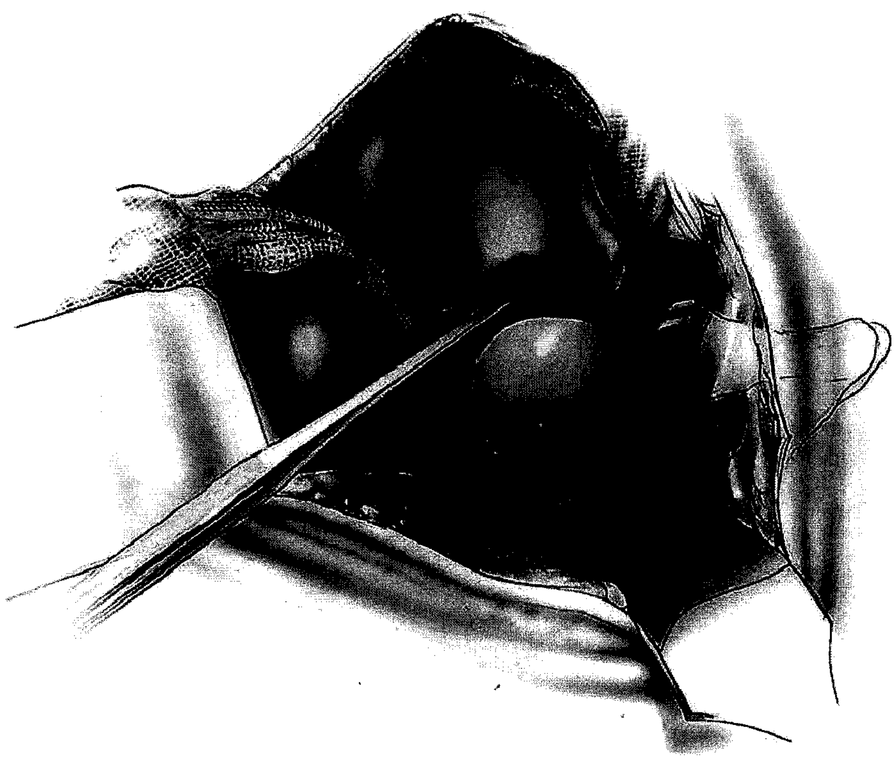


FIGURE 23-111. The Albee Shelf Arthroplasty. The exposure of the ilium is the same as for the Salter osteotomy. Soft-tissue release, open reduction, and femoral osteotomy can be performed at the same time to gain the concentric reduction of the femoral head, which is a prerequisite for this osteotomy and most other osteotomies.

The osteotomy is begun about 0.5 to 1 cm above the acetabulum on a line that extends from the anteroinferior iliac spine to the sciatic notch. The cortex is completely divided with a straight osteotome along the desired line.

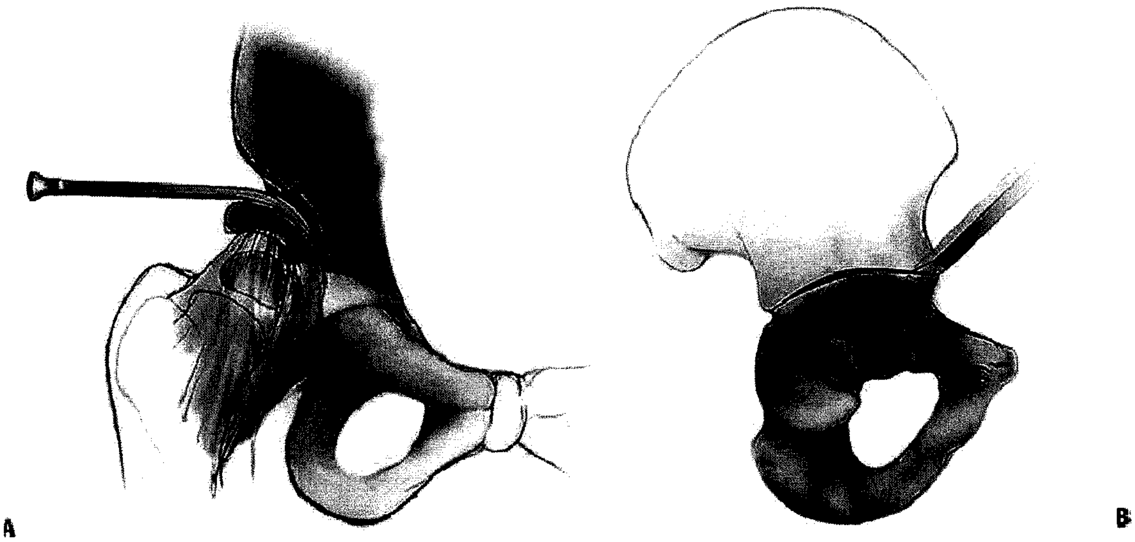


FIGURE 23-112. Using a combination of straight and curved osteotomes, the osteotomy is deepened, heading medially and caudally behind the acetabulum. This cut must proceed between the medial wall of the ilium and the medial wall of the acetabulum. This can be monitored on an image intensifier. Mubarak and colleagues (2, 3) describe the osteotomy as going to, but not through, the triradiate cartilage. In our experience, the osteotomy does not have to be carried to the triradiate cartilage, as illustrated here. In the soft bone of the usual child with paralytic hip disease, there is sufficient mobility without using the triradiate cartilage; in fact, the osteotomy can be used **(A)** in some cases in which the triradiate cartilage has closed.

Next, a Kerrison rongeur is used to remove the cortex anteriorly and posteriorly as it extends around to the medial iliac wall. This is essential to allow the fragment to bend freely. In contradistinction to the Dega osteotomy, which cuts a considerable portion of the medial iliac cortex, these two areas removed with the Kerrison rongeur **(B)** are the only cuts in the medial wall.

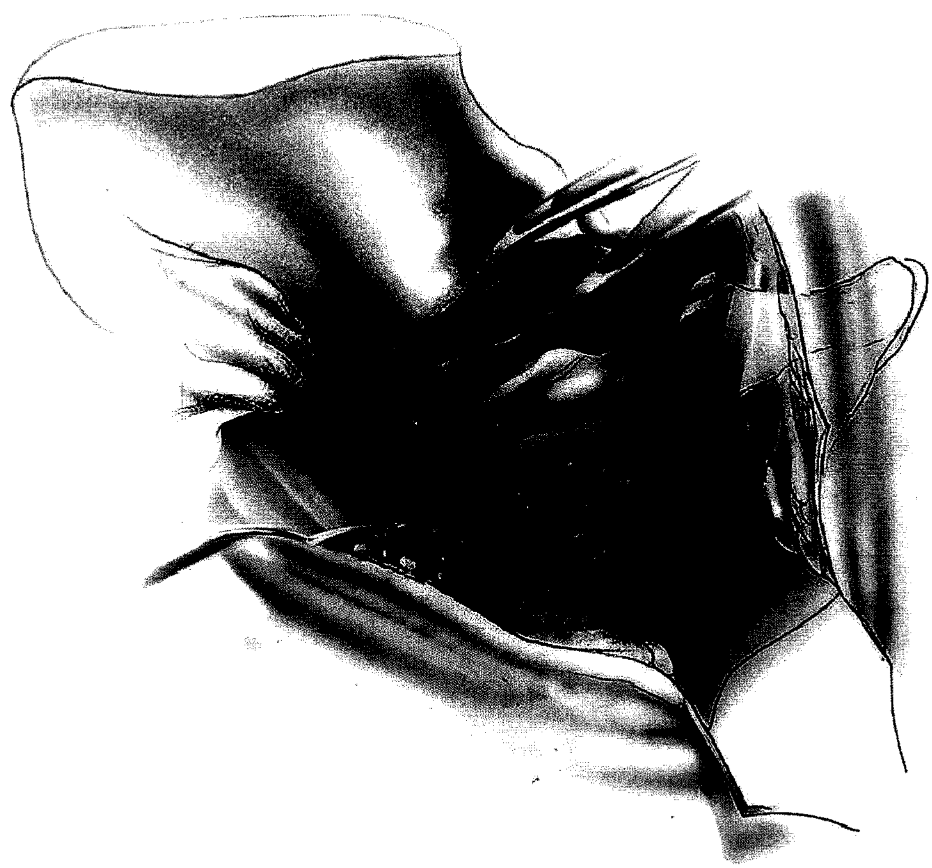
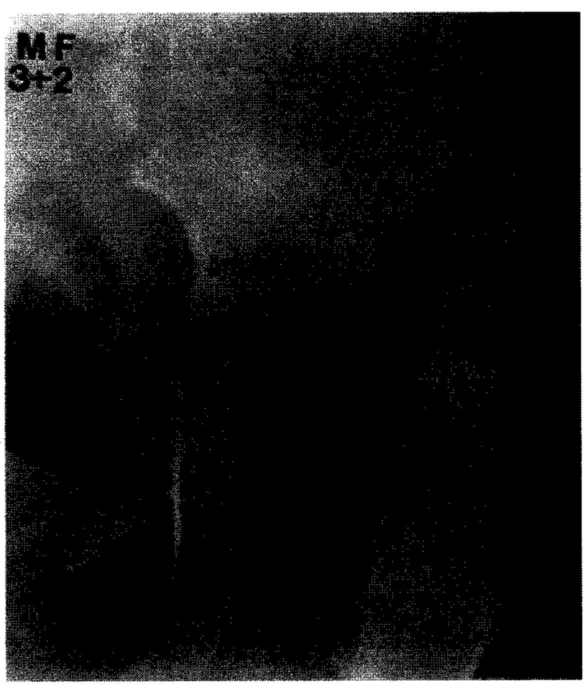


FIGURE 23-113. When the osteotomy is completed, the superior aspect of the acetabulum can be hinged downward by prying with a broad-curved osteotome and inserting a small lamina spreader. If the fragment does not move freely, there are two possible explanations: the cortex of the ilium as it wraps around the medial wall anteriorly and posteriorly has not been sufficiently removed, or the osteotomy within the cancellous bone has not been completed far enough caudally or is missing some portion anteriorly or posteriorly.

FIGURE 23-114. A piece of the ilium in the region of the anterosuperior iliac spine is removed, and three tricortical triangular pieces of bone are fashioned. These are wedged securely in the osteotomy site, which is held open with a lamina spreader. As with the Pemberton or Dega osteotomy, if femoral shortening accompanies the procedure, the resected piece of femur can be used as the source of bone graft. The amount of correction and where it occurs vary slightly with the size of the grafts and the site of placement of the largest and smallest grafts. Usually, the largest graft is placed anteriorly. It has seemed difficult to attempt to get more posterior coverage by placing the largest graft posteriorly. The amount of coverage should be verified, and the surgeon should be certain that the grafts are secure. No internal fixation is necessary. The wound is closed.



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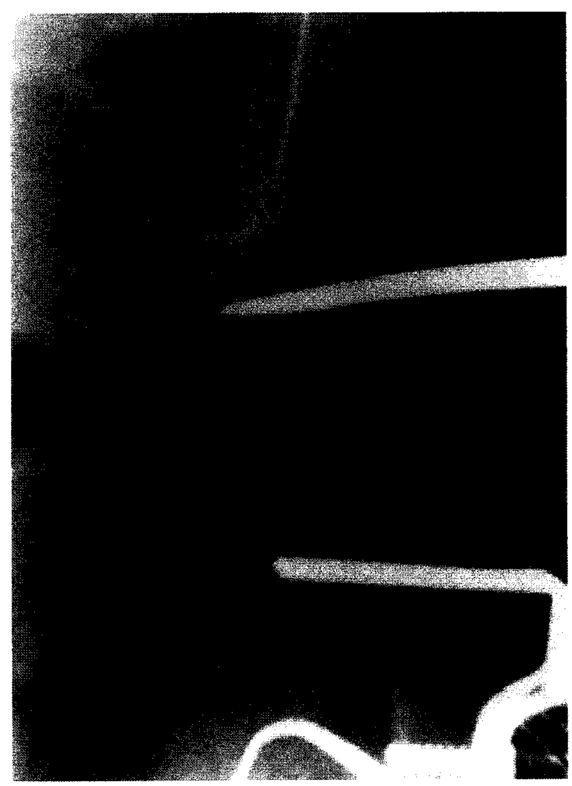
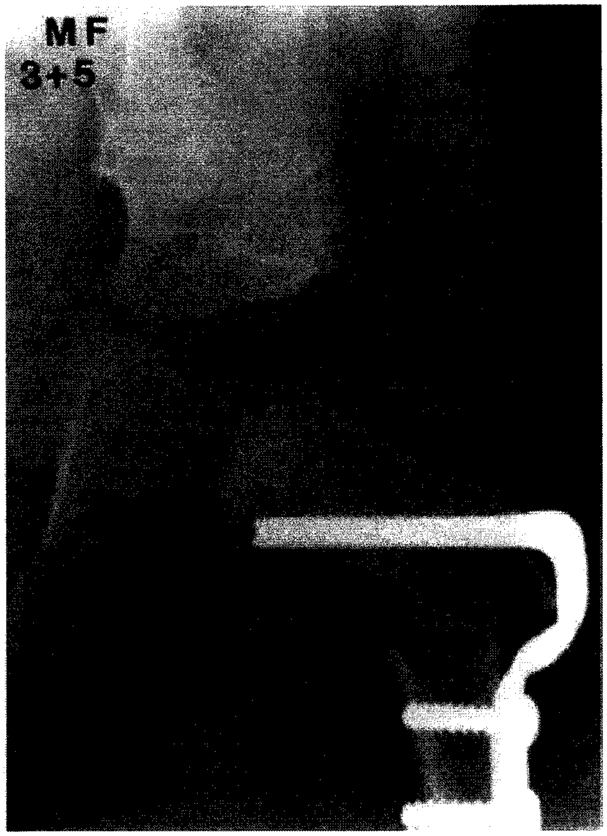


B

FIGURE 23-115. **A:** A dislocated hip in a young boy with spastic cerebral palsy. Note the significant acetabular dysplasia. **B:** An image obtained with the image intensifier during the Albee Shelf osteotomy shows the direction of the cut. It appears that the osteotomy has cracked into the triradiate cartilage. **C:** After 2 months, the osteotomy is healed and the coverage of the femoral head proves to be excellent. (Courtesy of Scott Mubarak, M.D., Children's Hospital of San Diego, San Diego, CA.)



C

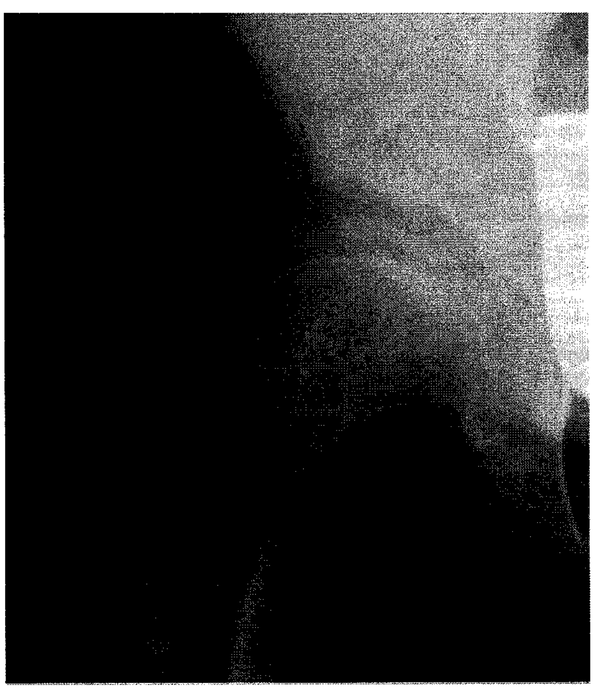
FIGURE 23-115. *(continued)*

excellent pain relief in most series. Results in this younger age group, however, and particularly in children, are harder to find. It has a biomechanical advantage: It medializes the hip and reduces the force through the hip joint. This also shortens the abductor lever arm and produces increased gluteal weakness and a consequent limp. The biggest problem with the operation is that, although it appears simple, the postoperative radiographs may not accurately reflect the amount of coverage obtained (9).

The incision and the exposure of the ilium are the same as those described for the Salter osteotomy. Although Chiari did not expose the inner wall of the ilium, this adds no morbidity to the procedure, whereas it increases safety and aids in orientation.

Postoperatively, it is not necessary to place the older, reliable patient in a cast. The osteotomy has a high degree of intrinsic stability that, if supplemented with strong internal fixation, permits a partial weight-bearing crutch gait. Crutches should be continued until radiographic evidence of healing is seen and the patient has rehabilitated the abductor muscles. If a spica cast is used in the younger child, it should be continued until radiographic evidence of union is present and the pins are removed. This is usually 8 to 12 weeks.

Following a Chiari osteotomy, patients may limp for as long as 1 year. There is some concern that bilateral Chiari osteotomies may interfere with a woman's ability to deliver children. This is one of the few procedures for which long-term results are available, and these show that, in the absence of subluxation and



A

B

FIGURE 23-116. **A:** Preoperative anteroposterior radiograph of an 8-year-old patient with residual dysplasia and proximal femoral growth disturbance. **B:** Anteroposterior radiograph 2 years after shelf arthroplasty. **C:** False profile lateral radiograph 2 years after operative procedure.

C

FIGURE 23-116. *(continued)*

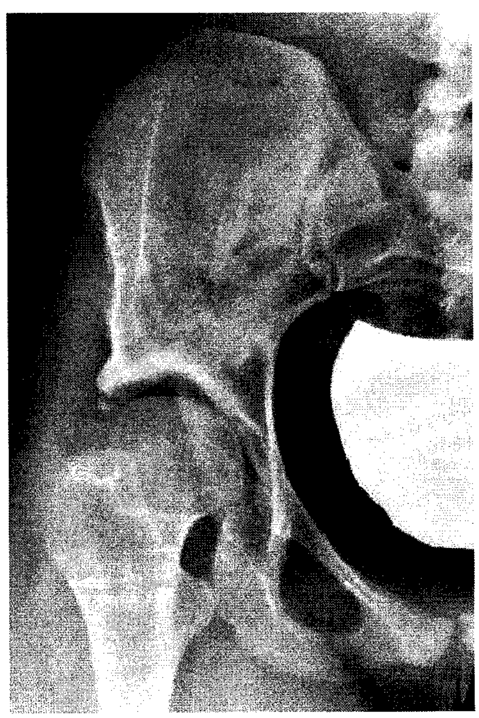
degenerative joint disease, good long-term outcomes may persist for many years (130, 476, 486, 497–508).

Procedures for creating a shelf of bone to augment a deficient acetabulum were first performed early in the 20th century. In its various forms, it remained the main method of treating the dysplastic acetabulum until procedures that redirected or displaced the acetabulum became popular. Since the 1980s, the popularity of the shelf procedures has waned because of the poor technical performance of these procedures and because of the increasing use of the newer osteotomy procedures. The primary goal in the creation of an acetabular shelf, as in any of the acetabular procedures, is to increase the load-bearing area between the femoral head and the acetabulum or to increase the stability of the hip. The shelf procedures, like the Chiari osteotomy, are salvage procedures because they use bone over capsule rather than articular cartilage and subchondral bone for the increased area. Although this may seem less than ideal at first, in certain circumstances, a salvage procedure is the only choice. The indications for the slotted acetabular augmentation are the same as for any shelf procedure: hips with asymmetric incongruity. The operation should not be done in a hip with congruity in which acetabular redirection is more appropriate. The operation is not ideal when the capsule must be opened, although like the Chiari, it can be performed. The slotted acetabular augmentation developed by Staheli (Figs. 23-124 to 23-127) is a shelf procedure in which a slot in the ilium is created for the bone graft. This aids in the correct and secure placement of the graft. The amount of coverage can be calculated by determining the length of the graft that is necessary to create the desired CE angle. The exposure for the operation is the same as for the anterior approach for the open reduction of congenital hip dislocation. Larger teenage children can be placed on a fracture table if the surgeon chooses. The outer table of the ilium and the entire superior capsule must be visible. The inner table of the ilium does not have to be exposed.

Postoperatively, the patient is placed in a single-leg spica cast with the hip in the position abduction, 20 degrees flexion, and neutral rotation. The cast can be removed and radiographic assessment of graft incorporation can be made. Reliable begin partial weight bearing. In less-reliable patients, weight bearing in a walking spica. It usually takes 4 months for complete graft incorporation.

The fourth group of procedures includes hybrids of the above groups, such as addition of a shelf to a Salter or Pemberton innominate osteotomy when the surgeon feels that inadequate coverage has been obtained by the primary procedure.

A



B

FIGURE 23-117. An 11-year-old girl with pain and residual right hip subluxation with severe acetabular dysplasia. **A:** Immediately after the right Chiari osteotomy. Note the additional graft placed anteriorly. **B:** Eight years after the operation, there is excellent remodeling of the acetabulum with sourcil development.

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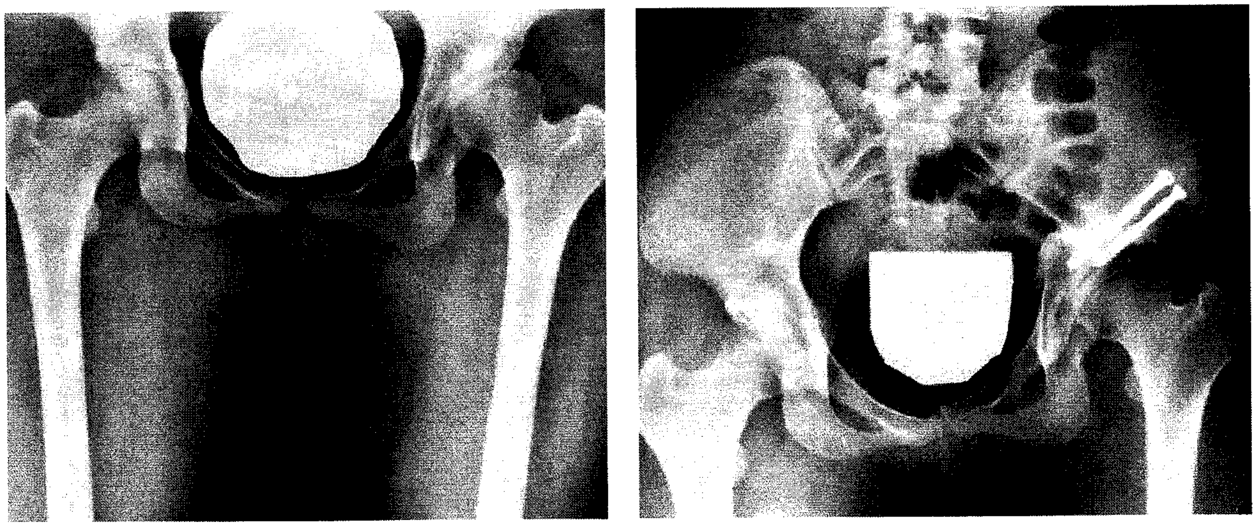
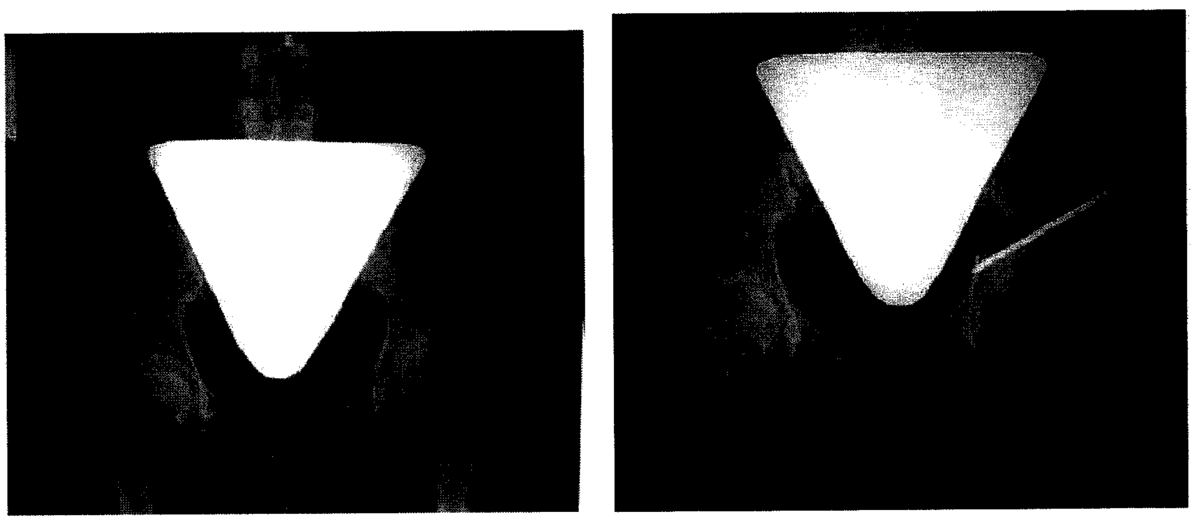
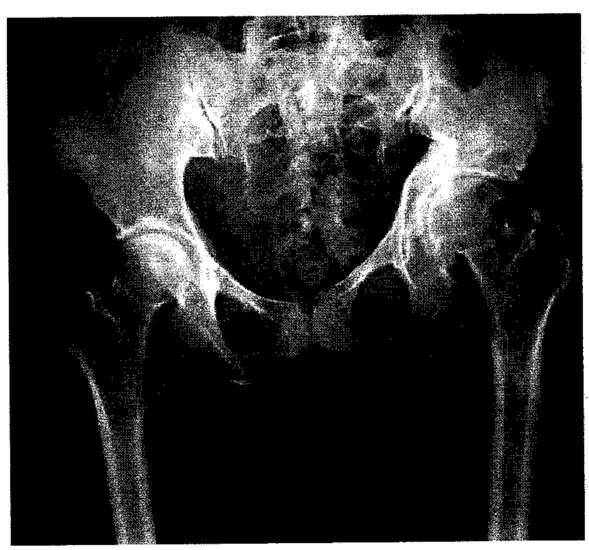


A B

FIGURE 23-118. This girl underwent open reduction of the left dysplastic hip at 18 months of age. She presented at 17 years of age with subluxation, as seen on the radiograph. **A**: Preoperative anteroposterior view of the pelvis. **B**: Eight weeks after Chiari osteotomy. Note the additional graft placed anteriorly.



A B



C

FIGURE 23-119. **A**: 25 year old female with hip subluxation and pain. **B**: Intra operative Radiograph of Chiari Osteotomy. **C**: Age 53 years, 23 year follow up post op; patient has no hip pain and is fully functional.

Chiari Medial Displacement Osteotomy of the Pelvis (Figs. 23-120 to 23-123)

FIGURE 23-120. Chiari Medial Displacement Osteotomy of the Pelvis. The placement of the osteotomy is crucial to the success of the operation. If it is too high, it does not provide coverage for the hip, and if it is too low, there is not sufficient capsule between the femoral head and the ilium. Therefore, it is important that the superior aspect of the hip capsule is well exposed anteroposteriorly. In addition, it is necessary to know where the roof of the acetabulum lies. This may be difficult in many subluxated hips because of a markedly thickened capsule. In some cases, it may be necessary to thin this capsule.

Conceptualizing how the distal fragment is displaced medially in relation to the proximal fragment, despite the fact that the pelvic ring is divided in only one place, is important to the understanding of osteotomy. The displacement occurs as the distal fragment rotates on the symphysis pubis. This is the reason why the direction of the osteotomy is important in obtaining the "displacement." Proceeding lateral to medial **(A)**, the osteotomy should incline cephalad by about 10 degrees. This permits the inferior fragment **(B)** containing the hip joint to displace medially.

These two crucial points, the location of the acetabular roof and the direction of the osteotomy, can be verified by drilling a small guide wire or driving an osteotome, lateral to medial, in the estimated direction of the osteotomy at the proposed site of the osteotomy, while viewing this with a radiograph or image intensifier. The osteotomy should incline cephalad 10 degrees to 15 degrees from lateral to medial to facilitate the displacement (or, more correctly, the rotation).

The osteotomy, as originally described by Chiari, was straight, anterior to posterior. Most commonly today, this cut is modified to produce a dome-shaped osteotomy that more closely conforms to the hip capsule after displacement. This is easily accomplished **(C)** in the anterior and midportion of the osteotomy but cannot be achieved posteriorly.

The lateral cortex **(D)** is cut first and then the medial cortex **(E)**. This allows the surgeon excellent orientation. These cuts are not extended into the sciatic notch because splintering of this posterior cortex may impinge on the sciatic nerve. The cuts in the lateral and medial cortex are then connected, leaving only the posterior cortex of the sciatic notch intact.

FIGURE 23-121. A Gigli saw is passed through the sciatic notch, as described for the Salter osteotomy. This is used to complete the osteotomy. Some surgeons prefer to make this cut first for a short distance to avoid having the bone splinter as the osteotomes approach the sciatic notch.

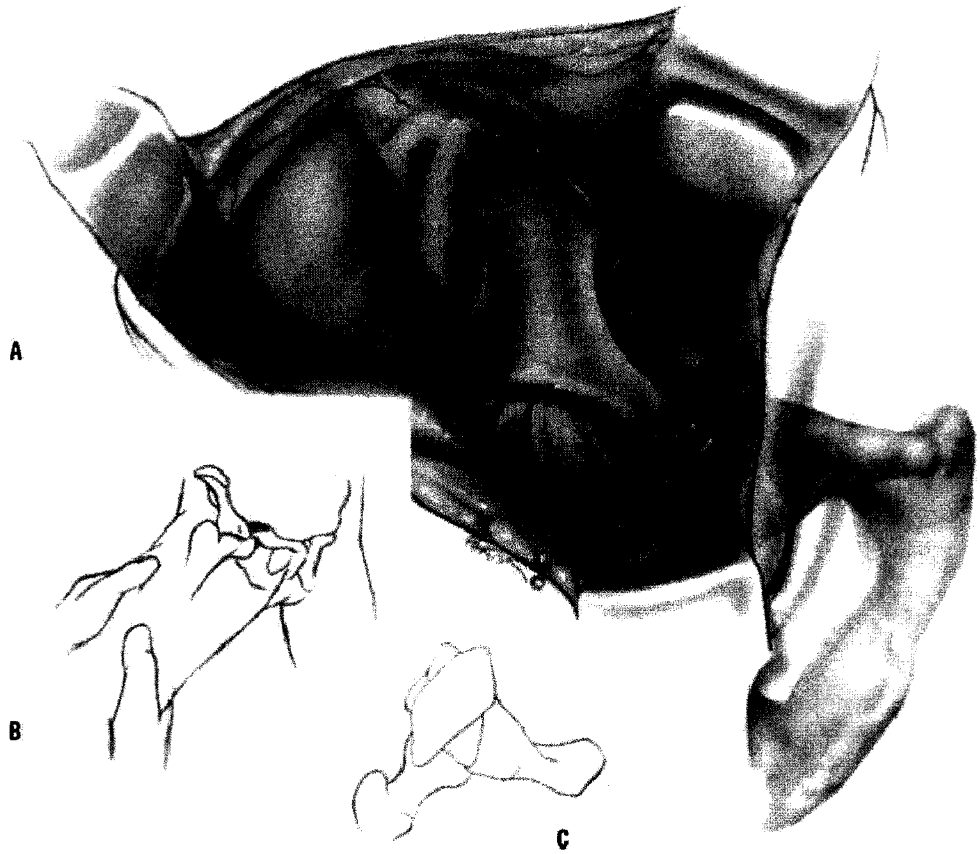


FIGURE 23-122. With the osteotomy complete **(A)**, the distal fragment is displaced medially. A common error at this point is to hinge the osteotomy on a posterior tether. This results in only the anterior aspect displacing. Without careful inspection of the posterior aspect of the osteotomy, this may go unnoticed, and it will not be reflected on postoperative radiographs.

The osteotomy **(B)** is usually displaced by abducting the leg. If the osteotomy has been performed properly, it should move easily by this maneuver. Further displacement can be achieved with direct pressure over the greater trochanter. There is a tendency for the inferior fragment with the hip joint to displace posteriorly. This probably should be avoided because it may increase the pressure on the sciatic nerve. Posterior displacement **(C)**, however, increases the amount of coverage because the ilium is wider in its posterior aspect than in its anterior aspect.

How much displacement is advisable is a matter of debate, with some authorities saying that there should be no more than 50% displacement. Such admonitions do not account for the variable width of the ilium, which is very thin in cross-section anteriorly and wide posteriorly. It is possible and often advisable to achieve nearly 100% displacement at the midportion of the osteotomy over the dome of the hip joint. If this much displacement is achieved, it should be secured with strong fixation to prevent further displacement and supplemented with bone graft to avoid delayed union or nonunion.

Healing may be slow, especially if the patient is older and the displacement greater. In these circumstances, it is best to fix the osteotomy with two or three strong screws, which can be left in place for several months without bothering the patient. In cases in which more rapid healing is anticipated, heavy-threaded pins can be used and left subcutaneously for easy removal.

FIGURE 23-123. As has been mentioned, it is often necessary to augment the coverage obtained with the Chiari osteotomy. This is especially true anteriorly where the ilium is thin. An excellent method for accomplishing this coverage has been described (1, 2). An appropriately sized piece of corticocancellous bone is removed from the inner table of the ilium. This is placed in the osteotomy site before fixation. The screws or pins used for fixation then transfix this graft. Additional cancellous bone graft is added over this graft and held in place by the periosteum and muscles when the wound is closed.

Asymptomatic Mature Patient with Incidentally Discovered Hip Dysplasia. Decision making is somewhat difficult and controversial in the case of the asymptomatic mature patient with hip dysplasia. For the asymptomatic adolescent with minimal radiographic dysplasia (because degenerative arthritis is a probability but not a certainty), the author prefers to inform the family about the potential for an adverse natural history and recommend surgery only at the onset of symptoms. There is usually a long interval between the onset of symptoms and degenerative joint disease as evidenced on radiographic images (67). The patient can be reassured that if symptoms develop, surgical treatment can help in avoiding long-term degenerative joint disease. However, faced with an adolescent with radiographic evidence of subluxation, regardless of the symptoms, the author recommends surgical correction, because without treatment an adverse natural history is certain.

Acetabular Rim Syndrome. Over the last several years, as more has been learned about the natural history of hip dysplasia (26, 67, 171, 213, 216, 221, 222, 225, 378, 460, 509–511), much attention has been focused also on acetabular rim syndrome (overload of the acetabular rim) (224) in young adults as a primary disease, or as a residual of childhood hip disease. These patients may present with sudden onset of sharp groin pain. They may describe symptoms such as sudden "locking" or a clicking sensation (454). These sensations are precipitated by movements that combine hip flexion, adduction, and internal rotation. Patients may also experience sudden "giving way" sensations. As the site of acetabular rim overload is usually anterior, symptoms are provoked on physical examination by the so-called impingement test. This test brings the anterior aspect of the femoral neck in contact with the anterior acetabulum by internally rotating the hip as it is gradually flexed to 90 degrees and adducted. In acetabular rim syndrome, the patient's original symptom of pain (usually in the groin) will be reproduced. Films taken in a weight-bearing situation and false profile lateral views will show evidence of dysplasia, as previously discussed. One may also see evidence of an acetabular rim fracture suggestive of the rim overload (224, 454). A gadolinium-enhanced MRI arthrogram of the hip is the best test for assessing labral disease (512, 513), and a three-dimensional CT scan is the best diagnostic study for ascertaining the acetabular deficiencies.

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Staheli Shelf Procedure (Figs. 23-124 to 23-127)

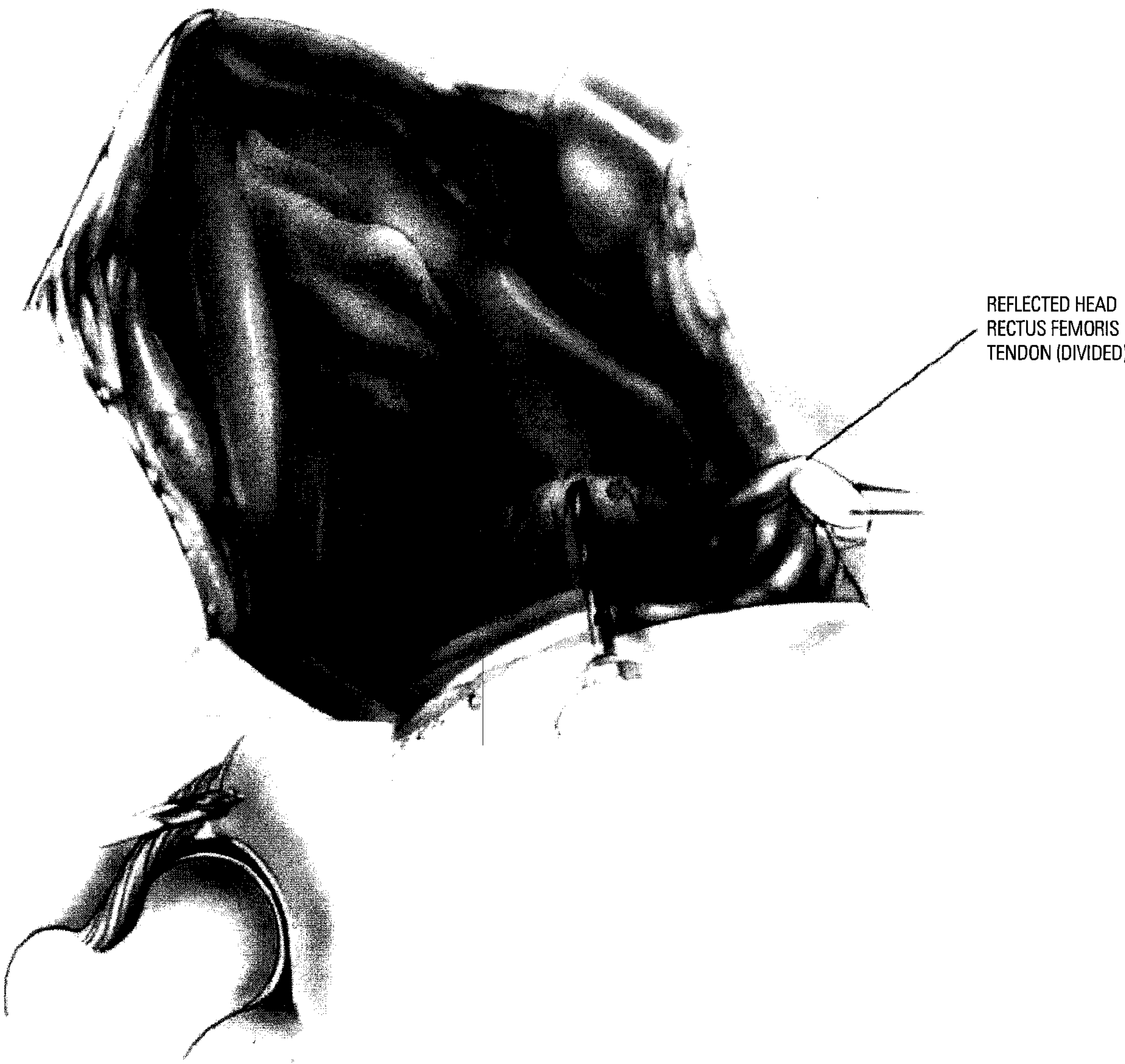


FIGURE 23-124. Staheli Shelf Procedure. During the exposure, the reflected head of the rectus tendon should be identified, dissected free from the capsule, and divided somewhere between its midportion and its junction to the conjoined tendon. This is used to secure the grafts in place. If it is not present, flaps can be created from the thickened capsule, which serves the same purpose.

The most important part of the surgery is to identify the correct location for the slot. It should be placed at the exact acetabular edge. The surgeon must determine whether this is the true or false acetabulum, based on which of the two affords the greater stability and congruity. The acetabulum is identified by creating a small incision in the capsule or by inserting a probe. In the subluxated and dysplastic hip, the capsule is usually thickened and adherent to the ilium, causing the surgeon to place the slot and therefore the graft too high. The correct location should be verified radiographically by placing a guide pin into the ilium at the presumed acetabular edge. In some cases, it may be necessary to thin the capsule to permit the graft to be placed in the proper location.

After the correct location is verified, a 5/32-inch drill is used to make a series of holes at the edge of the acetabulum. These holes should be drilled to a depth of about 1 cm and should incline about 20 degrees, as illustrated. They should extend far enough anteriorly and posteriorly to provide the necessary coverage. Alternatively, a high-speed burr can be used to initiate the groove which can be then deepened and angled with straight and angled curettes.

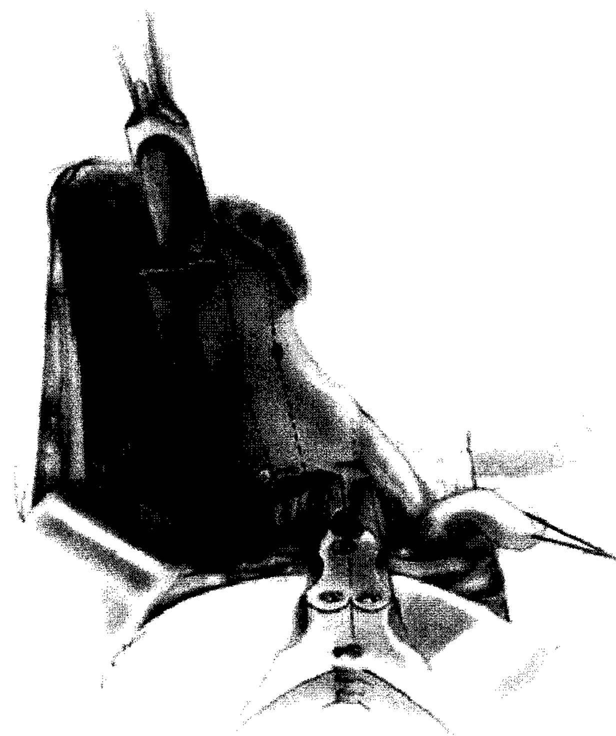


FIGURE 23-125. If a drill is used to make holes, a narrow rongeur is used to connect these holes and produce the slot. The floor of this slot should be the subchondral bone of the acetabulum, and it should be level with the capsule.

The bone graft is obtained from the outer table of the ilium. Starting at the iliac crest, corticocancellous and then cancellous strips of bone are removed. In the region above the slot, the decortication should be shallow to aid the incorporation of the graft without disrupting the integrity of the slot. It may be necessary in some patients with neuromuscular disorder to use bone from the bone bank.

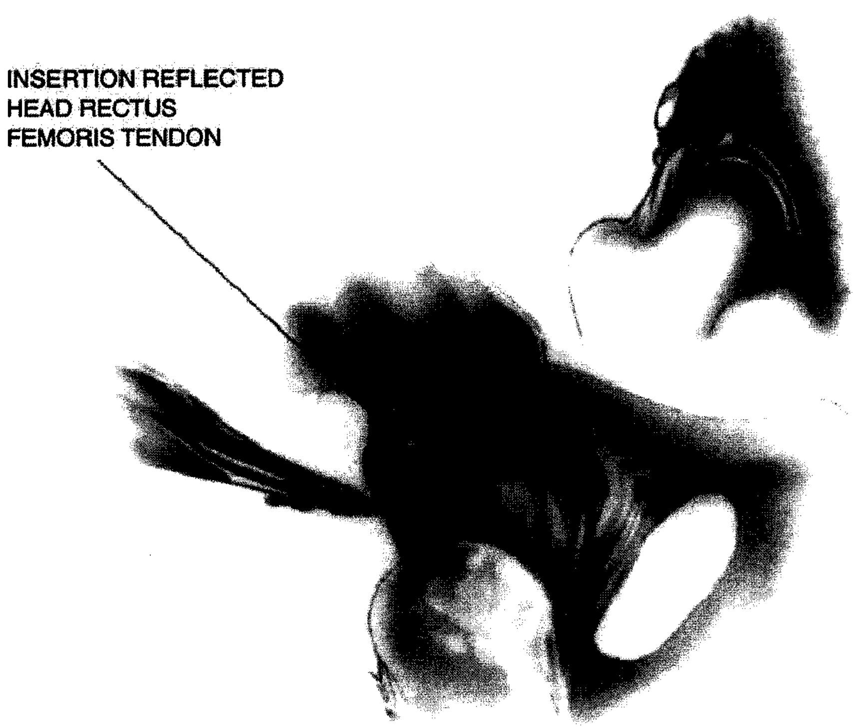


FIGURE 23-126. The cancellous grafts are cut in strips 1-cm wide and of appropriate length to provide the desired amount of lateral coverage. These are placed in the slot extending out over the capsule. A second layer of cancellous strips are placed at 90 degrees to the first layer of strips of graft. The grafts must not extend too far laterally or anteriorly in the quest for spectacular radiographic coverage of the hip because this could result in a loss of motion secondary to impingement.

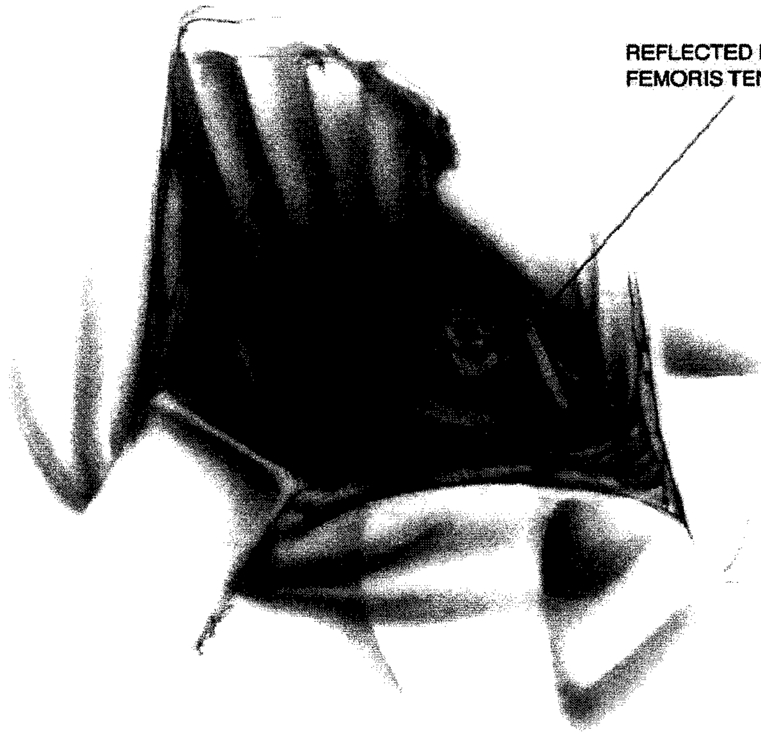


FIGURE 23-127. The reflected head of the rectus tendon is sutured, holding the grafts in place. The remaining bone is cut into small pieces and placed over the previously placed graft. This is held in place by the abductor muscles when the wound is closed.

In a symptomatic patient with hip dysplasia and no or very minimal evidence of arthritis, one of the joint preserving operations (Ganz, Salter, Tonnis, Naito, Steel, etc., as described in the preceding text) is indicated in order to try to improve an otherwise poor long-term prognosis. A radiograph with the leg in maximal abduction must demonstrate that the femoral head is reduced, covered, and congruent and that good joint space is maintained. These are absolute prerequisites for considering a PAO (p. 1060). Labral pathology may have to be dealt with in conjunction with the PAO procedure. There is considerable debate as to whether the labral pathology need be addressed at the time of PAO and if one chooses to address this pathology whether it should be done openly or arthroscopically.

In extreme cases of degenerative joint disease in the late teens or early adult years, hip fusion or total joint arthroplasty may be the only treatment alternatives available. Arthrodesis while rarely used today remains an excellent procedure in the young patient with end-stage arthritis of the hip with a normal hip on the opposite side, normal ipsilateral knee, and a normal spine.

Despite advances in total joint arthroplasty, arthrodesis of the hip joint (Figs. 23-128 to 23-134) remains a good option for the adolescent or young adult with destruction of the joint and pain. Despite the limitations imposed by hip arthrodesis, this paradigm will probably remain true until technologic advances have solved the problem of loosening in total joint arthroplasty, especially in young, active patients.

Most long-term studies have demonstrated that most patients are satisfied with the results of hip joint arthrodesis and lead active lives without hip pain (514–518). However, it is also apparent from such long-term studies that a significant number of patients develop back and knee pain along with radiographic signs of osteoarthritis, with onset decades after the arthrodesis. Conversion to total hip arthroplasty is solving these problems (519, 520). This does not necessarily negate the value of hip arthrodesis because, at the present time of conversion to total hip arthroplasty, patients are more suitable candidates for this procedure and receive the benefit of several decades of technologic advancement.

The relevant message from these studies for the surgeon performing a hip arthrodesis on a young patient is twofold. First, as much of the normal architecture of the hip as possible should be preserved so that total joint arthroplasty can be accomplished. This rules out the use of the cobra plate or other methods that alter the normal anatomy. Second, the position of the leg in relation to the pelvis is an important factor in the development of late back and knee symptoms. Specifically, any abduction of the hip should be avoided (521).

A technique that has proved successful is that described by Thompson (522) and evaluated by Price and Lovell (516). It uses an intertrochanteric osteotomy to relieve the effect of the long lever arm of the leg on the arthrodesis and to allow accurate positioning of the leg after the drapes are removed.

Postoperatively, depending on the surgeon's confidence in the internal fixation of the hip, the effectiveness of the immobilization of the femoral osteotomy by the spica cast, and the patient's ability to follow instructions, the patient can be mobilized on crutches or kept at bed rest. Bed rest is the usual recommendation initially. When early radiographic signs of healing are observed at the osteotomy site, usually by 6 weeks,

Text continued on page 1091

Arthrodesis of the Hip Joint (Figs. 23-128 to 23-134)

FIGURE 23-128. Arthrodesis of the Hip Joint. The hip is approached as for the Salter osteotomy. It is important that the hip capsule be exposed widely because dislocation of the diseased hip is difficult and requires an extensive capsulectomy. Both the inner and outer table of the ilium should be exposed subperiosteally.

FIGURE 23-129. The femoral head is dislocated by adducting, externally rotating, and extending the leg. This dislocates the femoral head anteriorly into the wound. Because of the amount of flattening of the femoral head, especially in cases of avascular necrosis, it is usually not possible to use a reaming cup to recreate the ideal rounded shape of the femoral head that is often seen in diagrams of hip arthrodesis. Rather, curved osteotomes or gouges should be used to remove the remaining articular cartilage and dead avascular bone, accepting the more flattened surface that results. The surface, regardless of its shape, should be bleeding bone.

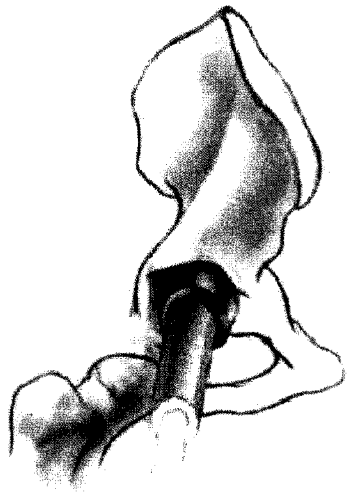


FIGURE 23-130. Flexion and internal rotation of the leg displaces the femoral head posterior to the acetabulum. Because access to the acetabulum is restricted and the acetabulum is not deformed, a reaming tool is ideal to remove the cartilage and subchondral bone. It is usually not necessary to alter the resulting shape of the acetabulum because the femoral head can be moved into the most congruous position. Typically, this is abduction.

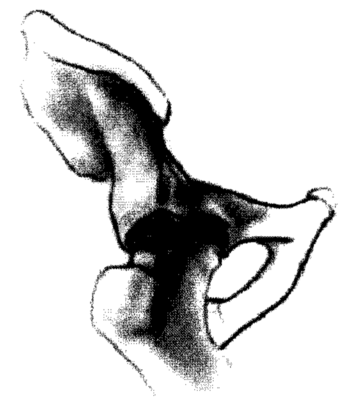


FIGURE 23-131. After the femoral head is placed in the desired position, one or two large, long, and strong screws with washers can be directed from the inner side of the ilium, through the acetabulum, and into the femoral head and neck (8). This provides fixation of the femoral head to the acetabulum. This fixation, however, will prove insufficient unless a proximal osteotomy is performed.

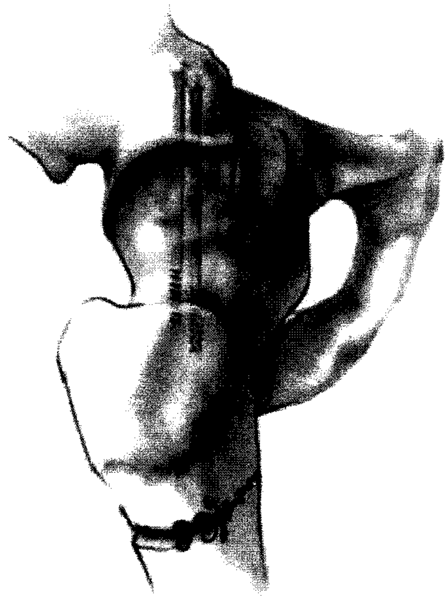


FIGURE 23-132. Using osteotomes or an oscillating saw, a trough is cut into the superior aspect of the ilium, just above the acetabulum and lateral to the iliopubic eminence, extending down onto the femoral neck. This should be as wide as the anterior portion of the iliac crest and about 1.5 cm deep to accommodate a tricortical piece of graft that was taken from the anterior iliac crest. This graft is wedged into place and can be secured by two screws. Cancellous bone can be removed from the exposed surface of the iliac crest with a curette and packed into the acetabulum around the femoral head.

FIGURE 23-133. An osteotomy of the femur is performed just above the lesser trochanter. The surgeon may prefer to perform this step before fixing the femoral head to the ilium. If this is done, a large Steinmann pin should be drilled into the femoral head fragment so that it can be controlled. Performing the osteotomy at this stage ensures that sufficient, but not excessive, mobility is achieved at the osteotomy site to allow proper positioning of the leg in the cast.

The osteotomy can be performed through a small anterolateral incision that splits the fibers of the tensor fascia muscle to reach the proximal femur. The periosteum is cut in the direction of the bone and elevated with a curved Crego periosteal elevator. The less the periosteal disruption created, the more stable the osteotomy. Multiple drill holes are made, and the osteotomy is completed with an osteotome. In our experience, this results in quicker union than with the use of the oscillating power saw—an important factor because rigid internal fixation is not used. The limb is moved to ensure that sufficient mobility is present at the osteotomy site.

With time, the distal fragment, the femoral shaft, tends to displace posteriorly. This presents a difficult situation regarding stem placement if revision to total joint arthroplasty is needed in the future. The situation can be avoided by placing a drill hole through the anterior cortex on each side of the osteotomy and passing a heavy strong suture through the holes. This is tied loosely enough to permit flexion and some extension as well as abduction and adduction at the osteotomy site while preventing any significant posterior displacement. The use of the anterolateral incision gives the surgeon a better exposure for this step than the traditional lateral incision.

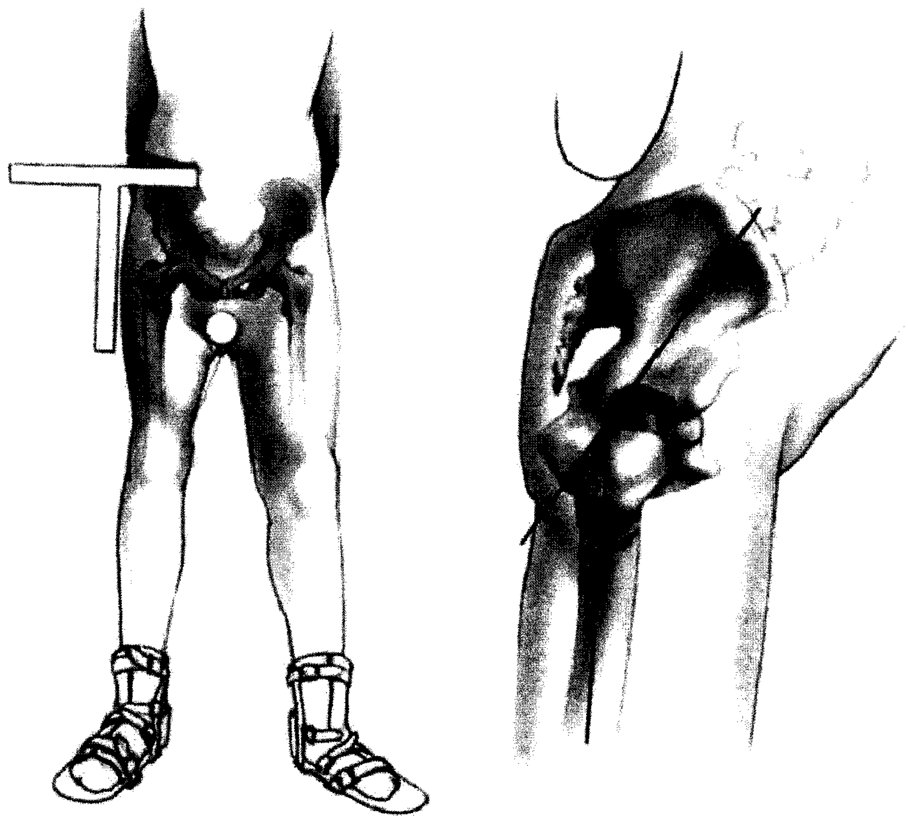


FIGURE 23-134. After the wounds are closed, the patient is moved to a fracture table for application of a spica cast. This is a critical stage in the operation because it determines the position of the leg relative to the pelvis, the importance of which has already been discussed. The best position for the leg is 30 degrees of flexion, 0 degrees of abduction, and 0 to 5 degrees of external rotation. In most situations, the correct amount of flexion is achieved by keeping the unoperated leg parallel to the floor and elevating the operated leg about 10 degrees. The resulting pelvic tilt, as evidenced by the lumbar lordosis, results in about 30 degrees of hip flexion. Because of the dressings and the absence of the anterosuperior iliac spine on the operated side, it is difficult to be sure of the degree of abduction. Because of its importance, the degree of abduction should be verified by radiographic control. This is made easier by the use of a large metal T square and an image intensifier.

The initial spica cast should include the entire leg and the foot if the knee is not bent, so that rotation of the osteotomy site is controlled. It is wise to verify the position of the limb radiographically again after cast placement. An alternative method of intraoperative positioning using prepositioning on beanbags has been described (9). This requires careful attention to detail before beginning surgery and is well suited to techniques that accomplish arthrodesis of the hip without a femoral osteotomy. Such techniques require that the leg be positioned correctly as the fixation is applied. No adjustment is possible after the drapes are removed.

the cast can be altered to allow knee motion, and the patient is mobilized on crutches. This is important to avoid permanent knee stiffness in these patients, who depend on full motion of adjacent joints to achieve full function. The cast is discontinued when there is radiographic evidence of union between the femoral head and the ilium. This usually takes 12 weeks.

Total hip arthroplasty in the young patient is beyond the scope of this text.

Disturbance of Growth of the Proximal Femur. The most disastrous complication associated with the treatment of DDH involves various degrees of growth disturbance of the proximal femur, including the epiphysis and the physeal plate. This is commonly referred to by the term *aseptic necrosis*. Because there has never been a study of a pathologic specimen from a patient with what is called *aseptic necrosis*, the author prefers to use the term *proximal femoral growth disturbance* (213). These growth disturbances can be precipitated experimentally by creating vascular injuries in animals; the results resemble the growth disturbances seen in humans with treated DDH. The disturbance to growth may be caused by vascular insults to the epiphysis or the physeal plate, or by pressure injury to the epiphyseal cartilage or the physeal plate (287, 303, 304, 523–537). The blood supply to the proximal femur is described in Chapter 24.

Growth disturbance of the proximal femur in DDH occurs only in patients who have been treated. This may also occur in the other normal hip in a patient who has been treated for the involved hip (538, 539). The reported incidence of proximal femoral growth disturbance varies from 0% to 73% (213, 215, 452, 453, 540–542). Different opinions exist about the reasons for this variation (543–545). The use of prereduction traction (205, 213, 215, 271, 274, 290, 528, 540, 546), adductor tenotomy (306, 530, 547), open or closed reduction (44, 121, 126, 334, 528, 548–550), the force applied during reduction (540, 547, 551, 552), the position in which the patient is immobilized postoperatively (264, 271, 274, 303, 312, 505, 531, 533–535, 553), and the age at reduction (271, 274, 279, 531) have all been implicated as etiologic factors. Others think that the incidence may be much less variable than the means by which it is assessed (213, 544).

In an extensive study of the development of ischemic necrosis published by the German Society for Orthopaedics and Traumatology (3, 348), conservatively treated hips and operatively treated hips were evaluated in order to determine the factors associated with the development of ischemic necrosis (185). The factors associated with necrosis included high dislocations and dislocations with inversion of the labrum, narrowing of the introitus between the superior labrum and the transverse ligament in the position of reduction, inadequate depth of reduction of the femoral head (>3 mm from the acetabular floor), the age of the patient (older than 12 months), immobilization in 60 or more degrees of abduction for joint instability, and adductor tenotomy.

Westin et al. believed that the marked variation in the reported incidence indicated a lack of definition of terms (546). Thomas et al. concluded that there was some association between the reported incidence in a given series and the rigor with which the diagnosis had been sought (544). Buchanan et al. concluded that if signs of growth disturbance were not present within 12 months of reduction, they were highly unlikely to appear (271).

Bucholz and Ogden (524) and Kalamchi and MacEwen (528) identified a lateral physeal arrest pattern that may not be evident until a patient is older than 12.5 years (mean, 9 years) (Fig. 23-137). This is the most common pattern of growth disturbance reported. Kalamchi and MacEwen stressed that it may be difficult to identify this group early, and studies reporting growth disturbances with follow-up periods of <12 years must be regarded as preliminary and may not reflect the actual incidence of proximal growth disturbance (528).

The incidence of proximal femoral growth disturbance increases with delay in reduction (274, 279). Younger patients have a lower rate of growth disturbance. Kalamchi and MacEwen, however, documented an increase in the incidence of the severe form (type IV) in younger patients (528). Salter et al. (312) and Ogden (533, 534) proposed that the femoral head in DDH is most vulnerable to ischemic changes during the first 12 to 18 months of life, when it is composed mostly of cartilage. According to some orthopaedic specialists, the risk of total head involvement becomes somewhat less after the appearance of the femoral ossific nucleus, although, as mentioned in the preceding text, this concept has recently been challenged (279, 315).

Several factors associated with an increased incidence of proximal femoral growth disturbance have been documented in the clinical setting and in experimental studies. These include extremes in positioning of the proximal femur in abduction and abduction with extreme medial rotation. Extremes in position can cause compression of the medial femoral circumflex vessel as it passes the iliopsoas tendon and compression of the terminal branch between the lateral femoral neck and the acetabular margin (312, 533, 534). Anatomic and experimental investigations have persistently shown that strong medial rotation with concomitant abduction, and extreme abduction alone (i.e., the Lorenz position), can compromise the blood flow to the capital femoral epiphysis. If the hip is maximally abducted against firm resistance, the blood flow can be completely or almost completely arrested. The same is true in forced medial rotation. The blood vessels, and consequently the blood supply to the proximal femur, can be occluded by compression, either outside the femoral head or as the vessels cross through the epiphyseal cartilage (304, 312, 537). Schoenecker et al. showed a diminution of epiphyseal profusion with increasing pressure, which was relieved after the external fixation device was removed (303, 536).

The extreme positions of abduction, frequently called the *frog-leg position* (Fig. 23-36) used in cases of unrelieved adduction contracture, as seen in dislocations, uniformly result in severe growth disturbances of the epiphysis (311, 312, 536).

Extreme positions can also cause pressure necrosis of the vulnerable epiphyseal cartilage and the physeal plate. This has been experimentally shown by Law et al. (530) and by Schoenecker et al. (536). These studies and others demonstrated the severe effects of cartilage necrosis (185, 304, 312). These effects can also be precipitated by circumscribed pressure, such as using the vulnerable femoral head as a "dilating sound" to overcome the intraarticular obstacles to reduction.

Severin advocated placing the femoral head in close apposition to the acetabulum in order to induce regression of the obstacles to reduction (126). The idea is that sustained pressure from the femoral head causes the labrum to adapt itself to the spherical contour of the head. This maneuver can be used for obtaining reduction, but the price may be an increased incidence of necrosis (185, 547), and hence the author's unwillingness to use the femoral head as a "dilating sound" to obtain closed reduction. Although the use of prereduction traction

TABLE 23-2 Salter's Classification of Growth Disturbance of the Femoral Head

Class	Features
1	Failure of the appearance of the ossific nucleus of the femoral head within 1 year after reduction
2	Failure of growth of an existing ossific nucleus within 1 year after reduction
3	Broadening of the femoral neck within 1 year after reduction
4	Increased radiographic bone density, followed by fragmentation of the femoral head
5	Residual deformity of the femoral head and neck when reossification is complete; these deformities include coxa magna, coxa plana, coxa vara, and a short, broad femoral neck.

From Salter RB, Kostiuk J, Dallas S. Avascular necrosis of the femoral head as a complication of treatment for congenital dislocation of the hip in young children: a clinical and experimental investigation. *Can J Surg* 1969;12:44.

has been implicated as a factor in reducing the incidence of necrosis, the German Orthopaedic Study Group did not find this to be the case (185).

The continued use of closed techniques in an attempt to make the femoral head overcome the intraarticular obstacles to reduction can lead to severe necrosis (185). If closed reduction is attempted, in the author's opinion, the only acceptable result is an anatomically perfect reduction; otherwise, the hip must be reduced openly so as to prevent damage to the vulnerable femoral head (185, 554, 555).

The most widely used classification of proximal femoral growth disturbance is that of Salter et al. (312)(Table 23-2). The author disagrees with the inclusion of coxa magna, because coxa magna is often seen after open reduction as a result of the stimulation of blood flow to the proximal femur (556–558). It is also often difficult to ascertain whether some of the residual deformities seen after treatment for DDH are alterations in the proximal femur secondary to disturbances that occurred before the reduction, or whether they are the result of complications associated with the reduction. One of the most common deformities seen is the flattening of the medial aspect of the proximal femur, which occurs because of the pressure of the femoral head lying against the ilium before reduction.

Another area of uncertainty relates to temporary irregular ossification of the femoral epiphysis, and whether this represents damage to the epiphyseal cartilage or merely multiple ossification centers that eventually coalesce. These areas may be analogous to the accessory centers of ossification seen in the periphery of the acetabulum. This pattern usually does not result in growth disturbance of the proximal femur. Only long-term follow-up studies of this entity can resolve this issue.

Kalamchi and MacEwen developed a classification of necrosis, emphasizing the growth disturbances associated with various degrees of physeal arrest (528). This classification (Fig. 23-135) puts all the growth disturbances seen in the ossific nucleus into one category if they are not associated with physeal involvement. Bucholz and Ogden provided an additional classification based on patterns of vascular supply resulting in partial or total ischemia (524). There are few studies documenting the interobserver or intraobserver reliability of these classifications of growth disturbance. As many as 25% of hips may not fit into any particular classification.

O'Brien et al. discussed the importance of identification of growth disturbance lines in predicting future deformity of the proximal femur (559, 560) (Fig. 23-136). These growth arrest lines may provide the physician with early evidence of a future problem. However, the utility of this approach must await long-term follow-up studies.

There are long-term follow-up studies of patients having proximal femoral growth disturbance (185, 287, 561). The results indicate that any alteration or disturbance of proximal femoral growth decreases the longevity of the hip. As previously discussed, recent attention has focused on FAI syndrome in patients with residual deformities of the proximal end of the femur, and their effect on the induction of labral tears and early osteoarthritis (562–564). In recent years, open dislocation of the hip to treat impingement has been advocated by the Bern group (565, 566). Ganz approach is an anterior dislocation through a posterior approach with a trochanteric flip (Fig. 23-138).

In cases where exploration of the acetabulum or consideration of treatment of FAI is concerned, the technique described by Ganz et al. is ideal in the adolescent age group. Previous studies from the authors demonstrated that the majority of the blood supply to the femoral head comes from the deep branch of the medical femoral circumflex artery. These vessels are protected by the intact obturator externus muscle using the trochanteric flip approach.

In the treatment of the residual effects of necrosis, reduction must be maintained by corrective femoral and/or acetabular procedures (566, 567). With arrest of the proximal femoral physeal plate, trochanteric overgrowth ensues, producing an abductor lurch (Fig. 23-139). If the problem is identified, greater trochanteric physeal plate arrest may be carried out, and this may maintain articular trochanteric distance if performed in children younger than 8 years (22, 527, 528, 568, 569); otherwise, distal transfer of the greater trochanter may be necessary (465, 529–531, 570–572).

The key to the diagnosis and management of DDH is early detection. This results in a 95% success rate of treatment with a low risk of complications. It is the initial treating physician who has the greatest chance of successfully achieving a normal hip. Orthopaedic surgeons must educate primary care colleagues in making the diagnosis early and initiating prompt referral (573).

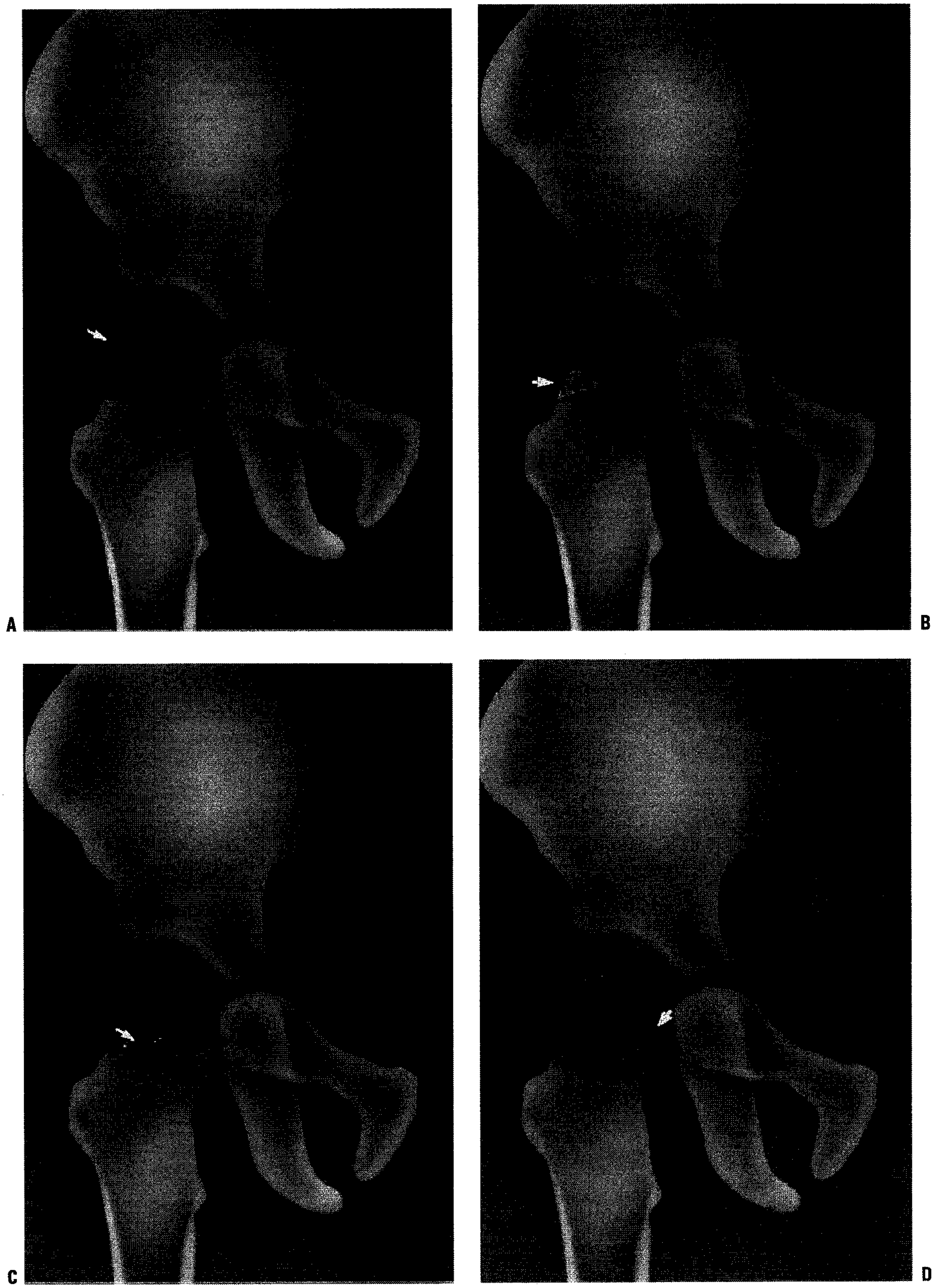
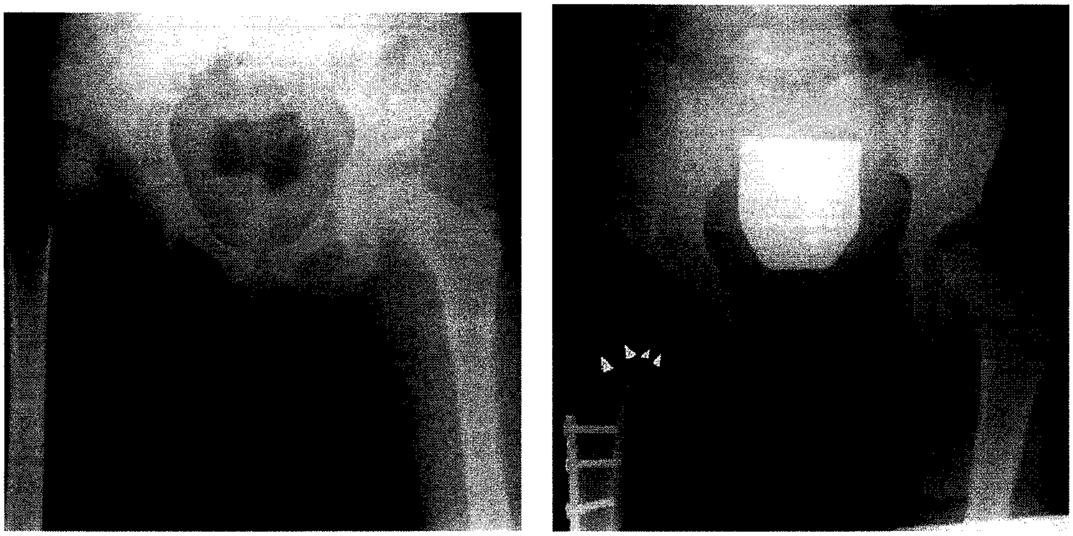
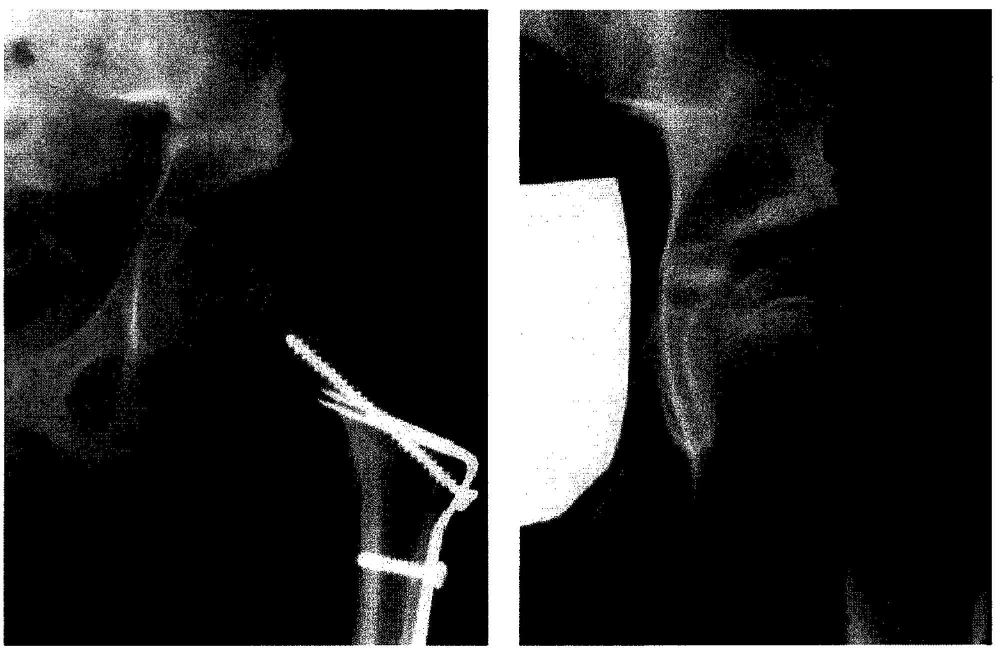


FIGURE 23-135. Classification of proximal femoral growth disturbances. **A:** Group I. **B:** Group II. **C:** Group III. **D:** Group IV. (Adapted from Kalamchi A, MacEwen GD. Avascular necrosis following treatment of congenital dislocation of the hip. *J Bone Joint Surg Am* 1980;62:876.)



A B

FIGURE 23-136. A 3-year-old girl with right developmental dysplasia of the hip. **A:** Preoperative radiograph. **B:** Ten months after operative open reduction, femoral shortening, and Pemberton osteotomy. Note the presence of growth arrest line at the proximal femur (O'Brien lines; *arrows*); also note similar lines on the opposite, normal hip.

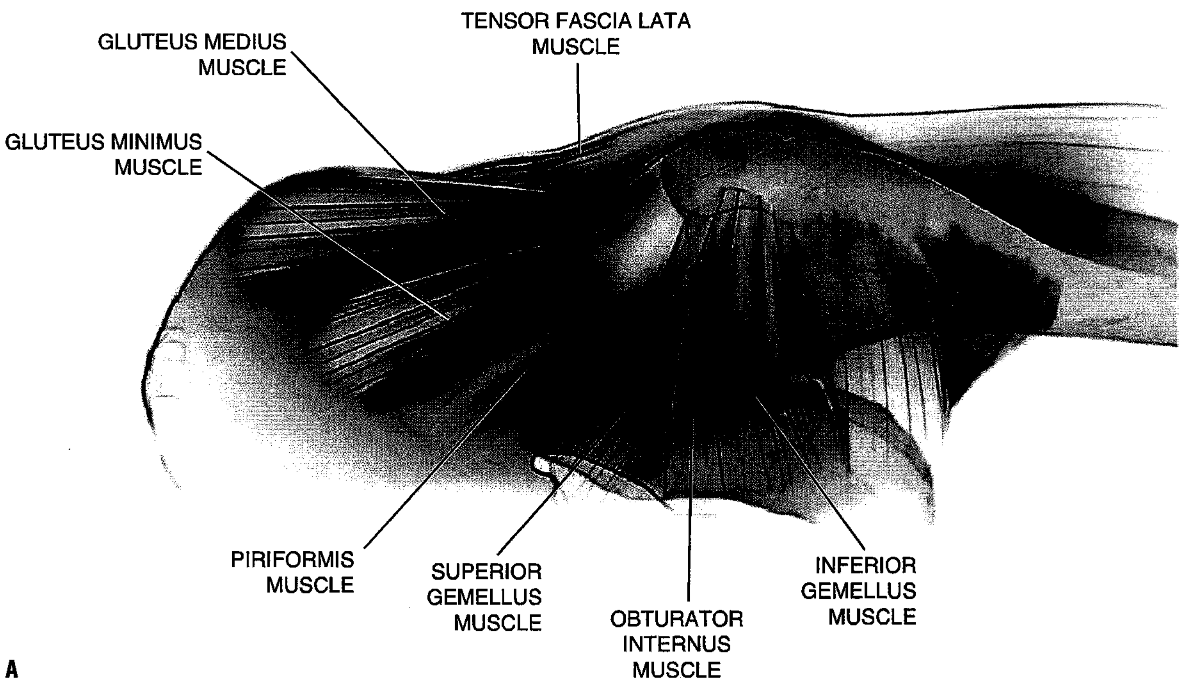


A B

C

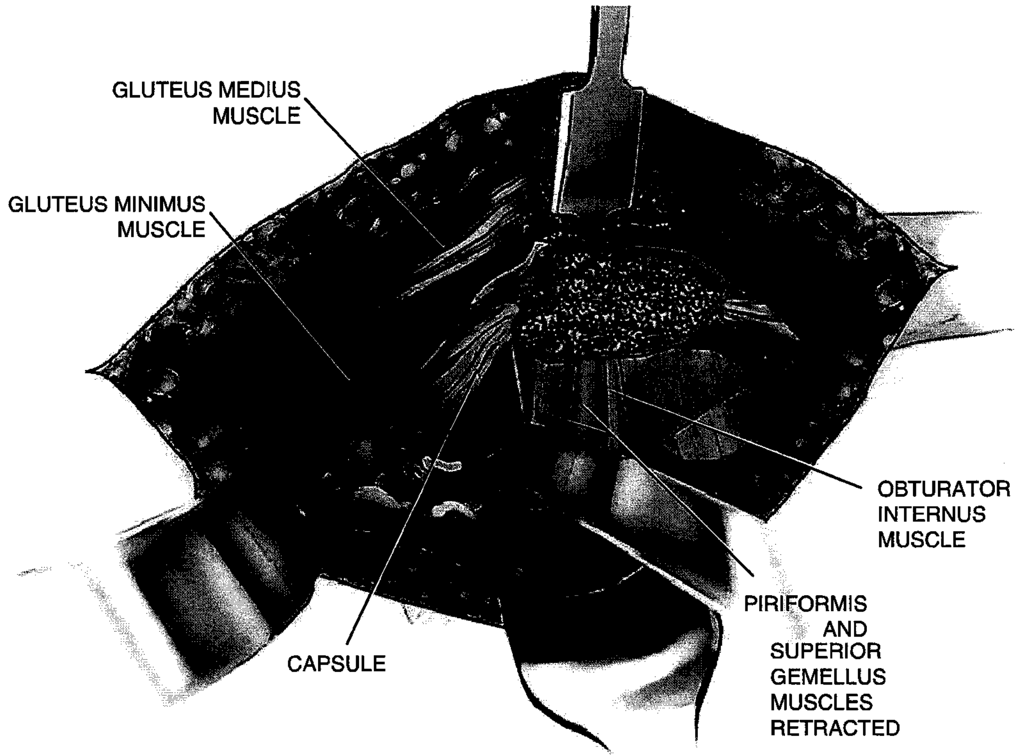
FIGURE 23-137. **A:** Anteroposterior view of a 5-year-old girl, 3 months after varus derotation osteotomy, an innominate osteotomy for residual dysplasia. She had undergone an open reduction procedure 3 years previously. **B:** Anteroposterior view at 9 years of age. Note the valgus tilt to the proximal femur. **C:** Anteroposterior view at 11 years of age. Note the lateral tether, a typical type II physeal plate tether, and how the tether produces hip subluxation. A physeal growth arrest pattern may not be evident until a patient is 9 years of age or older.

Surgical Dislocation of the Hip (Fig. 23-138)



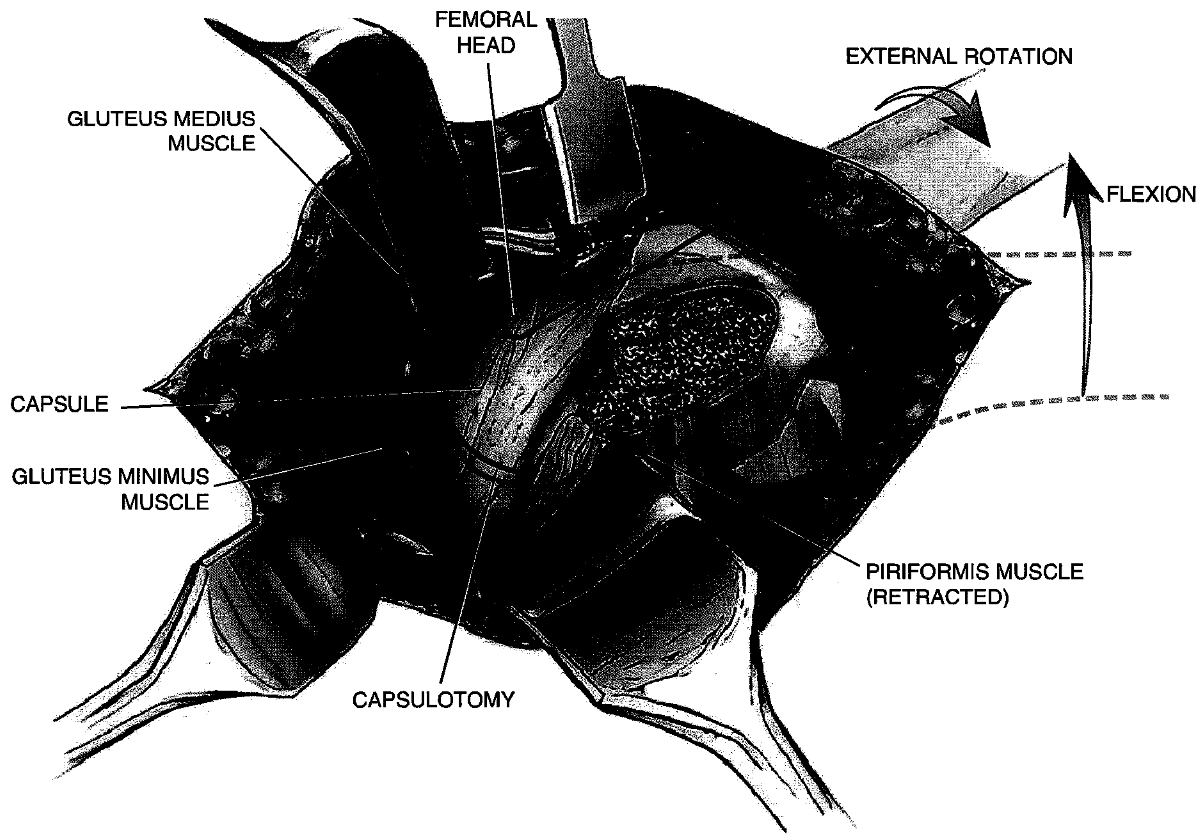
A

FIGURE 23-138. A: Surgical Dislocation of the Hip. The patient is placed in the lateral decubitus position and the hip exposed through a Kocher-Langenbeck incision. With the leg internally rotated, the posterior border of the gluteus medius is identified. An incision from the posterior superior edge of the greater trochanter extending distally along the posterior border of the trochanter to the vastus lateralis ridge is made.

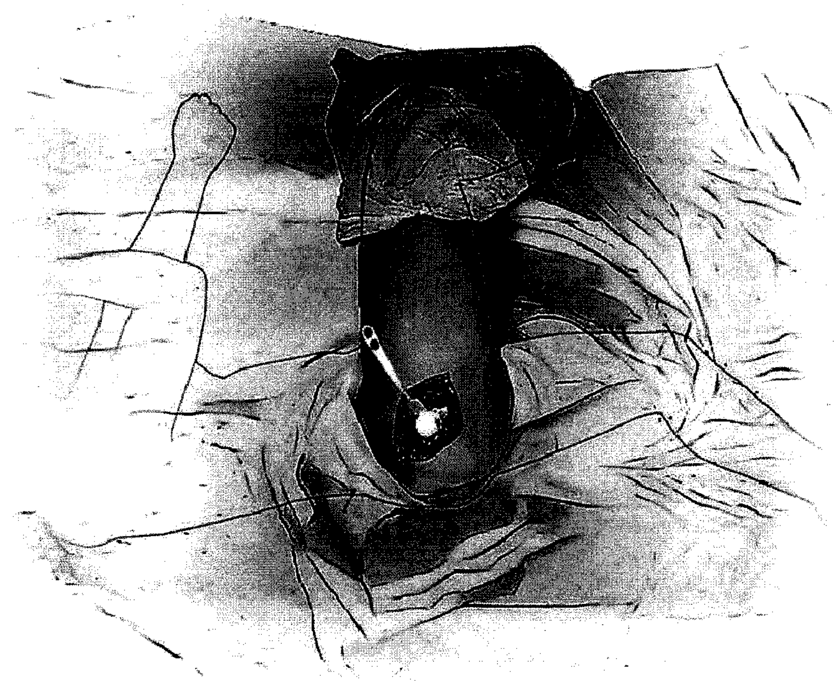


B

FIGURE 23-138. (*continued*) **B**: A trochanteric flip osteotomy is accomplished with an oscillating saw removing an approximately 1.5 cm fragment of the greater trochanter. The osteotomy should exit just anterior to the most posterior insertion of the gluteus medius which will allow preservation and protection of the medical femoral circumflex artery, which becomes intracapsular at the level of the superior gemellus muscle. The trochanteric fragment is mobilized anteriorly with the vastus lateralis after releasing it along its posterior border to the middle of the tendon of the gluteus maximus. The vastus lateralis and intermedius are elevated from the lateral and anterior aspects of the femur. This is aided by flexing and slightly externally rotating the leg. The inferior border of the gluteus minimus is separated from the piriformis and the underlying hip joint capsule. The sciatic nerve that passes in most cases inferior to the piriformis muscle must be protected to avoid injury.

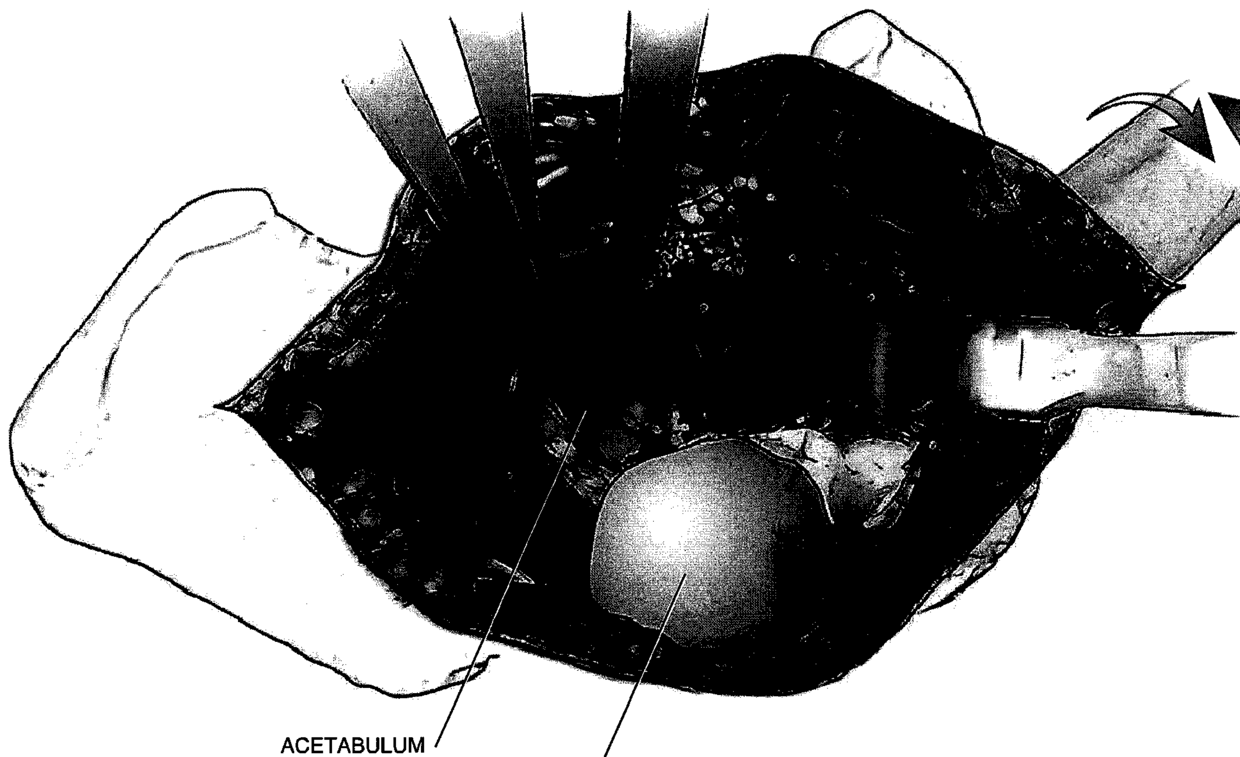


C



D

FIGURE 23-138. *(continued)* **C**: The entire flap including the gluteus minimus is retracted anteriorly and superiorly to expose the hip joint capsule. Exposure is facilitated by further flexing and external rotation of the hip. The anterosuperior and posterosuperior capsule are easily visualized. The first capsular incision extends along the long axis of the femoral neck anterolaterally. This incision must remain anterior to the lesser trochanter in order to avoid damage to the main branch of the medial femoral circumflex artery. The capsular incision is then extended toward the acetabular rim where it is then sharply turned posteriorly parallel to the labrum reaching the retracted tendon of the piriformis. It is critically important to avoid injury to the labrum during this capsular incision. **D**: The hip joint can now be dislocated with the leg in flexion and external rotation off the front of the operating table. This allows complete exposure of the femoral head and the acetabulum.



E

FIGURE 23-138. (*continued*) **E**: By careful manipulation of the leg, the entire femoral head and acetabulum can be visualized for surgical intervention. It is usually necessary to divide the ligamentum teres to complete dislocation. It is important during the surgical procedure to continue to irrigate the exposed cartilage of the femoral head and acetabulum with Ringer lactate solution. Viability of the femoral head can be assessed by a 2-mm drill home in the dislocated femoral head.

After surgical intervention, the femoral head is easily relocated into the acetabulum and the hip joint capsule can be repaired loosely. The greater trochanter is attached using two or three 3.5-mm cortical screws or a cerclage wire. Ganz does not recommend prophylaxis against heterotopic ossification. Laser Doppler flowmetry may also be used to assess perfusion of the femoral head. (Adapted from [Ganz R, Gill TJ, Gautier E, et al. Surgical dislocation of the adult hip: a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *J Bone Joint Surg Br* 2001;83:1119–1124. 2001 JBJS].)

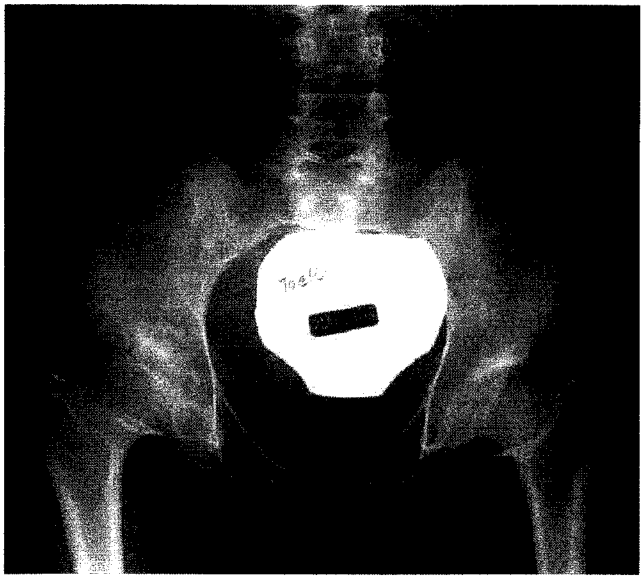


FIGURE 23-139. A 14-year-old girl with residual dysplasia, type III growth arrest, and trochanteric overgrowth. The patient had bilateral open reductions at 14 months of age. She had a type III growth arrest of the proximal femur with resultant disturbance of growth and corresponding acetabular deformity and trochanteric overgrowth. Her Trendelenburg test was negative. Some patients with this deformity have an abductor lurch, necessitating distal transfer of the greater trochanter.

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