A

B

FIGURE 29-36. **A:** When the foot is abducted, the heel varus corrects as the calcaneus externally rotates under the talus. **B, C:** (From the private collection of Vincent S. Mosca, MD.) The focus of deformity correction quickly shifts from cavus to the forefoot adductus and hindfoot varus. The forefoot is gently abducted, and the hindfoot is everted around the talus through the subtalar complex, while maintaining supination of the forefoot. The talus is secured against rotation in the ankle mortise by applying counterpressure with the thumb of the other hand against the dorsolateral aspect of the head of the talus (not the calcaneus or cuboid). The forefoot must *never* be pronated. When the foot is abducted against the fulcrum pressure point on the lateral aspect of the head of the talus, the forefoot abducts on the hindfoot and the calcaneus everts (externally rotates, dorsiflexes, and pronates) under the talus. The calcaneus cannot evert unless it can freely rotate posteriorly. This requires that it not be touched or restrained posteriorly. Instead, the posterior pressure and stabilization point is the medial malleolus, which is held firmly by fingers of the hand that is used to stabilize the head of the talus. Gentle continuous pressure for a few seconds is used and repeated several more times when the baby is relaxed until the ligaments are felt to be relaxed, such that minimal pressure needs to be applied to maintain the corrected position. The correction obtained by manipulation is maintained by immobilizing the foot in a thinly padded well-molded toe to groin cast.

C

FIGURE 29-36. *(Continued)*

A  B

FIGURE 29-37. A, B: The thinly padded, well-molded cast is applied in two sections. One or two layers of padding are applied over the foot and leg. The padding, as well as the cast that follows, should be wrapped snugly over the foot and ankle for better molding and loosely over the calf and thigh to prevent unnecessary pressure on the muscles. The cast should initially extend to below the knee while it is molded very carefully with the foot held in abduction and supination. The thumb should never rest for long over the lateral aspect of the head of the talus to avoid an indentation in the cast that could cause a pressure sore. The heel prominence should be emphasized by molding above and around it. Never crush or flatten the heel pad, or the foot will pull back in the cast and the deformity correction will be lost. The correction is maintained not through pressure but through careful molding. The cast is then extended to the upper thigh with the knee flexed at 90 degrees with the leg in slight external rotation. The cast is trimmed over the toes to allow the toes to extend freely. (From the private collection of Vincent S. Mosca, MD).

FIGURE 29-38. Improvements obtained by each manipulation are maintained by immobilizing the foot in a well-molded cast. Repeat manipulation and casting are done at 5- to 7-day intervals until the deformities are slightly overcorrected or until no further correction is noted. The hindfoot is gradually and almost inadvertently dorsiflexed, using the abduction/eversion maneuver for the subtalar joint, while avoiding excessive dorsiflexion stress on the forefoot. This generally takes four to eight manipulation and casting sessions. To fully stretch the medial tarsal ligaments in the last few casts, the foot in front of the talus must be hyperabducted. The entire foot is also abducted under the talus and is no longer supinated (and never pronated). The navicular has moved laterally away from the medial malleolus to a distance of about 1.5 cm. The lateral aspect of the head of the talus can no longer be palpated because the navicular covers it. The heel should be in some degree of valgus. All components of the clubfoot deformity must be corrected simultaneously, but in a sequence from cavus to adductus to varus to equinus. The equinus is corrected last by dorsiflexing the foot, though it must be acknowledged that it is uncommon for the equinus to correct fully. One can be easily fooled by the gross appearance of the foot into thinking that the equinus is being corrected. It's best not to crush the talus or get false dorsiflexion through the midfoot by overly aggressive dorsiflexion molding. To ensure that the equinus is being corrected at the ankle and that there is not false dorsiflexion hypercorrection through the midfoot, the calcaneus must be palpable in the normal position in the heel pad. Radiographic confirmation might be needed, particularly in feet with abundant fat. An Achilles tenotomy is indicated if at least 10 degrees of dorsiflexion cannot be achieved.

FIGURE 29-39. With each cast, the thigh–foot angle is progressively increased toward its final position of 70 degrees of external rotation. (From the private collection of Vincent S. Mosca, MD).

FIGURE 29-40. Long leg casts are used to ensure that the pressures are maintained where they are applied, that the forces are directed appropriately, and to prevent the short-leg component from slipping down on a fat, conical leg. There is *no* role for short-leg casts in the correction of clubfoot deformity. (From the private collection of Vincent S. Mosca, MD.)

demonstrated. A percutaneous heel cord tenotomy was performed in 31 of 34 patients in Herzenberg's series.

In 2003, Lehman et al. (195) reported similar results using the Ponseti method of clubfoot management. Ninety-two percent of patients achieved deformity correction within the first year of life with the use of Ponseti's method. Hattori et al. (196) showed the positive effect of the Denis-Browne bar in the postcasting management of clubfoot, particularly if applied in the first months of life.

The importance of postoperative foot abduction bracing cannot be overstated. Much effort must be made to convince parents of affected children that the value of bracing far outweighs any inconvenience endured. If deformity recurs in the early years of life, manipulation and casting are reinitiated, followed again by foot abduction bracing and stretching exercises. Although it is uncommon for recurrence of deformity in a fully corrected clubfoot after the age of 5 years, Dobbs et al. (197) have documented relapse in an 8-year-old child who was previously fully corrected. Long-term follow-up is mandatory for clubfeet managed by the Ponseti method, just as for those treated by any other technique.

As I stated in the Foot chapter for the fifth edition of this textbook and reiterate here, the Ponseti method for clubfoot management is the gold standard by which all other methods must be compared. Other reported nonsurgical methods for the management of clubfoot include taping, physical therapy and splinting (198), and continuous passive motion (CPM) with a machine (130).

The French, or functional, method for clubfoot treatment was developed in the 1970s by Masse (199) and Bensahel et al. (198). It has been popularized and further developed by Dimeglio (130, 200) in France and by Richards et al. in the United States (185, 201, 202). This is a dynamic method of management, utilizing physiotherapist-implemented exercises for correction of the deformities, supplemented by taping and, more recently, by CPM in some cases. Exercises are begun immediately after birth to stretch the tight plantar-medial structures, including the posterior tibial tendon and plantar soft tissues. An attempt is also made to strengthen the peroneal muscles by stimulation. Adhesive taping (Fig. 29-43) is applied to maintain the correction that is achieved by stretching. Taping holds the foot in the corrected position, but allows some functional motion that is not permitted in rigid casts. Daily treatments are continued for 2 months. The treatment frequency in this program is then decreased to three sessions per week until 6 months of age. After that time, the child is continued on a physical therapy program, and night splinting is used for 2 to 3 years.

In the early 1990s, CPM was added to this regimen (130). Use of a CPM machine at night was advised, and this

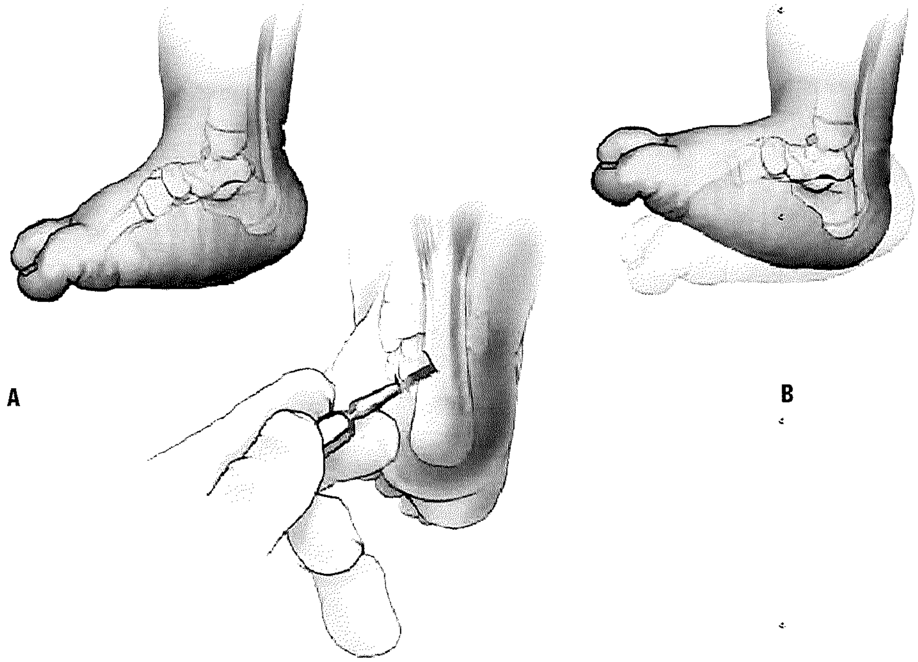


FIGURE 29-41. The percutaneous Achilles tenotomy is performed in the outpatient clinic under local anesthetic if dorsiflexion is limited **(A)**. An assistant holds the leg at the knee and at the forefoot. The heel and lower portion of leg are given a generous Betadine prep. A small amount of local anesthetic is injected with a 25- to 27-gauge needle medial to the tendo Achilles. Large volumes of the anesthetic should be avoided because this can obscure palpation of the tendon. Alternatively, a Xylocaine cream can be applied to the posterior ankle region before the tenotomy to avoid obscuring the tendon with the injected anesthetic. The liquid local anesthetic can be injected immediately following the tenotomy in this scenario. At a position approximately 1 cm above the insertion of the Achilles tendon on the calcaneus, a small cataract knife or narrow Beaver blade is inserted from the medial side of the heel perpendicular to the medial border of the foot, with the blade parallel to the Achilles tendon and directed at the tendon. Upon encountering the tendon, the blade is slowly moved anteriorly until it slips past the anterior border of the tendon. This technique will help ensure that the blade does not pass near the posterior tibial neurovascular bundle. The knife blade is then turned to a 90-degree angle posteriorly and the tendon sectioned. The knife blade should not go through the skin posteriorly. The release that is obtained after complete tenotomy is easily felt, and 10 to 20 degrees of additional dorsiflexion are easily obtained **(B)**. The skin is then cleaned with alcohol to remove the Betadine. A small square of Adaptic or Xeroform gauze can be placed over the wound and covered by sterile gauze. With the final cast applied, the foot should be in 20 degrees of dorsiflexion and 70 degrees of abduction (see Fig. 29-38 and Fig. 29-39). This final cast is worn for 3 weeks.

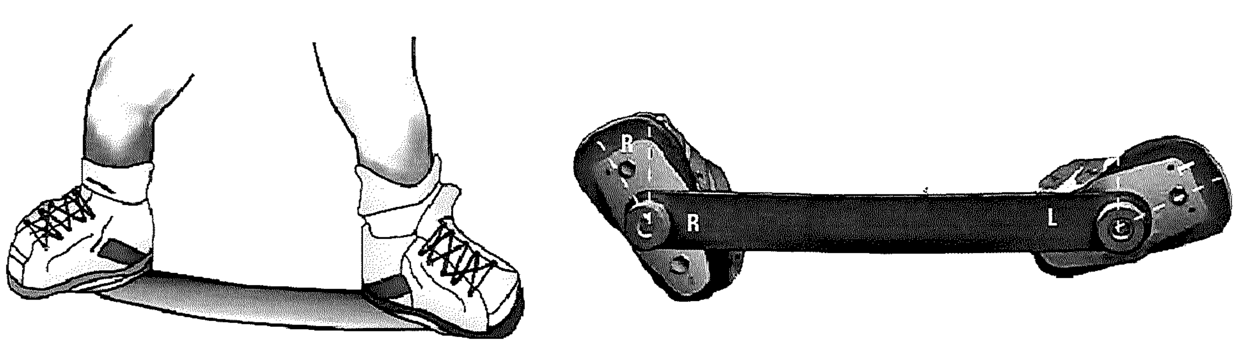


FIGURE 29-42. L clubfoot shoe set at 70 degrees external rotation; in this example, R foot was normal, so foot set at 45 degrees external rotation. The bar is bent to give approximately 10 degrees of dorsiflexion. The width of the bar from one shoe heel to the other should be the width of the child's shoulders. In bilateral cases, both feet are externally rotated 70 degrees. Following casting, full-time brace wear with the use of a FAB is critical to prevent recurrences.

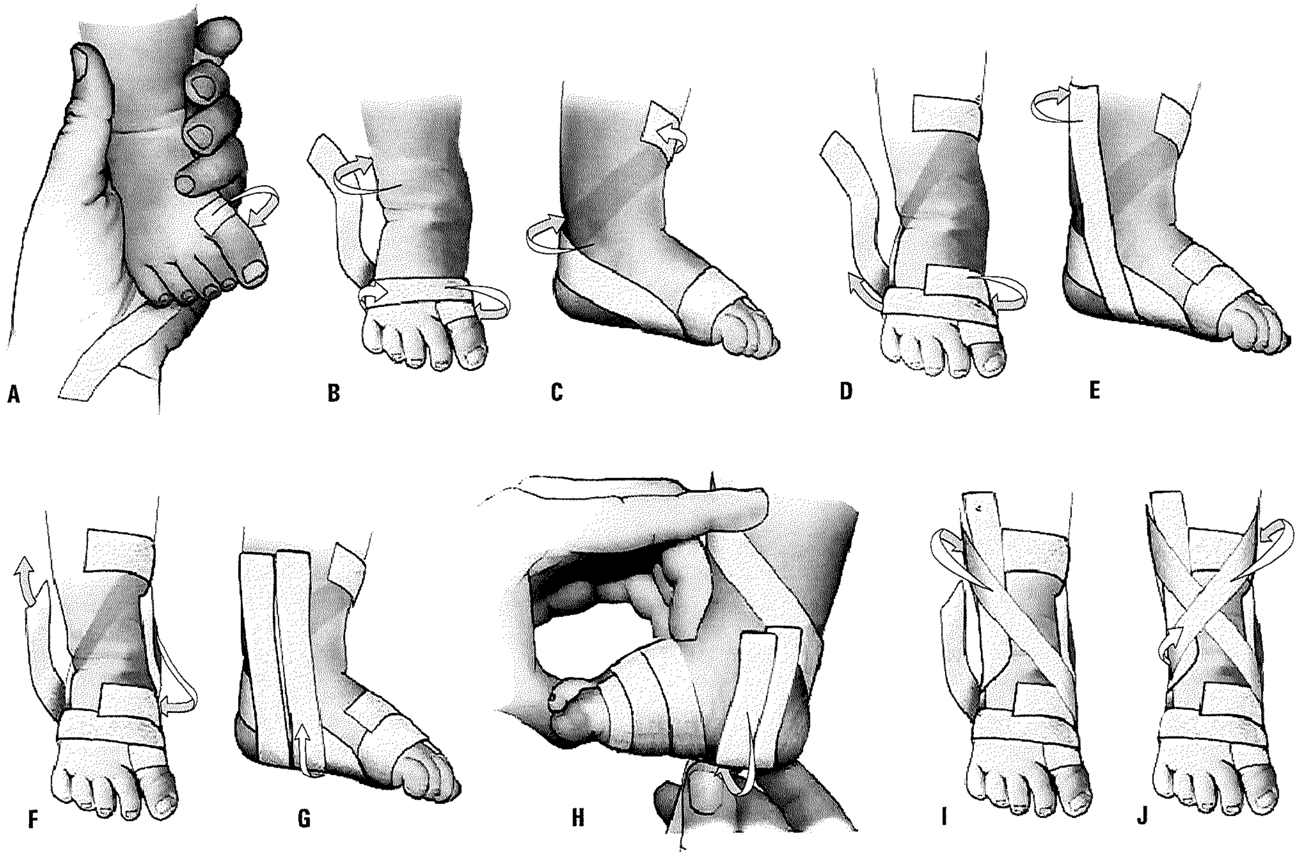


FIGURE 29-43. Taping is used to maintain the passive range of motion achieved during manipulation sessions when clubfeet are managed by the French method. As the tape is applied sequentially in Steps *A* to *J* as pictured, the foot can be derotated with correction of the forefoot, midfoot, and hindfoot deformity, including equinus. (From Noonan KJ, Richards BS. Nonsurgical management of idiopathic clubfoot. *J Am Acad Orthop Surg* 2003;11:392–402, with permission.)

resulted in fewer patients requiring surgical treatment for residual clubfoot deformity. Using this technique, Bensahel et al. (198) achieved good results in 48% of 338 patients, as reported in 1990. An overall success rate of 86% in the good and excellent category was achieved by adding surgical releases in approximately half of the patients. Dimeglio et al. (130) reported a high rate of success, without the need for surgery, in a large percentage of patients by using physiotherapist-implemented exercises and a more intensive CPM program than had been used by Bensahel. The results were directly correlated with the stiffness and severity of the clubfoot deformity according to the classification system of Dimeglio et al. (121).

Van Campenhout et al. (186), in 2001, found that 75% of feet treated with the functional method required surgical therapy. A coauthor, Fabry, felt that there was a greater benefit to the treatment of clubfoot with exercise in the Dimeglio grade 1 and 2 feet, than in the mild and moderate foot. With a Dimeglio score <10, he found consistent success, whereas in higher grades, surgical treatment was required.

In the same year, a group led by Richards et al. (185) from the Scottish Rite Hospital in Texas reported their initial results with this technique. A very well-conducted study by the same group comparing the Ponseti method with the French functional method was published in 2008 (202). They found that the nonoperative correction of idiopathic clubfoot deformity can be maintained over time in most patients using either method. Though not statistically significant, there was a trend showing improved results with the Ponseti method, with fewer children requiring operative intervention for residual and recurrent deformities. They also found that the parents selected the Ponseti method twice as often as the French method based on parental time, travel, and expense.

Surgical Treatment. Surgery is indicated for those clubfeet that fail to achieve full deformity correction by nonoperative methods. Using traditional and historical nonoperative methods, most clubfeet failed to respond, resulting in surgical rates of 75% to 100% (97, 163). Complications frequently reported for surgically treated clubfeet include wound-healing problems, neurovascular injury, bone/cartilage damage, avascular necrosis of the talus and navicular, pain, stiffness, weakness, residual deformity, recurrent deformity, dorsal bunion, and overcorrection at the talonavicular, talocalcaneal, and talocalcaneonavicular joints (187, 203–206, 527). In 2006, Dobbs et al. (203) reported the average 30-year follow-up of 73 clubfeet that were treated with extensive soft-tissue releases. Many were found to have poor foot function long-term. Most feet underwent one or more repeat surgical soft-tissue releases, and these feet were characterized by pain, stiffness, and arthritis. These young adults experienced a significantly impaired quality of life.

The Ponseti and French nonoperative methods have significantly reduced the frequency and extent of surgical releases in idiopathic clubfeet, but have not completely eliminated the need for surgery. Furthermore, surgery is frequently required for syndromic and neuropathic clubfeet as well as for idiopathic clubfeet that present late for treatment or develop recurrences at an older age. For these indications, pediatric orthopaedic surgeons need to maintain their clubfoot surgery skills despite fewer opportunities to practice them.

The definition of treatment failure is debated, as are the issues pertaining to the timing of surgery, the technique of surgery, the importance and type of short-term and long-term postoperative management, the definition of recurrence or other secondary deformities, and the indication for additional surgery after the first (or second). The need for additional surgery after the first operation is reported to range from 5% to 50% (176, 203, 204, 207–210). However, these data are not helpful, because there are no strict indications for additional surgery. Painless recurrent or residual deformity might be an indication for surgery in one center but not in another. The data are also of limited validity based on the short length of follow-up in most of these studies.

As stated earlier, throughout the 1970s, 1980s, and 1990s, there was a proliferation of clubfoot surgical techniques, while interest in nonoperative treatment waned. The surgical approaches are each attributed to an individual. Each is based on a slightly different understanding of the pathoanatomy with an often dramatically different approach to the surgical management of the soft tissues. Nevertheless, 60% to 80% good or excellent results (118, 163, 176–178, 180) have been consistently reported at short-term follow-up in most series.

The Turco procedure (175, 176) was very popular in the 1970s. A medial incision is used to perform a posteromedial release. The subtalar joint is *opened like a book* with its binding at the posterolateral corner of the foot, more specifically the calcaneofibular ligament, which is not released. At follow-up, many feet exhibited excessive internal rotation and valgus deformity of the hindfoot, due to lateral translation of the calcaneus.

The Goldner procedure (163, 179, 528) is based on the premise that the primary deformity is an internal rotation of the talus in the ankle joint. Correction requires lengthening of the deltoid ligament with extensive medial release and reconstruction of the talonavicular joint. The subtalar joint is not released.

Carroll (151, 152, 155, 180, 207) and McKay (154, 178) agreed with each other that circumferential release and rotation of the subtalar joint were necessary to correct the clubfoot deformity. Both believed in the importance of preservation of the talocalcaneal interosseus ligament if possible. They disagreed with Goldner and with each other on the alignment of the talus in the ankle joint. Carroll (151, 152, 155) believed that it was externally rotated, and McKay (154) believed that it was in neutral alignment.

Simons (177, 181) developed the most extensive surgical release yet described for management of the clubfoot. His was a circumferential release of the subtalar joint with release of the talocalcaneal interosseus ligament and, often, with circumferential release of the calcaneocuboid joint. These releases completely destabilize the bones and joints, often resulting in the creation of gross translational deformities from which it is extremely difficult to recover. Simons (162) brought attention to the alignment at the calcaneocuboid joint. Debate surrounds the implication of the apparent or real medial subluxation at that joint seen on plane radiographs. His approach was to release the joint circumferentially and realign it. Others have recommended a partial plantar-medial release of the calcaneocuboid joint, allowing it to hinge open without completely destabilizing it (152, 180). In the latter situation, the Hueter-Volkmann law of cartilage remodeling may work to correct the pathoanatomy, which in many cases is a varus deformity of the anterior calcaneus with a medial tilt of the calcaneocuboid joint (139, 140, 153, 156–158).

Unfortunately, a review of the short-term and intermediate-term follow-up studies on these procedures does little to help one choose the best operative approach in those cases in which nonoperative management fails to correct the deformity. Different classification and evaluation systems were used in the studies. Other variables not controlled or comparable between studies include age at the initiation of casting, number and method of casts, age at surgery, type and duration of postoperative cast management, type and duration of postcast splinting, and length of follow-up. Wientroub and Khermoush (211) has written an excellent review and comparison of several of the most popular surgical procedures for clubfoot. But when it comes right down to it, most surgeons choose an operative approach based on his or her understanding of the pathoanatomy, an impression of the results seen in training, and one's own experience.

The pathoanatomy of a clubfoot is one of severe inversion of the subtalar joint complex around the talocalcaneal interosseus ligament with equinus, adductus, and cavovarus deformities. The Ponseti manipulation and casting method directly addresses that pathoanatomy. When an extensive surgical release is indicated, the techniques that best address that pathoanatomy are those of Carroll (152, 180) and McKay (178). Both originators stress the importance of preserving the talocalcaneal interosseus ligament that, if released, puts the calcaneus at risk for lateral translation, a disastrous complication. The alignment of the talus in the ankle joint is probably a moot point to consider, as it seems to rotate spontaneously to the correct position following the subtalar release in both procedures.

Although some authors have an all-or-none approach to surgery (212, 213), many support an à la carte approach (118, 119, 130). It makes sense that if there is a range of severity for clubfeet, such that some do not require surgery at all, that there should be a range of surgical releases that can be performed. In the à la carte approach, the pathologic structures are released in a consistent order, addressing only those deformities that have not responded to the nonoperative treatment that has been employed.

Controversy surrounds the age at which clubfoot surgery should be performed. The argument for early surgery and realignment is that it allows for better remodeling of the cartilage anlage. Ponseti has documented the high cellular nature of the medial ligaments in the infant clubfoot, and Zimny et al. (164) have documented the presence of myofibroblasts that might well be stimulated by early surgery, leading to a more rigid foot and unsatisfactory outcome. Nevertheless, neonatal surgery has been reported (214–216). The technique is demanding, the results are variable, and the anesthetic risks are higher than for the older child. This approach obviates the avoidance of surgery that might result from manipulation and casting. Data do not support an optimal age range during which clubfoot surgery should be performed. Most surgeons operate on the child between ages 3 and 12 months (176, 180, 213, 217). Anesthetic risks, difficulty with venous access, and the technical challenge related to foot size are greater under age 6 months.

Surgical Correction of Clubfoot (Figs. 29-44 to 29-54)

General anesthesia with supplemental caudal epidural anesthesia has been shown to decrease the postoperative narcotic requirement, provide good pain control for several hours after surgery, and shorten the hospital stay (218).

The most useful type of skin incision(s) is debated, but this is certainly less important than the procedures performed under the skin, as long as all components of the deformity can be exposed and treated safely and effectively (Fig. 29-44).

Most surgeons use the Cincinnati incision (219) because it is extensile, cosmetic, and safe, as long as it is placed at least 1 cm proximal to the deep posterior ankle skin crease. Lower placement may risk slough of the heel pad. The Cincinnati incision can be used for revision surgery, even crossing longitudinal scars from previous surgery. Another approach is Carroll's two-incision technique (152, 180). It is safe and extensile, but less cosmetic.

The operation typically begins with heel cord lengthening and posterior release of the ankle and subtalar joints, with release of the calcaneofibular ligament (Figs. 29-45 to 29-50).

Residual cavus, adductus, and varus require a plantar-medial release that starts with release of the plantar fascia and the three origins of the abductor hallucis muscle from the calcaneus (Figs. 29-11, 29-51).

If the talonavicular joint is not normally aligned at this point, the posterior tibial tendon is lengthened (Figs. 29-12, 29-51 to 29-53).

If still not aligned, the talonavicular joint capsule is released judiciously, starting medially and carefully progressing plantar and dorsal. Once there is a straight talus–first metatarsal angle visualized on minifluoroscopy, no further release is necessary. Excessive release of the talonavicular joint can lead to unrecoverable subluxation/dislocation and must be avoided (Figs. 29-12, 29-51 to 29-53).

The interosseous talocalcaneal ligament is *always* left intact. Percutaneous releases of the flexor hallucis longus and flexor digitorum longus (FDL) tendons at the base of the toes or supramalleolar lengthenings of these tendons are preferable to lengthening these tendons in the midfoot. Finally, the posterior tibial and Achilles tendons are repaired under slight tension with the joints in anatomic alignment to avoid postoperative weakness (Fig. 29-54).

Debate surrounds the need for internal fixation with wires. Procedures that involve more extensive capsular releases tend to require fixation. One of the many challenges of wire fixation is the inability to accurately determine the proper alignment of the bones and joints. There is minimal ossification of the tarsal bones in infants, so the accuracy of radiographic analysis is marginal at best. Pinning in a poor alignment is perhaps as likely as pinning in the anatomic position. I personally do not use wire fixation, but instead depend on sufficient, but not excessive, soft-tissue releases and fluoroscopic guidance to produce proper joint alignment. Others prefer internal fixation.

Before closure of the wound, some steps should be taken to minimize the bleeding in the foot because this can cause considerable swelling, which may necessitate splitting or removal of the cast. Release the tourniquet and achieve wound hemostasis before closure. Approximate the subcutaneous tissues with interrupted absorbable sutures, and approximate the skin edges with a running subcuticular absorbable suture, such as 4-0 Monocryl.

Apply a solid long-leg cast with the foot in the fully corrected position and with the knee bent 90 degrees and the thigh–foot angle set at 45 degrees outward. Attempts at early motion with a hinged cast, as advocated by McKay (154, 178), have not been widely utilized. At 6 weeks, the cast and the pins, if utilized, are removed in the office. Another long-leg cast is applied and maintained for 4 to 6 weeks, depending on the age of the child. After the final cast is removed, there are options for maintaining deformity correction. One is to utilize a FAB, as is used in the Ponseti method after cast correction. Another option is to use an ankle–foot orthosis in an overcorrected position, either day and night or at nighttime only. Generally speaking, special shoes are not required, but the use of arch supports or simple shoe modifications may be of benefit in selected cases.

In a severe clubfoot that has not responded well to casting, it may not be possible to immediately approximate the edges of the Cincinnati incision with the foot in the fully corrected position without compromising the circulation of the skin. It has been suggested to leave the skin edges separated with the foot in the fully corrected position and allow for wound closure by secondary intent (220). Alternatively, the skin edges can be approximated (with or without a pin inserted across the talonavicular joint), the cast can be applied with the foot in plantar flexion, and the foot can be manipulated safely into further dorsiflexion during a cast change under anesthesia 1 to 2 weeks later (175–177, 219).

Surgical Complications and Their Management. The laundry list of operative complications was mentioned earlier. The approach to management of some of the postoperative deformities will now be discussed.

Text continued on page 1439

Surgical Correction of Clubfoot (Figs. 29-44 to 29-54)

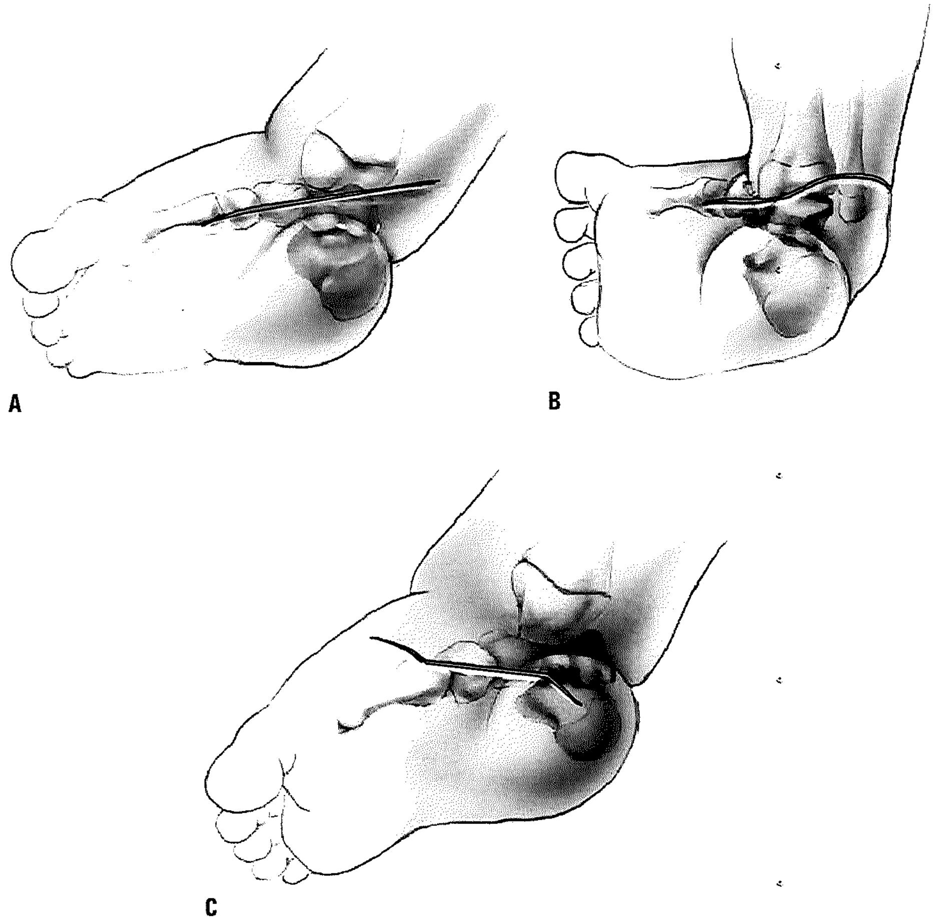


FIGURE 29-44. Surgical Correction of Clubfoot. The incisions used for clubfoot surgery vary widely and are more numerous than can be described here. All have been used successfully, but what is done beneath the incision is far more important to the result than the incision itself. Turco (175) described a straight incision that ran from the base of the first metatarsal, under the medial malleolus, until it reached the Achilles tendon **(A)**. He pointed out that a proximal extension of the incision along the Achilles tendon was contraindicated and that no undermining of the wound should be done. Ignoring these two admonitions has led to many wound problems. Crawford et al. (219) described an incision popularized by Giannestras in Cincinnati **(B)**. This transverse incision begins on the medial side of the foot, over the naviculocuneiform joint. From there, the incision passes posteriorly to cross just beneath the tip of the medial malleolus. It continues across the back of the ankle at least 1cm proximal to the posterior heel crease and continues laterally to pass under the lateral malleolus, ending at the sinus tarsi. Although some surgeons have abandoned this incision because of wound complications, many more report using it routinely without problems. It is my incision of choice. Some surgeons prefer to use two incisions: one posterior and one medial, with a third incision laterally over the calcaneocuboid joint, if this is necessary. Carroll (152) has described a medial incision with three limbs **(C)**. The center of the calcaneus, the front of the medial malleolus, and the base of the first metatarsal form a triangle. The center part of this incision is parallel to the base of the triangle, whereas the proximal part angles toward the center of the heel and the distal part crosses over the dorsum of the foot. The posterior incision (not shown) runs from a point in the midline about 4 cm above the tibiotalar joint obliquely to a point midway between the Achilles tendon and the lateral malleolus.

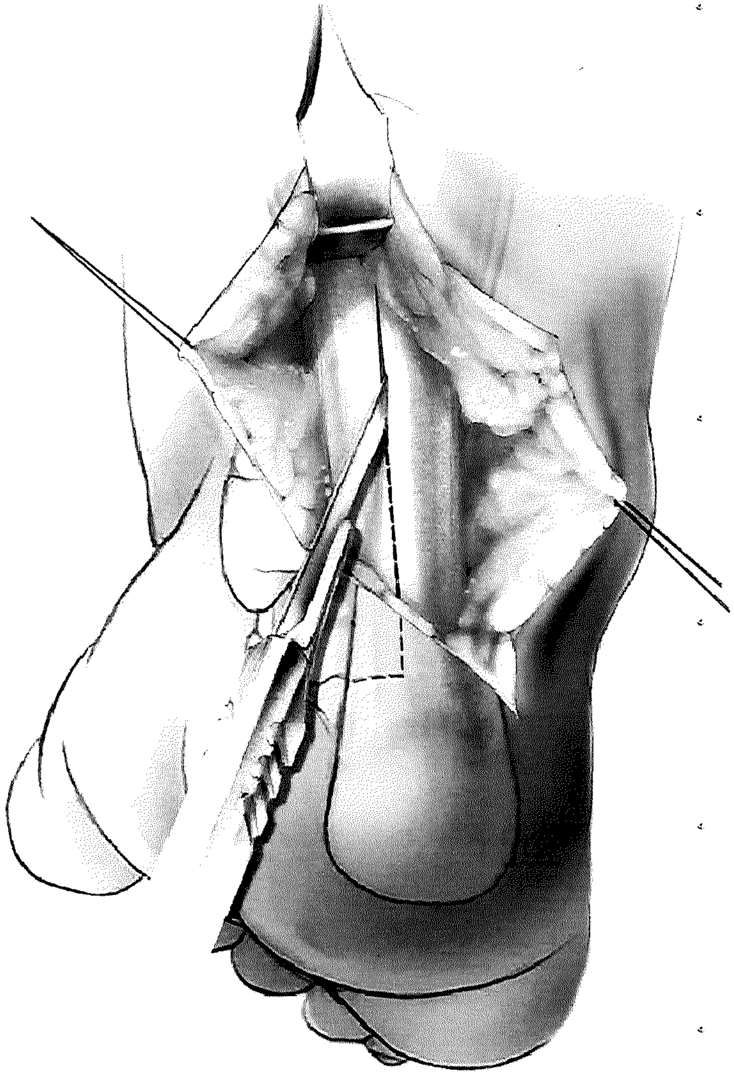


FIGURE 29-45. The patient is positioned prone for the clubfoot operation. The foam head cradle used by anesthesiologists to support the head serves as an excellent support for the prone infant. The foot can be raised with a folded sheet underneath it to allow better access to it. The skin is divided sharply down to the Achilles tendon. It is important to preserve the sheath of the tendon. This is best accomplished by leaving the sheath attached to the subcutaneous tissue. Therefore, the incision in the skin and subcutaneous tissue is carried directly down onto the tendon, passing through its filmy sheath. Then the tendon is exposed circumferentially by gently teasing its sheath away with a small elevator. A large amount of proximal exposure can be achieved by placing the blade of a Senn or Langenbeck retractor proximally and pulling upward while "toeing in" on the retractor. Divide the tendon in a Z fashion. This starts proximally with a cut in the middle of the tendon. It should be sufficiently long because it is often surprising how much length is needed in a severe clubfoot. When the knife reaches the calcaneus, it is turned medially to detach the medial half of the tendon from the calcaneus. The medial half is detached to lessen the varus force. With the Senn retractor elevating the skin proximally, the lateral half of the tendon is detached proximally. Both halves are dissected free. Sutures can be passed through the free end of both halves to act as handles to aid with later repair.

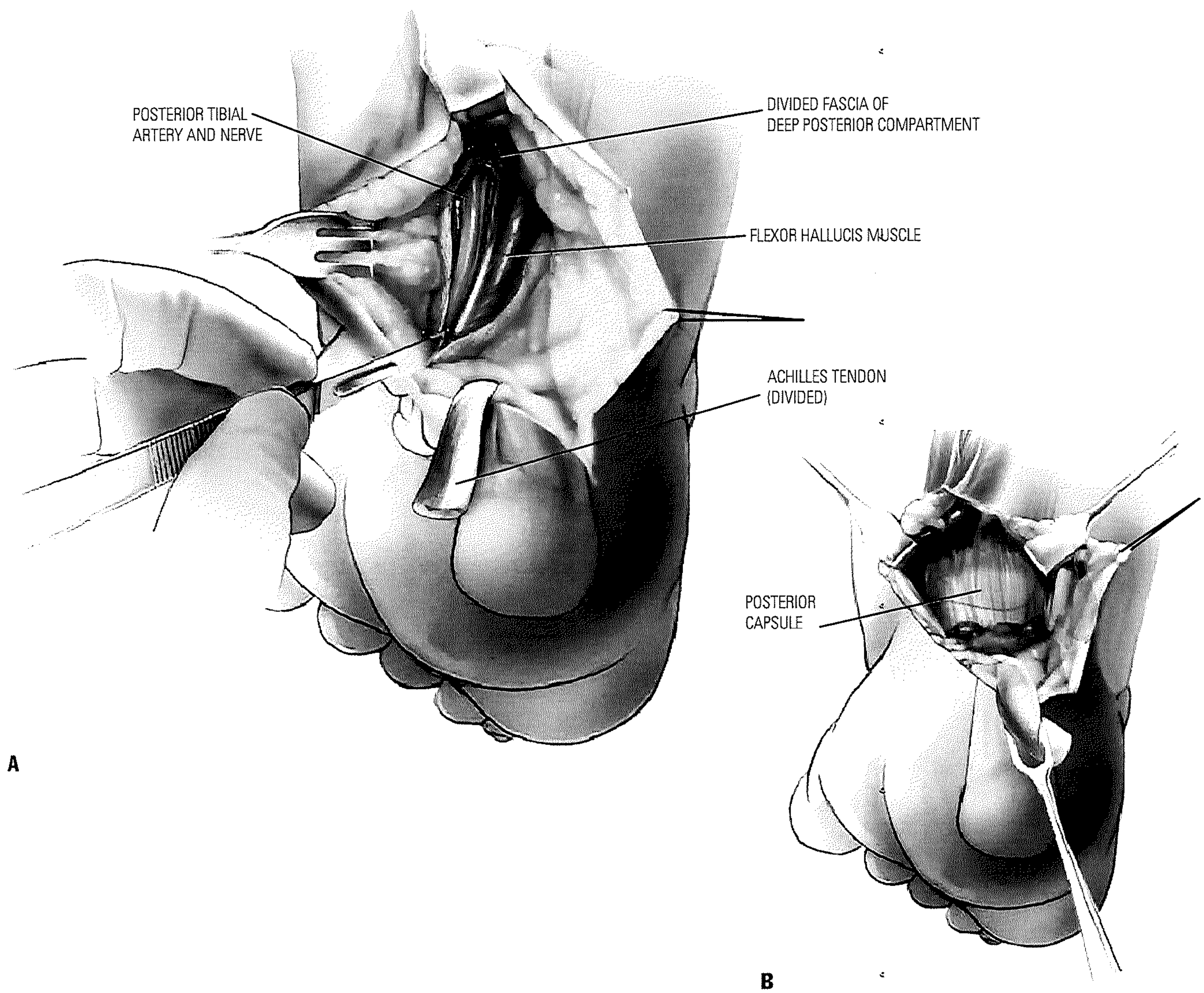
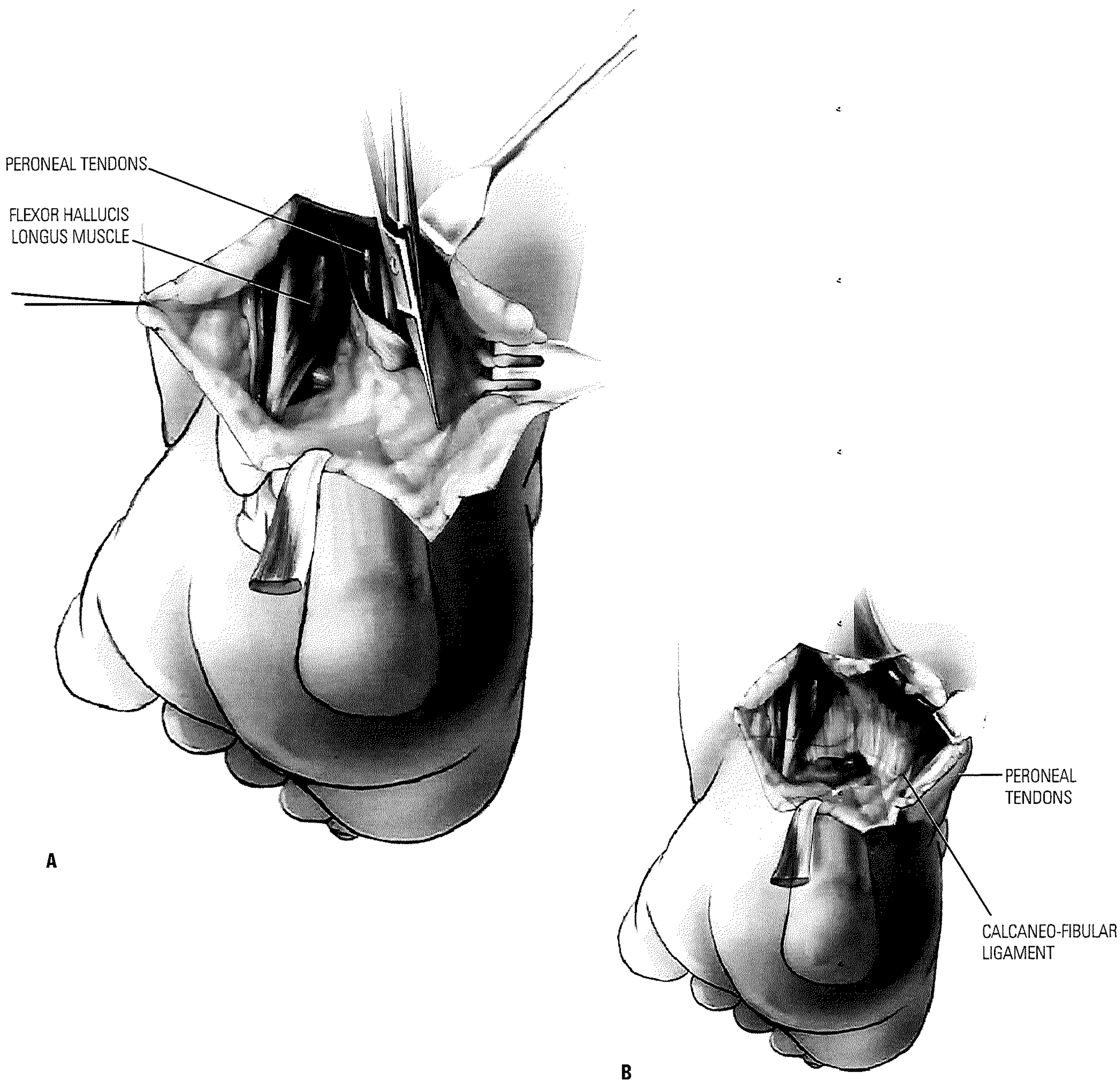


FIGURE 29-46. The next step is to open the deep posterior compartment, a distinct anatomic compartment that can be opened by incising it with a knife. Starting proximally, the fat under the Achilles tendon is sharply incised in a longitudinal straight line. As this incision is deepened, the fascial boundary of the compartment is encountered and, beneath it, more fat in the posterior compartment. Often, after this incision is completed, the anatomic structures in the posterior compartment come instantly into view **(A)**. In the severe clubfoot, the normal anatomic relationships may not be appreciated. In such cases the incision may come down directly over the posterior tibial nerve, as illustrated here. Note the flexor hallucis longus just lateral to the nerve. This structure is the first landmark to identify in the posterior compartment and is easily recognized as the only tendon passing behind the medial malleolus in which the muscle belly extends this low. This is easily remembered as the only muscle with "beef at the heel." A small periosteal elevator is used to dissect beneath this muscle, staying in close contact with the posterior capsule. This dissection is continued around the medial side of the ankle as far as the posterior aspect of the medial malleolus. The dissection is facilitated by opening the sheath of the flexor hallucis longus tendon longitudinally until the sustentaculum tali is encountered. This is the point at which the tendon can no longer be seen and is the landmark that identifies the subtalar joint, as that joint is immediately adjacent to the sustentaculum tali. This early and definitive identification of the subtalar joint helps ensure subsequent proper identification of the ankle joint which is often difficult, especially in severe deformities. The neurovascular bundle is elevated with the fatty tissue around it. A vessel loop can be used to gently retract the bundle. If a plantar release will be performed later in the procedure, it is easiest to dissect the neurovascular bundle out at this point to facilitate its exposure from the medial incision. A Senn or Langenbeck retractor can be used to retract all these structures, giving a clear view of the posterior capsules from the midline to the medial malleolus **(B)**. Allowing the foot to go into plantar flexion makes this exposure even easier.



A

B

FIGURE 29-47. The lateral side of the capsules must now be exposed in the same manner. This is most easily accomplished by incising the fascia over the peroneal muscle bellies. These muscles are enveloped in fat and fascia lateral to the flexor hallucis longus, whose muscle belly is shown exposed along the neurovascular bundle. After the muscle tissue is identified, a scissors is used to open this fascial envelope around the peroneal muscles and tendons **(A)**. This incision should be carried to the point where the peroneal tendons curve under the lateral malleolus so that these tendons can be retracted sufficiently to permit a complete division of the calcaneofibular ligament, which lies beneath the peroneal tendon sheath **(B)**. This completes the exposure of the posterior aspect of the tibiotalar and subtalar joints.

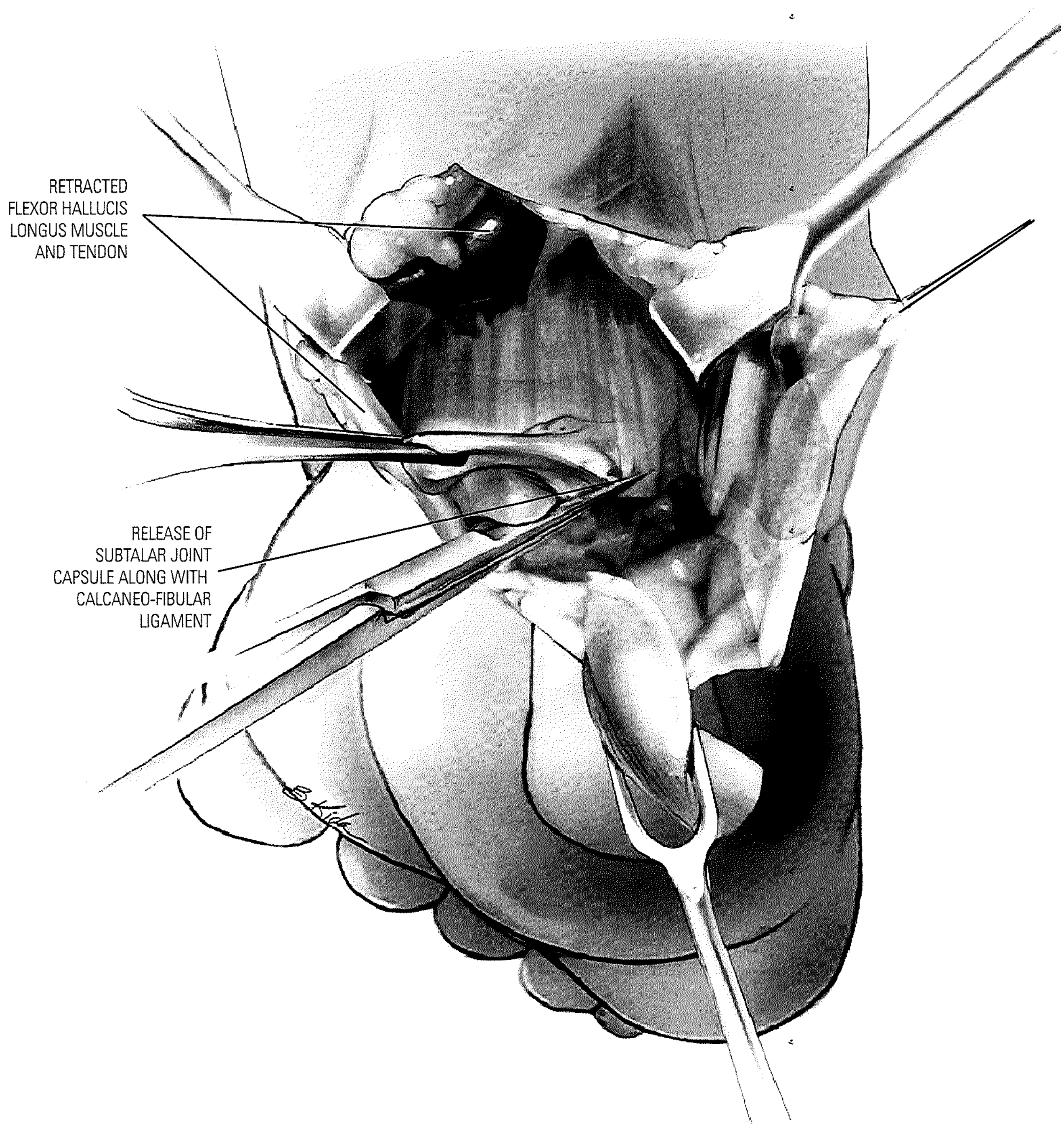


FIGURE 29-48. The next step is to open the posterior joints. In a severe clubfoot, the posterior edge of the calcaneus may be in direct contact with the posterior border of the tibia, obscuring the talus. To facilitate this exposure, the fibrofatty tissue over the posterior aspect of the joints is sharply excised with a knife. The subtalar joint, which has already been identified following release of the flexor hallucis longus tendon sheath down to the sustentaculum tali, can be released from medial to lateral with a scalpel or scissors. The peroneal tendons are retracted and the incision in the capsule is continued around the lateral side, including release of the calcaneofibular ligament.

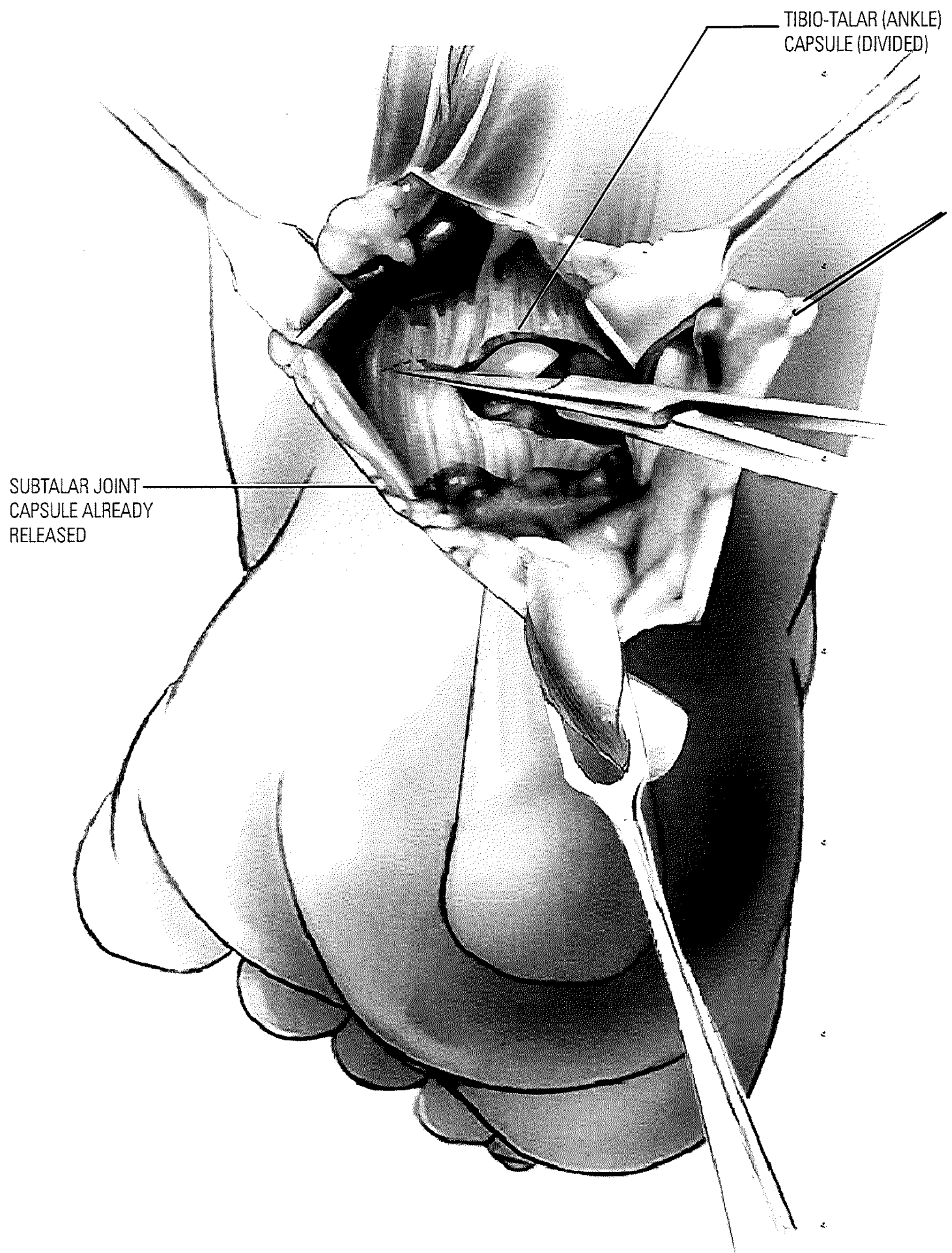


FIGURE 29-49. The tibiotalar joint can be identified proximal to the subtalar joint by palpation and inspection while the foot is plantar and dorsiflexed. The fibrofatty tissue is first excised with a knife, and then the scissors is inserted with one blade in the joint and the other outside the joint. The capsule is opened around the medial side until the FDL tendon is identified. Two notes of caution: ensure that the neurovascular structures are retracted and go slowly behind the medial malleolus to avoid dividing the FDL and posterior tibial tendons and the deep deltoid ligament. As the foot is dorsiflexed, the dome of the talus comes into view. Cutting the talofibular ligament usually makes the largest difference in the amount of dorsiflexion that is obtained.

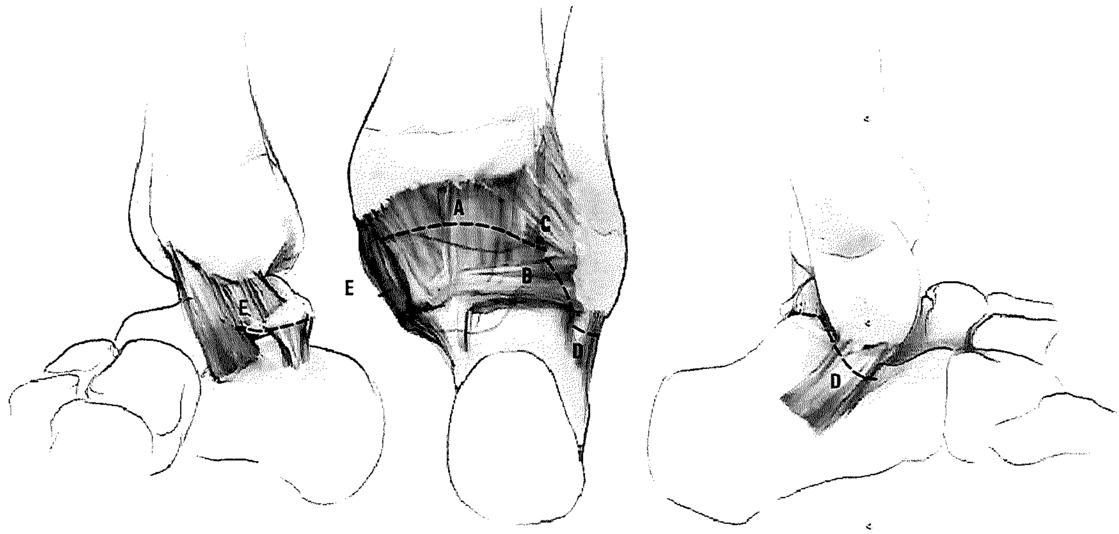


FIGURE 29-50. Although many illustrations of clubfoot surgery show the ligaments of the posterior capsule as distinct structures, the surgeon rarely sees them this way because they are merely condensations of the continuous posterior capsule. Occasionally, the posterior talofibular ligament and the calcaneofibular ligament stand out, the latter appearing like a tendon. The geographic cuts in the posterior capsule of the tibiotalar and subtalar joints divide the ligaments as shown: the posterior tibiotalar ligament (*A*), the posterior talofibular ligament (*B*), the tibiofibular ligament (*C*), the calcaneofibular ligament (*D*), and the deltoid ligament (*E*). The deltoid ligament consists of several parts. One part of the deltoid ligament, referred to as the deep deltoid ligament (anterior tibiotalar part of the deltoid ligament), is attached to the talus and, in the opinion of many surgeons, should not be divided in order to avoid the complication of lateral subluxation of the talus. Division of this part of the deltoid ligament is avoided by limiting the capsulotomy of the tibiotalar joint up to the posterior aspect of the medial malleolus. If it is desired to divide this portion of the deltoid ligament as a part of the operation, as is done in the procedure described by Goldner (191), it should be repaired.

FIGURE 29-51. **A:** The plantar-medial release is performed through the antero-medial extension of a Cincinnati incision. A vessel loop surrounds the posterior tibial neurovascular bundle (blue arrow) posterior to the medial malleolus. The proximal edge (black arrow) of the laciniate ligament (a.k.a. flexor retinaculum) is exposed. **B:** The laciniate ligament is released with scissors. **C:** The lowest (1) of the 3 origins of the abductor hallucis muscle is released from the calcaneus superficial to the lateral plantar neurovascular bundle. **D:** The plantar fascia and short toe flexors are next released superficial (plantar) to the lateral plantar neurovascular bundle. Release of those soft tissues using the tunnel of the NV bundle for guidance obviates injury to those important structures. **E:** The thin septum (2) of the abductor hallucis that separates the medial and lateral plantar NV bundles is divided under direct vision. **F:** The most dorsal origin (3) of the abductor hallucis, which is dorsal to the medial plantar NV bundle, is released. This completes the superficial plantar-medial release.

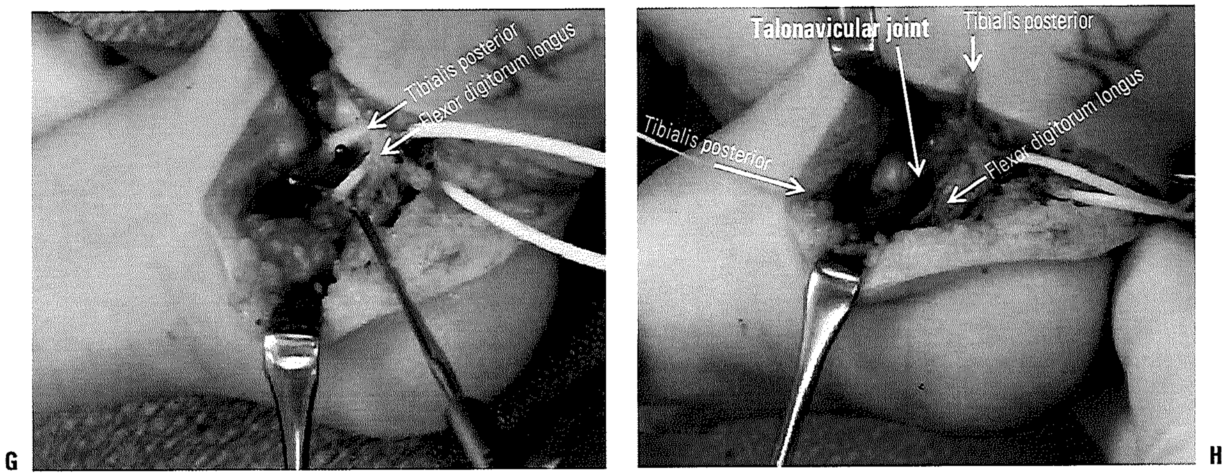


FIGURE 29-51. *(continued)* **G:** The tibialis posterior and flexor digitorum longus are released from their respective tendon sheaths. **H:** The deep plantar-medial release begins with z-lengthening of the tibialis posterior. The talonavicular joint capsule is release medially, extending to varying degrees dorsal and plantar, as required, to enable eversion of the subtalar joint. (From the private collection of Vincent S. Mosca, MD.)

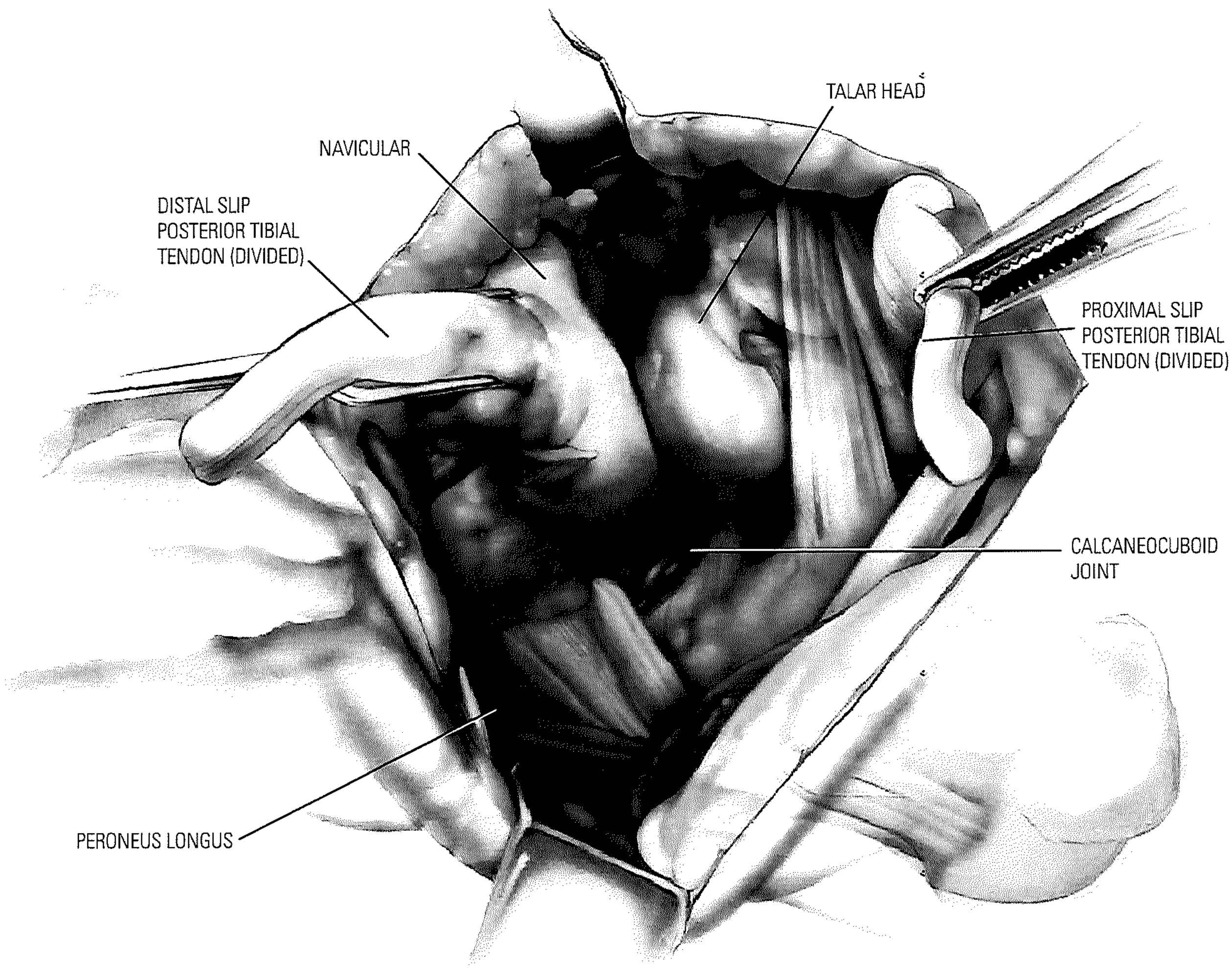


FIGURE 29-52. With the posterior tibial tendon detached, it is easy to identify the talonavicular joint in a normal foot. However, in a clubfoot it must be remembered that the navicular is displaced medially, causing it to lie on the medial side of the neck of the talus and closer than normal to the medial malleolus.

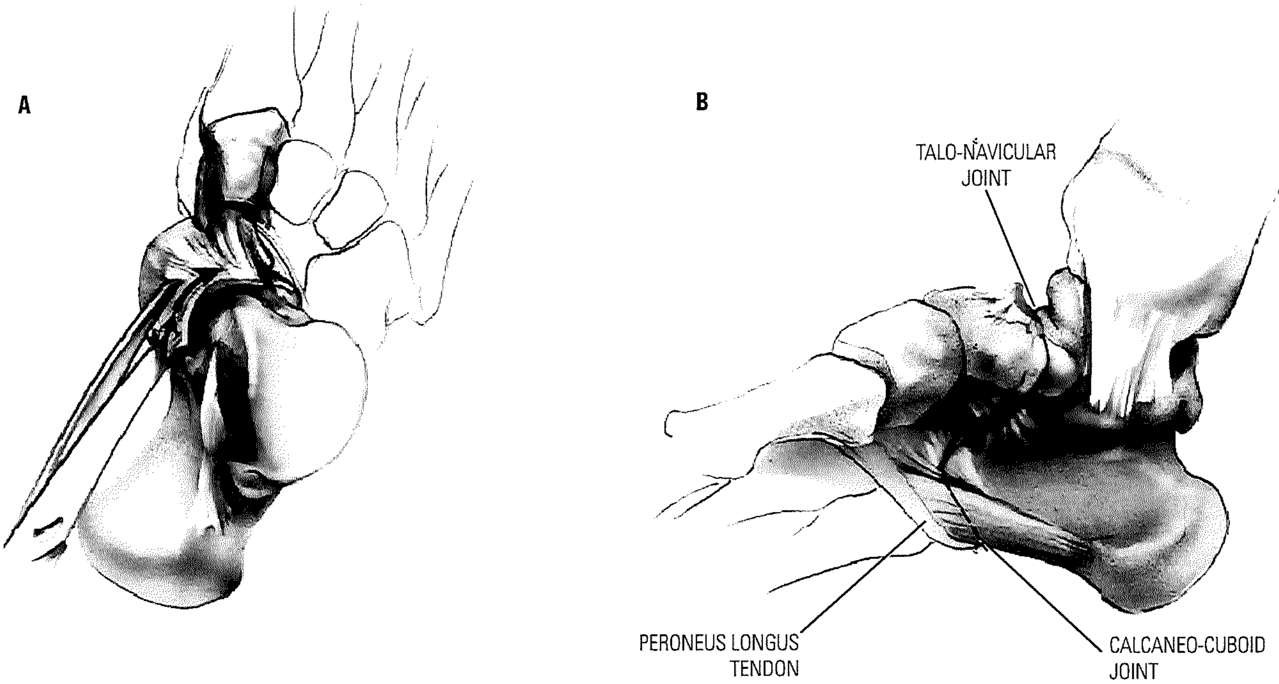


FIGURE 29-53. In addition, the space between the tuberosity of the navicular and the medial malleolus is filled with dense, fibrous tissue. If the surgeon knows the anatomy, this tissue can be excised with a knife. A scissors is used to open the talonavicular joint. This joint is found by directing the scissors distally toward the first metatarsal between the neck of the talus and the navicular **(A).** The error is to cut transversely across the foot as if the anatomic relationship between the navicular and the talus were normal. This is especially dangerous if done with a knife because it is not difficult to inadvertently divide the cartilaginous neck of the talus. At the same time, the surgeon should be careful to avoid opening the naviculocuneiform joint. This will further devascularize the navicular and tend to destabilize it permitting it to rotate out of position. The talonavicular joint capsule should be released primarily on the medial and plantar aspects, as those are the most contracted portions. The dorsomedial capsule should be released only to the extent that it limits eversion of the subtalar joint. Excessive release of the talonavicular joint capsule might result in hypermobility and dorsal subluxation of the navicular, a difficult situation from which to recover. (Much of the capsule in this drawing has been removed for clarity, but this should not be done during the surgery.) The plantar aspect of the joint may remain tight even after the capsule is cut. To free it, the plantar calcaneonavicular (spring) ligament and the anterior portion of the deltoid ligament inserting into the navicular (tibionavicular ligament) must be divided. Because these ligaments are condensations of the capsules, they will be divided when the capsules between the talus and the navicular dorsomedially and the calcaneus and the cuboid on the plantar aspect are opened. This can be done with a scissors or a knife when the surgeon is certain that he or she has identified the joint. Plantar and lateral to the talonavicular joint, and almost in line with it, is the medial side of the calcaneocuboid joint **(B)**. This medial capsule can be opened, but additional release is sometimes necessary. Because the peroneus longus tendon crosses the most plantar and lateral aspect of this joint, it should be retracted. The medial capsule of the calcaneocuboid joint, like all the other capsules, can be opened safely with a scissors, although some experienced surgeons prefer to use a knife.

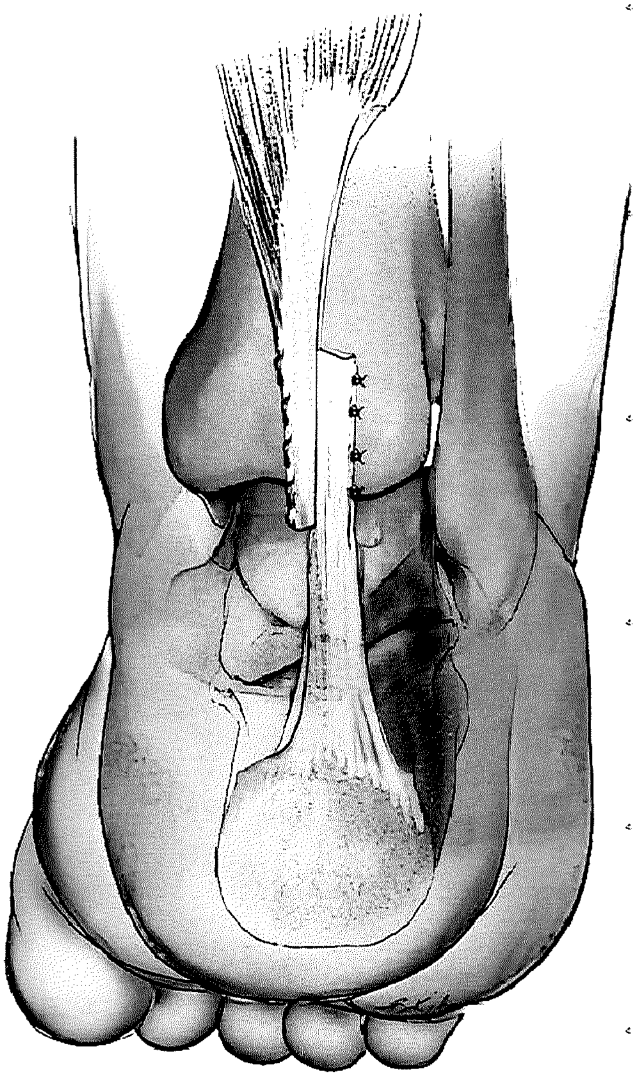


FIGURE 29-54. Repair of the Achilles tendon is all that remains to be done posteriorly. This should be done after the completion of the entire release and after the foot is reduced. The tendon may be repaired end to end with a Kessler type of stitch or side to side. The repair should be under modest tension to avoid unnecessary weakening of the gastrocnemius muscle.

Recurrent and Residual Deformity. Recurrent and residual deformities of the surgically, and nonsurgically, treated clubfoot in the young child are first treated with a series of manipulations and long-leg cast applications using Ponseti's method. Repeat soft-tissue release, using an à la carte approach, is indicated if the deformities cannot be corrected nonoperatively. In the older child, one or more osteotomies may be necessary to correct residual deformities that are identified after the joints are aligned by soft-tissue releases.

Residual midfoot adduction and supination are often a problem after clubfoot correction. The deformity is commonly referred to as the "bean-shaped foot." The symptoms are difficulty with rigid shoe wear and walking on the lateral border.

In the past, painful midfoot adduction was often treated by metatarsal osteotomies (459, 460) or tarsometatarsal capsulotomies (Hyman-Herndon procedure) (456). More recently, however, these operations have been used less frequently because they either fail to provide the desired correction or they result in painful stiff joints (457, 458, 461, 462).

Painful residual adductus of the midfoot in the older child can be treated with an opening-wedge osteotomy of the medial cuneiform (77, 221), a closing-wedge osteotomy of the cuboid (222), or both (223–225) (Figs. 29-55 to 29-61).

The choice depends on the radiographically determined site(s) of deformity and the age of the child. In residual adductus deformities of the forefoot, the medial cuneiform is usually trapezoid shaped with medial deviation of the first metatarsal–cuneiform joint. An opening-wedge osteotomy will correct this deformity, but cannot be performed until there is adequate ossification of the cartilaginous anlage, which is often over the

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Double Tarsal Osteotomy to Correct Midfoot Adduction (Figs. 29-55 to 29-61)

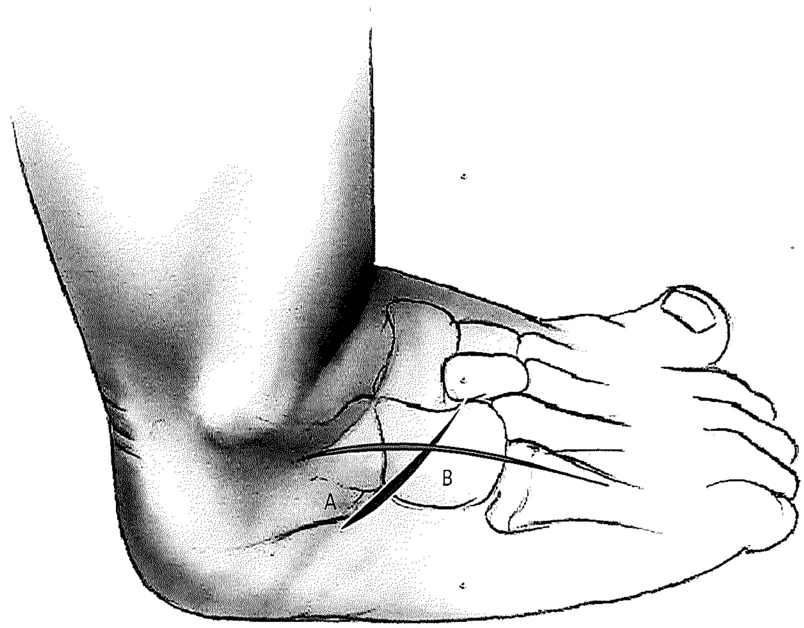

FIGURE 29-55. Double Tarsal Osteotomy to Correct Midfoot Adduction. The operation for midfoot adductus is started on the lateral side of the foot. A bolster is placed beneath the buttocks, turning the leg internally to facilitate the approach to the cuboid. The incision may be either oblique, following the skin lines directly over the cuboid, or curvilinear over the bone.

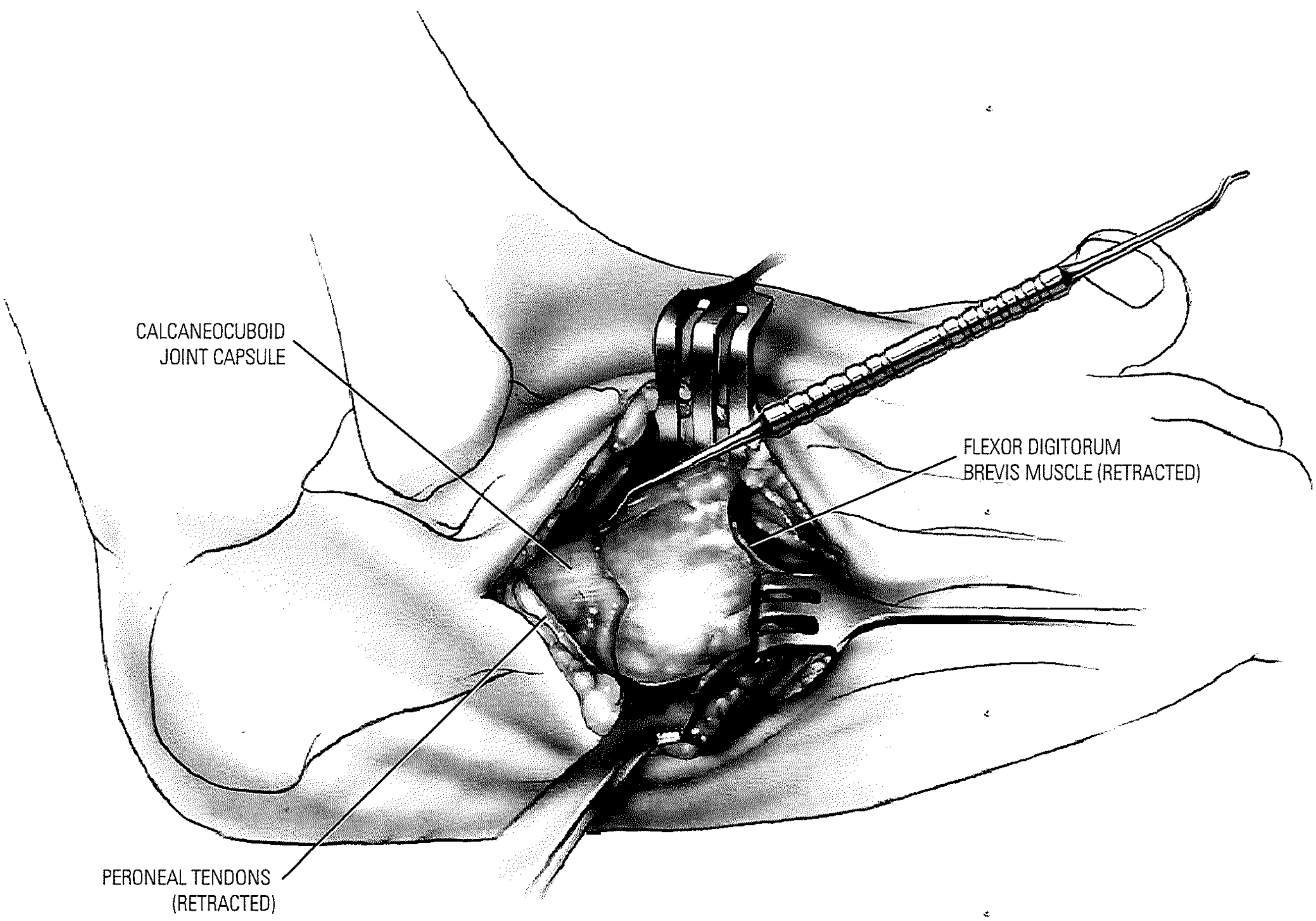

FIGURE 29-56. After opening the skin, the peroneus brevis is identified, freed from its sheath, and retracted plantarward. The soft tissues are freed dorsally and plantarward to expose the cuboid bone extraperiosteally, keeping the joint capsules intact.

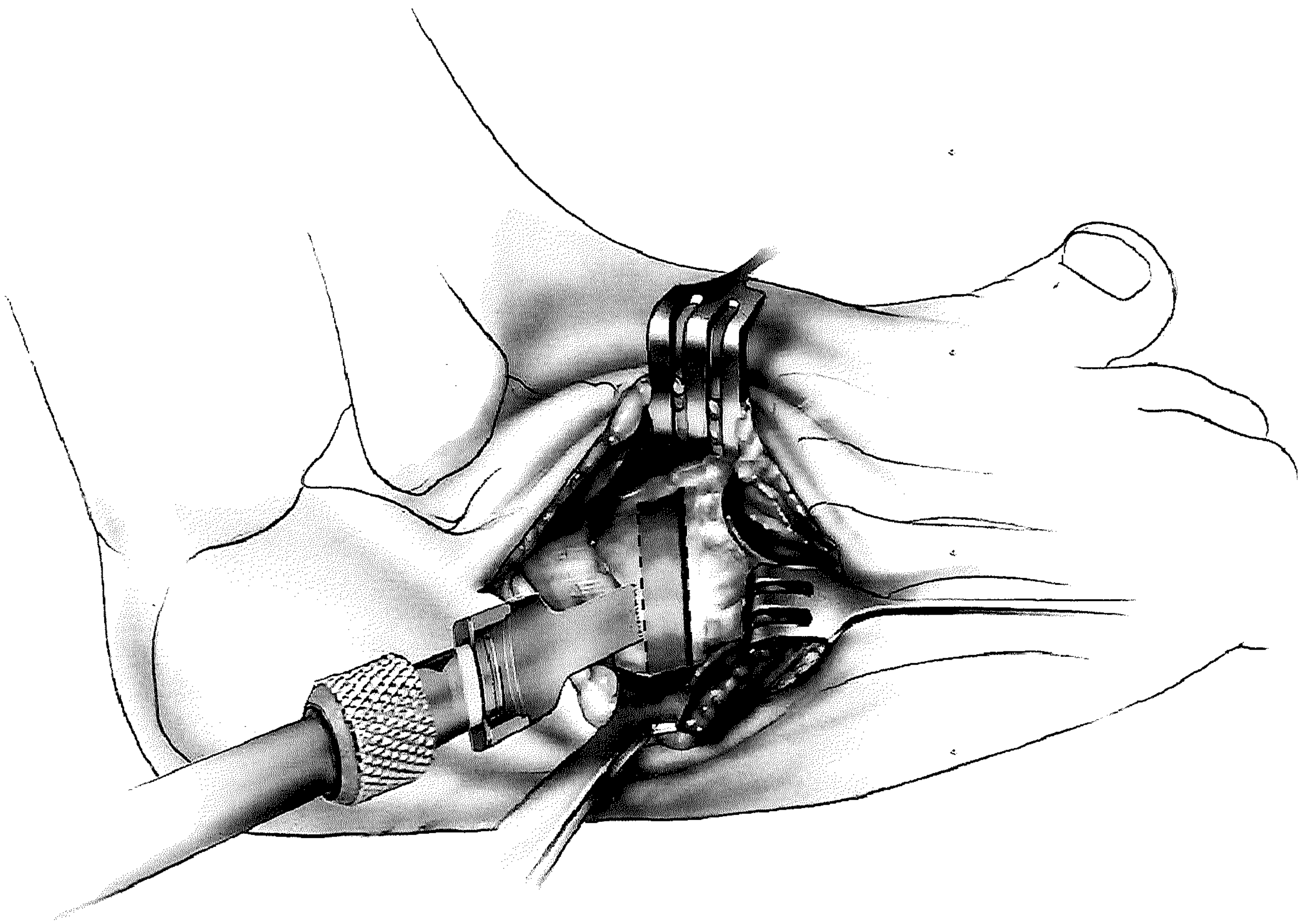

FIGURE 29-57. Using a microsagittal saw, a laterally based wedge of bone of the desired size is removed. It is important to go through the medial cortex of the bone so that the osteotomy is mobile and easy to close. The wound is left open, and the bolster is removed to provide better access to the cuneiform bone on the medial side of the foot.

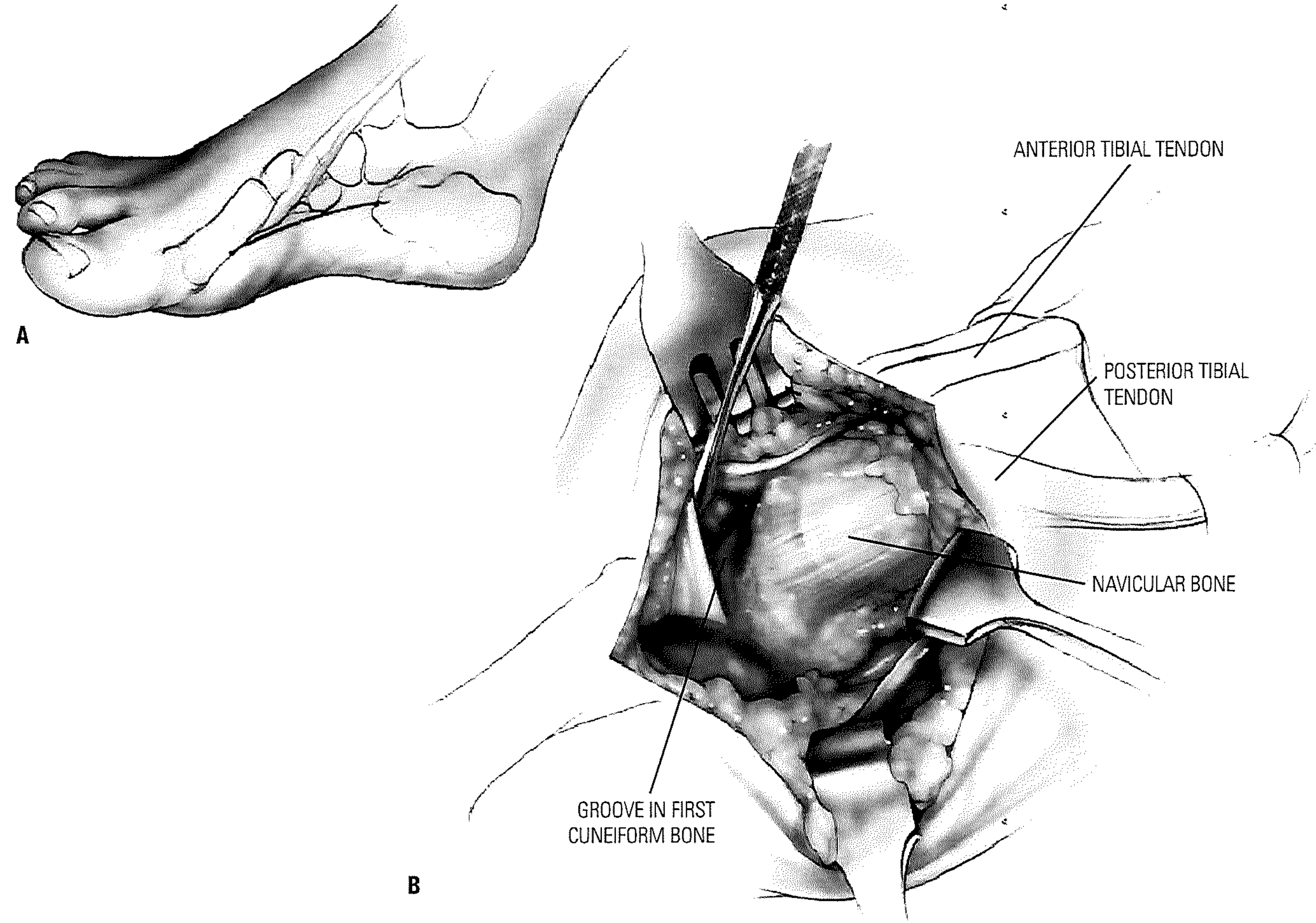

FIGURE 29-58. A straight linear incision is made directly over the first cuneiform bone **(A)**. As the dissection is deepened, the anterior tibial tendon will be identified coursing over the first cuneiform bone. This tendon can be dissected free without disturbing any of its essential attachments. The dissection is started on the inferior aspect of the tendon, and the tendon is reflected dorsally. This usually allows adequate exposure. In the idiopathic type of forefoot adduction, this tendon will appear to have cut a groove of variable depth into the bone **(B)**. Dissection of the cuneiform bone is continued extraperiosteally until both the anterior and posterior joints are identified positively, while trying to preserve intact the joint capsules and while the plantar and dorsal aspects are exposed. Because of the peculiar shape of the first cuneiform bone in this condition, it may be wise to check the path of the proposed osteotomy with the image intensifier.

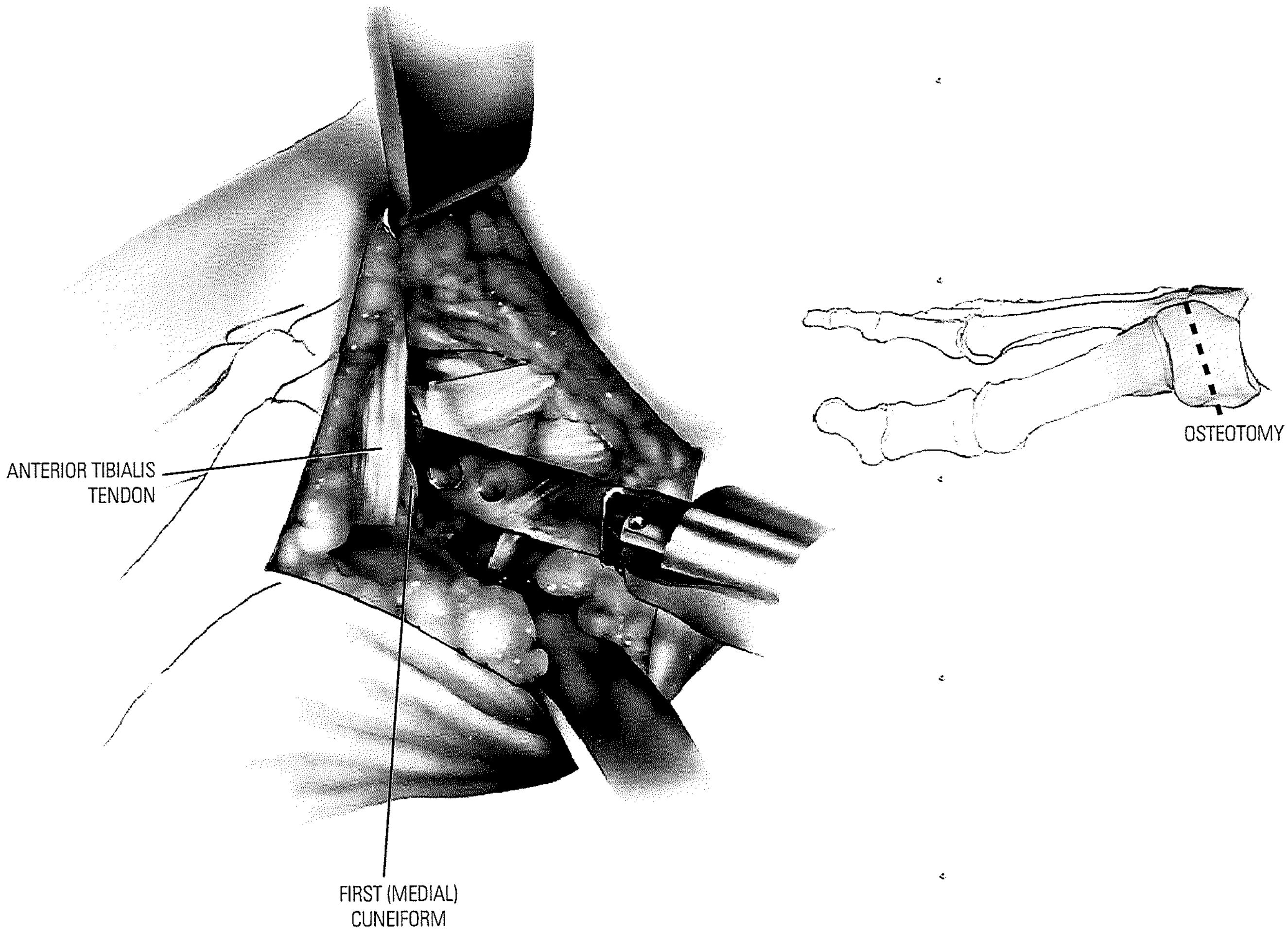

FIGURE 29-59. Using the microsagittal saw, a single osteotomy cut is made in the first cuneiform bone. Start half way between the anterior and posterior ends of the bone on the medial side and, while cutting laterally, angle slightly distally. This will result in the osteotomy of the first cuneiform ending adjacent to the second metatarsal–middle cuneiform joint (see Fig. 29-61). The bone segments will have better mobility if cut in this fashion. An image intensifier will help with positioning the osteotomy. After completing the osteotomy, an osteotome is inserted to spread apart the fragments and ensure their mobility.

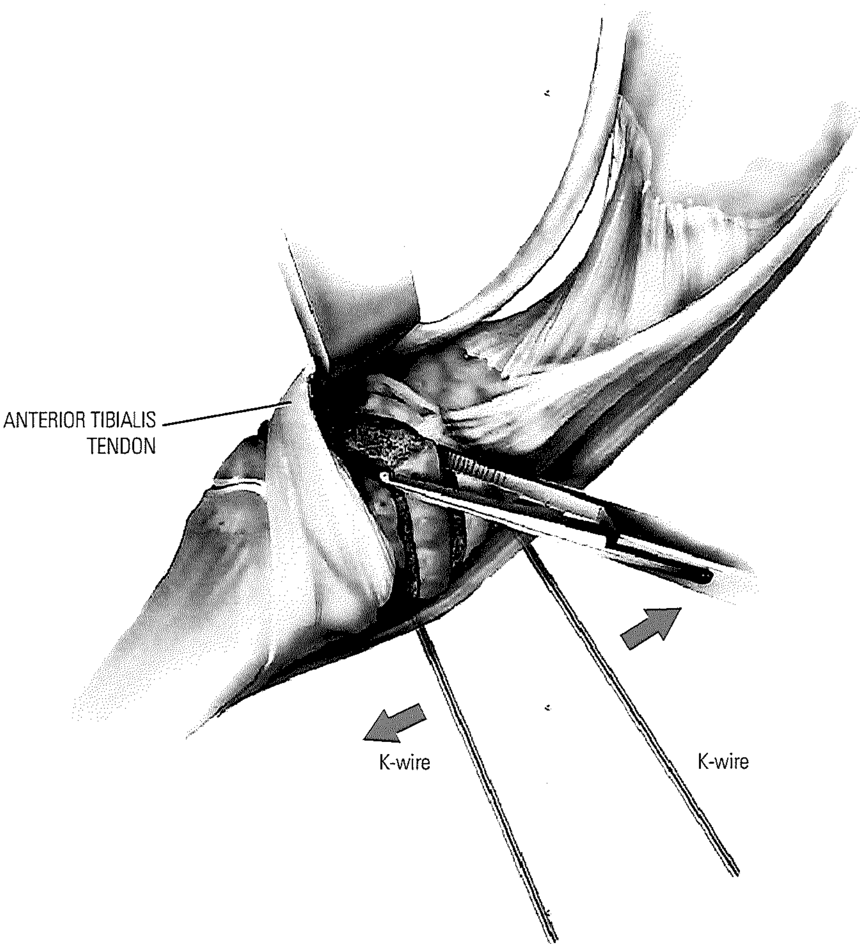

FIGURE 29-60. The graft that was taken from the cuboid is now inserted into the osteotomy of the first cuneiform. Kirschner wires are placed into the fragments and used as joy sticks to open the osteotomy. It may be necessary to release the abductor hallucis tendon if it is tight or produces adduction of the great toe after the graft is inserted. When the bone is in place, it should be relatively secure; however, it is reasonable to secure it with a Kirschner wire that is passed retrograde along the medial column of the midfoot through the base of the first metatarsal, the anterior fragment, the graft, and the posterior fragment.

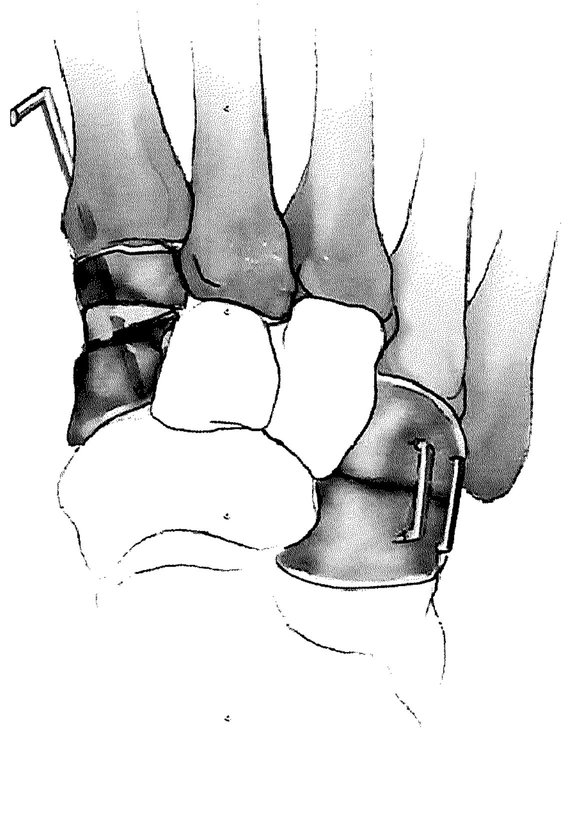

FIGURE 29-61. The cuboid osteotomy can be manipulated, closed, and held with one or two small staples or a Kirschner wire. After the wounds are closed and dressed, the patient is placed in a non–weight-bearing cast. After 6 weeks, the cast and pin are removed in the office. In older children, a short-leg weight-bearing cast is applied and used for an additional 2 weeks.

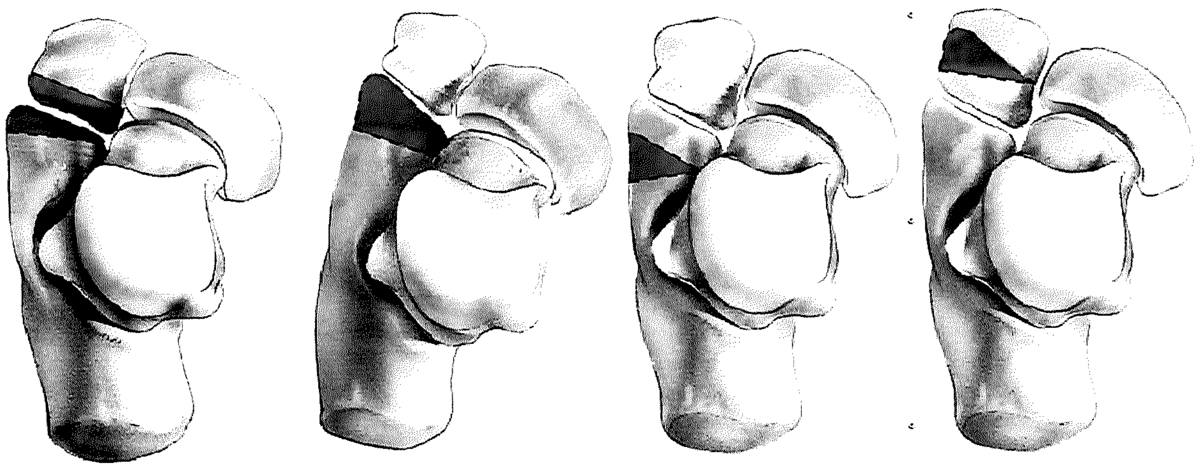

FIGURE 29-62. Although numerous methods have been described to shorten the lateral column of the foot, four receive the widest use. The first three (A-C) can be used to align an adducted navicular on the head of the talus when the subtalar joint is rigidly inverted. Evans (78) called attention to the lateral column of the foot. He recommended shortening the lateral column of the foot by excising a portion from each side of the calcaneocuboid joint. The defect created by the wedge is held closed by staples and is intended to result in fusion **(A)**. The operation is not recommended before the age of 4 years; before that age, too much of these bones is still cartilage and fusion will not result. There is also a risk that the foot might grow into abduction and eversion if the operation is performed under age 8 years. The Lichtblau procedure is based on the assumption that adaptive changes in the calcaneocuboid joint are what prevent adequate reduction (226). With the medial displacement of the navicular, the lateral side of the calcaneus overgrows, and the result is a calcaneocuboid joint that is angled in such a way that the cuboid cannot be laterally displaced on the calcaneus **(B)**. The operation, which is recommended for children over 2 years of age, excises a laterally based wedge from the anterior end of the calcaneus. The resulting fibrocartilaginous joint functions well and remains asymptomatic. A less commonly used technique for shortening the lateral column of the foot and thereby aligning the talonavicular joint is a closing wedge osteotomy of the anterior calcaneus **(C)**. It is a reverse calcaneal lengthening osteotomy. The ideal age range for using it is unknown. Goldner (163) achieved shortening of the lateral side of the foot by resecting a wedge of bone from the cuboid (Figures 29-59 to 29-61 and 29-65). This preserves the joint surfaces and is more effective than decancellation of the bone **(D)**. Unlike the other three lateral column shortening procedures, it does not pull the medially displaced navicular laterally on the head of the talus. It is, therefore, an operation for midfoot adductus and not for subtalar inversion. This operation can be used at any age, if the surgeon deems it necessary.

age of 4 years. There is also often a varus deformity of the cuboid, although it is harder to document the site of the deformity along the lateral border of the foot. The cuboid ossifies very early and can undergo a closing-wedge osteotomy to improve adductus deformity in the younger child. The ideal situation is to wait until the child is old enough to undergo the combined procedure.

There are other techniques for correcting the shape and length of the lateral column of the foot, such as the calcaneocuboid joint resection/arthrodesis described by Evans (78), the anterior calcaneal resection of Lichtblau (226), and the anterior calcaneus closing wedge osteotomy (Fig. 29-62).

These three procedures can be combined with plantar-medial soft-tissue release in the older child with residual or recurrent subtalar joint varus deformity. They help realign the navicular on the head of the talus. They are not, however, useful for the correction of midfoot adduction.

In the much older child and adolescent with persistent and stiff hindfoot varus, a posterior calcaneal lateral displacement osteotomy with or without a lateral closing wedge is generally the treatment of choice. Triple arthrodesis is the last option in this extreme situation.

Supination of the Forefoot and Dorsal Bunion. Regardless of treatment, clubfoot deformity tends to relapse, often due to muscle imbalance. Relapses after manipulation and casting techniques generally occur between 10 months and 7 years. Most relapses can be treated by manipulation followed by application of a toe-to-groin cast, as described in the previous section. These manipulations and castings are repeated every 5 to 7 days. If the foot cannot be dorsiflexed to at least 15 degrees, cast treatment may be followed by lengthening or relengthening of the tendo Achillis, percutaneously if the child is <1 year of age or openly if the child is over 1 year of age. This is followed by use of the Denis-Browne night splint.

In children over 2½ years of age, transfer of the tibialis anterior to the third cuneiform is often necessary to prevent recurrence (182, 228–231) (Figs. 29-63 to 29-65). There is muscle imbalance between the tibialis anterior and the peroneus longus and tertius in up to 50% of clubfeet (182). The tibialis anterior is strong, the peroneals are weak, and the flexor hallucis is involuntarily recruited in an attempt to plantar-flex the first ray. This is manifest as a dynamic and eventually, in some cases, a rigid supination deformity of the forefoot. There may be accompanying adductus of the forefoot and inversion of the hindfoot. This imbalance may ultimately lead to the development of a dorsal bunion, particularly in clubfeet that were treated operatively. Lateral transfer of the tibialis anterior to the lateral cuneiform in whole (182, 228–231) or in part (228) will improve muscle balance and prevent the development of a dorsal bunion. It should not be transferred to the cuboid or the fifth metatarsal as this may result in severe eversion of the foot, causing severe foot pronation and heel valgus. The tibialis anterior tendon transfer does not correct recurrent or residual deformities. They must be corrected with preoperative casting or concurrent surgery.

This transfer can be combined with midfoot osteotomies, as described above, if there is rigid adductus deformity of the forefoot.

If a rigid and symptomatic dorsal bunion has already developed in the older child, the tendon transfer is indicated in addition to other procedures (228–231). They include plantar release of the first metatarsophalangeal joint, transfer of the flexor hallucis longus to the neck of the first metatarsal, and plantar flexion osteotomy of the medial cuneiform or the base of the first metatarsal.

Dorsolateral Subluxation and Dislocation of the Navicular. Dorsal subluxation and dislocation of the navicular on the head of the talus can occur due to excessive release of the talonavicular joint, external rotational malalignment of the joint (232), and residual cavus deformity secondary to failure to release the plantar fascia. Kuo and Jansen (232) identified this iatrogenic deformity in about 8% of their patients regardless of the type of incision used. Mild talonavicular joint subluxation rarely causes pain or functional disability, though the foot is shorter than expected from heel to toe and taller than expected in the instep. The first ray is plantar-flexed, creating a cavus deformity. Asymptomatic talonavicular subluxation should be managed with observation and adaptive footwear if needed. Arch supports or cushioning of the shoe may relieve pain that is related to the small area of floor contact pressure on the sole of the foot. If symptoms continue unabated, surgery is indicated.

Once the navicular is displaced, its shape becomes altered from a bean-shaped bone with parallel-curved proximal and distal articular surfaces to a wedge-shaped bone that is nearly impossible to replace and maintain in its anatomic location. Stiffness of the joints along the lateral column of the foot contributes to the challenges of achieving and maintaining talonavicular joint alignment. Recurrent dorsal displacement following attempted reduction of the talonavicular joint has been frequently seen. The "third street procedure," described by Barnett (233), appears to be an effective method for realigning the joint in the young child, but the long-term results have not been reported. This procedure starts with a circumferential capsulotomy of the talonavicular joint. The capsulotomies then continue between the navicular and the cuboid, the lateral cuneiform and the cuboid, and finally between the proximal ends of the third and fourth metatarsals (the third street). The medial column of the foot is thereby separated from the lateral column, which allows the navicular to align completely and without tension with the head of the talus. Barnett (233) believed that the upper age limit for this procedure was 6 years presumably because, in this young age group, the navicular has the ability to remodel to a more normal shape. Treatment in the older child must be individualized and includes either a resection of the prominent dorsal portion of the subluxated navicular or a talonavicular joint arthrodesis (234). While the latter procedure decreases midfoot and hindfoot mobility, motion in the subtalar joint complex is already restricted. The trade-off for improvement in foot shape and alignment is at times advantageous.

Valgus Deformity of the Hindfoot. Overcorrection is a worse complication than recurrence and can occur at different sites in the foot. Overcorrection at the talonavicular joint has just been discussed. Overcorrection at the talocalcaneal (subtalar) joint is manifest by valgus deformity of the hindfoot. It has been my observation that overcorrection at this joint can occur as an exaggerated lateral translation of the calcaneus under the talus or as an excessive eversion of the subtalar joint complex. Each has its own iatrogenic etiology.

The most common type is a lateral translation of the calcaneus under the talus and is most often seen following complete release of the subtalar joint, including release of the talocalcaneal interosseous ligament, as described in the operation developed by Simons (177, 213). This type of translational subtalar joint malalignment can also be seen following the Turco-type (175, 176) surgical release in which the calcaneofibular ligament is not released (118, 154, 178). As Ponseti (182) has shown, this ligament is shortened and thickened in the clubfoot. Failure to release it changes the axis of rotation from the center of the subtalar joint (the interosseous talocalcaneal ligament) to the posterolateral corner. The result is effectively a translational-type malalignment that has all the features of an overreleased subtalar joint.

Translational overcorrection is manifest clinically by severe valgus deformity of the hindfoot, but with a neutral thigh–foot angle, and with lateral hindfoot impingement-type pain. The Achilles tendon is sometimes, but not always, contracted. Radiographically, the talonavicular joint is frequently well aligned in both the AP and lateral planes, the talus and calcaneus are parallel on the AP view, and there is minimal-to-no sag at the talonavicular joint.

Unfortunately, even in infancy, the calcaneus cannot be reliably repositioned. Over-the-counter or custom-molded orthotics can be used to try to alleviate symptoms and preserve the useful life of shoes in the older child. If symptoms persist in the older child, a posterior calcaneus medial displacement, or slide, osteotomy according to Koutsogiannis (235) is an effective procedure to correct the valgus deformity and relieve symptoms. This procedure creates a compensatory deformity, because the primary deformity cannot be primarily corrected. The calcaneal slide osteotomy will not affect any midfoot and forefoot

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Anterior Tibialis Transfer to the Third Cuneiform (Figs. 29-63 to 29-65)

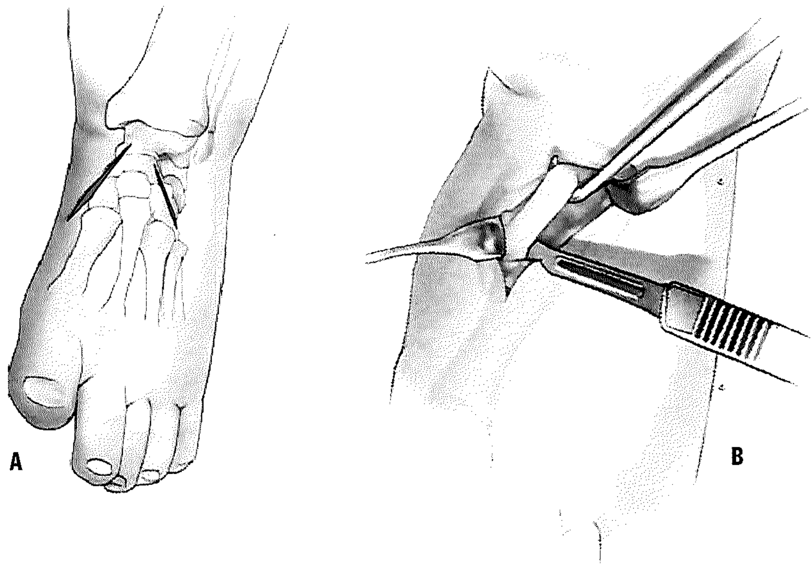

FIGURE 29-63. Anterior Tibialis Transfer to the Third Cuneiform. A, B: A 4-cm incision is made over the course of the tibialis anterior extending from its insertion proximally. The tibialis anterior tendon sheath is incised sharply. The sheath is opened as far distally as possible and then proximally to just short of the ankle extensor retinaculum. A button hook is placed under the tibialis anterior to help expose the tendon insertion. This broad extensive insertion is dissected as far distally as possible so as to gain maximum length of tendon for the transfer, with care taken to avoid injury to the first metatarsal growth plate. Once the tendon is freed, it is gently pulled distally while the soft-tissue attachments to the tendon are freed up to, but not beyond, the ankle retinaculum. To avoid bow stringing of the tendon, it is important not to release the ankle retinaculum. A strong absorbable suture (the author prefers 0 Vicryl) is woven in a Bunnell-type fashion through the released end of tibialis anterior tendon.

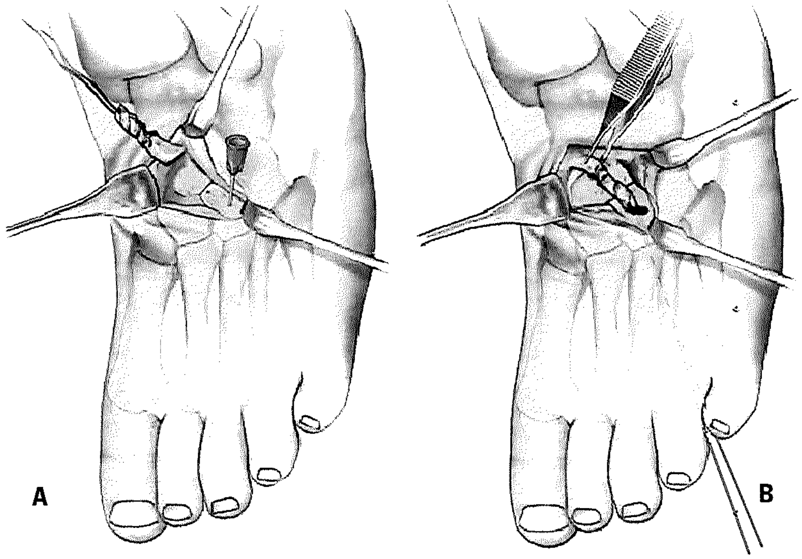

FIGURE 29-64. A, B: Anterior tibialis transfer to the third cuneiform. A second 4-cm skin incision is made over the third cuneiform, which is proximal to the third metatarsal and generally located between the extensor digitorum longus tendons and the peroneus tertius. A muscle splitting approach through the EDB muscle reveals the region of the third cuneiform. Insert a small gauge needle in the presumed location and confirm with minifluoroscopy. A cruciate incision is made directly over the third cuneiform, carefully avoiding the adjacent joint articulations. A drill hole is made directly in the center of the third cuneiform, drilling through the plantar aspect of the bone. All drill shavings are removed. A blunt hemostat is passed obliquely from the incision over the third cuneiform under the extensor tendons to the point where the tibialis anterior passes beneath the ankle retinaculum. The hemostat is then opened and withdrawn, providing a tract for the transfer of the tibialis anterior tendon. The hemostat is again passed along the same tract to the point where the tibialis anterior meets the ankle retinaculum, turned at an acute right angle, and passed out the proximal extent of the dorsomedial foot wound. The suture ends are grasped, and the tibialis anterior tendon is brought into the lateral wound. The medial wound is irrigated and closed in layers. The suture ends of the tibialis anterior are threaded onto Keith needles. The suture needles are passed through the third cuneiform and out the bottom of the foot.

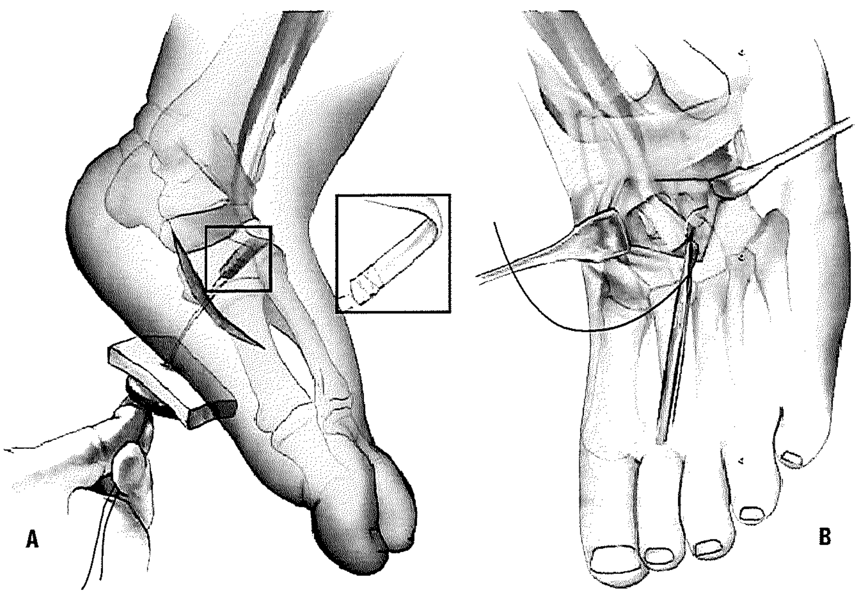

FIGURE 29-65. A, B: The needles are passed through a thick felt pad that approximates the size of the button to be used and then through the button. The foot is maximally dorsiflexed and everted and the tendon guided into the third cuneiform and secured over the plantar button. The periosteum of the third cuneiform is sutured with two interrupted absorbable sutures to the transferred tibialis anterior tendon. The wound is irrigated and the skin closed in layers. A long-leg cast is applied. In patients under 5 years of age, the long-leg cast is maintained with the patient non–weight bearing for approximately 6 weeks, by which time the suture has dissolved and the button is free in the cast padding. The patient is allowed to begin ambulation. In patients over 5 years of age, a short-leg walking cast is applied and used for an additional 2 to 3 weeks to ensure healing and to avoid tendon pullout.

deformities if present. It also will not affect the longitudinal arch of the foot nor the talonavicular joint alignment. (See Flatfoot section of this chapter for more details on this procedure.)

The second type of hindfoot overcorrection is an excessive eversion of the subtalar joint complex. This is generally the result of an iatrogenic excessive rotational malalignment after a circumferential release of the subtalar joint in a foot in which the interosseus ligament was preserved. It is manifest clinically by severe valgus deformity of the hindfoot, with a positive (outwardly rotated) thigh–foot angle and with pain under the medial midfoot. There is thick callus formation under the plantar-flexed talar head. The Achilles tendon is usually contracted. There may also be pain in the sinus tarsi region that represents impingement between the lateral process of the talus and the beak of the calcaneus. The foot has all of the clinical features of an idiopathic flatfoot, not just the valgus deformity of the hindfoot as seen in the translational type of overcorrection. Radiographically as well, the foot looks like an idiopathic flatfoot with plantar flexion of the talus, sag at the talonavicular joint, dorsolateral positioning of the navicular on the head of the talus, and exaggerated angular deviation between the talus and calcaneus. When over-the-counter or custom-molded orthotics no longer relieve the pain, the calcaneal lengthening osteotomy, conceptualized by Evans (236) and elaborated by Mosca (237, 238), is an effective technique to relieve the pain and correct all components of subtalar joint malalignment. These include the valgus deformity of the hindfoot, the flattened arch, and the malalignment at the talonavicular joint. Rigid forefoot supination is occasionally identified as an additional deformity and should be concurrently treated with a plantar-based closing-wedge osteotomy of the medial cuneiform (237, 238). If equinus coexists, it should be managed with a posterior release and Achilles tendon lengthening. (See Flatfoot section of this chapter for more details on this procedure.)

It is important to evaluate the alignment of the ankle joint in cases of apparent overcorrection of a clubfoot in which there is valgus deformity of the hindfoot. The subtalar joint may be well aligned, and the valgus deformity could be in the ankle joint. Stevens and Otis (239) identified ankle valgus in 67% of their patients with clubfoot. Medial malleolus screw hemiepiphysiodesis (239–241) is a safe, simple, and effective treatment for the skeletally immature individual with hindfoot pain caused by this deformity. The angulation corrects gradually. Once corrected, the screw can be removed as easily and simply as it was inserted. Supramalleolar angular osteotomy is required after skeletal maturity.

Severe Recurrent Clubfoot Deformity and Untreated Clubfoot. In the multioperated recurrent, severe, and rigid clubfoot, there are several options for treatment of pain and functional disability. The first is a conservative approach that employs arch supports, pads, braces, and shoe modifications. Failure of these modalities to relieve pain is an indication for surgery. Surgical modalities include additional soft-tissue releases and osteotomies, arthrodeses, and gradual deformity correction using an external fixation device such as the Ilizarov apparatus (242–245). Triple arthrodesis (Figs. 29-18 to 29-23) is not generally indicated in patients younger than 10 years, as foot growth will be severely compromised and the shift of stresses to the ankle joint will lead to degenerative arthrosis (19–21, 26, 27). Furthermore, the stiff, deformed foot can only be improved by triple arthrodesis if a stiff, plantigrade foot can be achieved. There is no question that a foot with at least some subtalar motion is more functional and often less symptomatic with vigorous activity than one with no subtalar motion (246). Accepting this, the role for arthrodesis should be limited to a rigid foot with established degenerative arthrosis of the subtalar joint in which deformity and pain compromise the child's ability to stand and walk.

Ilizarov management of the relapsed clubfoot was popularized by Grill and Franke (242); in 1990, they reported the use of this apparatus for correcting relapsed clubfeet to a plantigrade position in which normal shoe wear was possible. At the time of the report, deformity had recurred in 2 of 13 affected feet operated on in the early stages of the series. Many authors (243–245, 247–249) have since shown the value of Ilizarov management of severe relapsed and never treated clubfoot deformities. Synthesizing the available literature, it appears that a patient with a severe relapsed clubfoot will generally benefit from a combination of soft-tissue releases and osteotomies with Ilizarov frame distraction. Hutchinson et al. (249) has documented the benefit of Ilizarov management using pedobarography, showing a more normal pressure distribution of the foot following Ilizarov correction.

Persistent Internal Rotation Gait. Finally, be certain that the apparent recurrent or residual clubfoot deformity that is manifest by an in-toeing gait is, in fact, a foot deformity. There are reports of internal tibial torsion coexisting in limbs with clubfeet (250), though other studies show no difference compared with limbs without clubfeet (251–253). Quite recently, Howlett et al. (112) reported a significant association between increased internal hip rotation and clubfoot. This femoral and/or acetabular anteversion, like internal tibial torsion, creates an in-toeing gait that must be differentiated from recurrent or residual clubfoot deformity to ensure that surgical treatment, if needed, is performed at the correct site of deformity.

Congenital Hallux Varus

Definition. Congenital hallux varus is a medial deviation of the great toe on the first metatarsal that is present at birth. It may occur as an isolated deformity, but is very often associated with other local malformations of the foot, including a short and thick first metatarsal, longitudinal epiphyseal bracket of the first metatarsal, accessory metatarsals and phalanges, duplication of the hallux, and a fibrous band that extends from the medial side of the hallux to the base of the first metatarsal (254, 255) (Fig. 29-66).

Epidemiology/Etiology. This is a rare condition with unknown incidence, inheritance pattern, sex predilection, and incidence of bilaterality. The cause is unknown, but it is usually associated with a first metatarsal that is short and rounded,

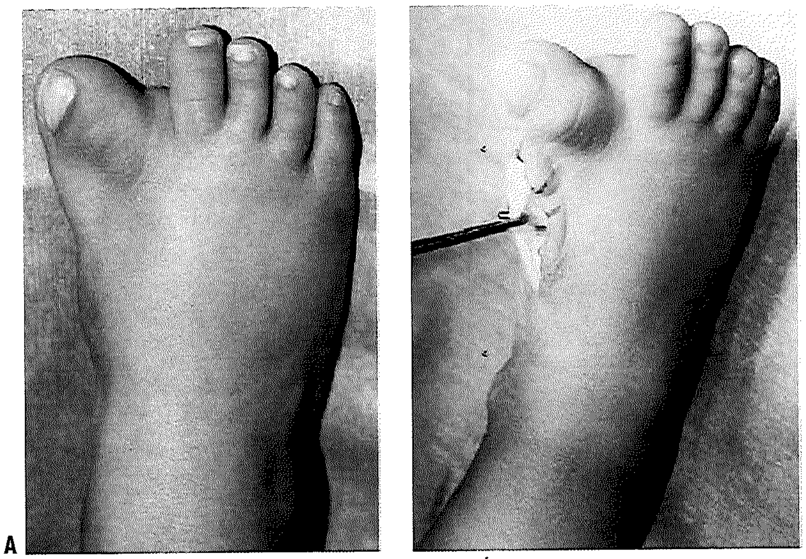

FIGURE 29-66. A: Clinical appearance of congenital hallux varus. B: Fibrous band between the hallux and the cartilaginous duplicate tarsal anlage. (From the private collection of Vincent S. Mosca, MD.)

leading to a very abnormal metatarsal–phalangeal articulation and medial deviation of the great toe with a widened web space between the first and second digits. Normal longitudinal growth of the first metatarsal is compromised. The medial tether leads to persistence or worsening of the deformity if untreated and possible recurrence of deformity if treated incompletely.

Clinical Features. The great toe may be adducted as much as 90 degrees and cannot be aligned by passive manipulation (Fig. 29-66). This should be differentiated from the flexible medial deviation of the great toe that is commonly seen in association with metatarsus adductus. The hallmarks of the congenital deformity are the subcutaneous fibrous band along the medial side of the foot, the widened web space between the first and second digits, and the apparent shortening of the first metatarsal. There may be duplication of the hallux as a separate toe, or it may be associated with simple (Fig. 29-67) or complex syndactyly. Congenital hallux varus with complex syndactyly is commonly seen in Apert syndrome (256).

Radiologic Features. An AP radiograph will provide only partial anatomic detail of the abnormalities, because many of them are not or not yet ossified. The varus alignment will be obvious. Duplication of the phalanges in a polysyndactylized hallux will also be apparent. A rudimentary duplicate metatarsal or medial cuneiform at the base of

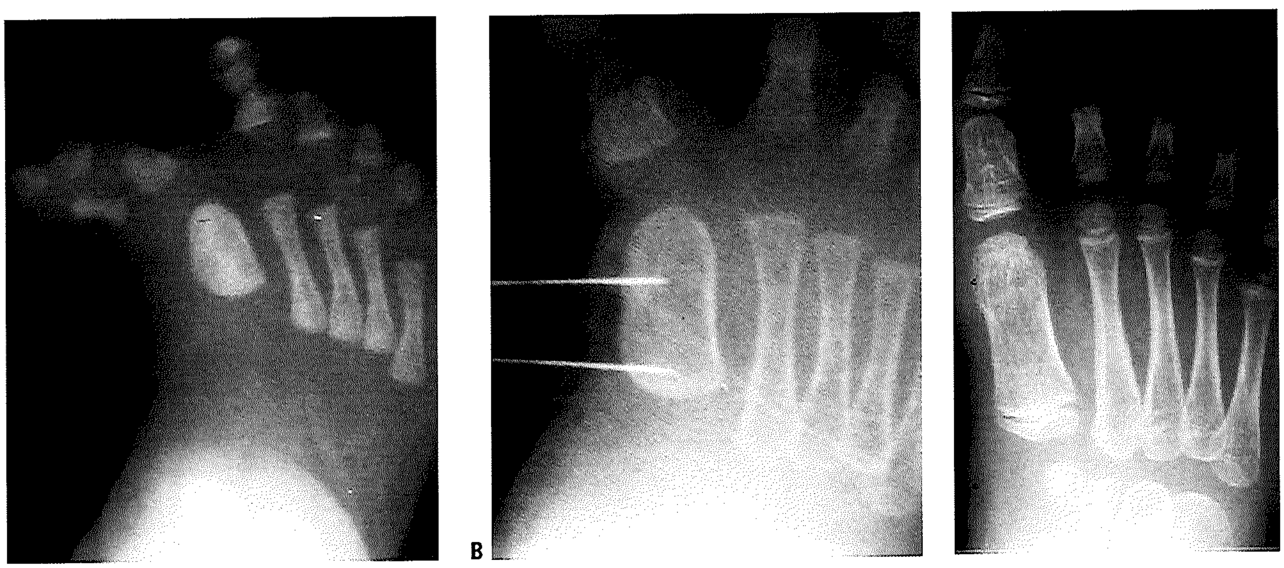

FIGURE 29-67. A: Radiographic appearance of congenital hallux varus with preaxial polysyndactyly and a metatarsal longitudinal epiphyseal bracket. B: Pins mark the extent of the resection of the longitudinal epiphyseal bracket. The distal pin was actually positioned further distally before resection. C: Radiographic appearance 5 years after resection and fat grafting of the longitudinal epiphyseal bracket. The metatarsal has grown normally. (From the private collection of Vincent S. Mosca, MD)

the fibrous band may not be visible due to lack of ossification in the early years of life. A longitudinal epiphyseal bracket will be suggested by the D-shape of the metatarsal with no cortical differentiation along the convex medial border of the diaphysis (257) (Fig. 29-67A).

Pathoanatomy. A possible explanation for a single toe varus deformity is that two great toes and perhaps a metatarsal originate *in utero*, but the medial or accessory one fails to develop. The rudimentary medial structure forms a fibrous band that acts as a taut bowstring that pulls the more fully developed hallux into a varus position creating an incongruous first MTP joint (258) (Fig. 29-66B).

In the foot with a longitudinal epiphyseal bracket, there is a varus deformity of the metatarsal creating the varus alignment of the hallux with the foot. The MTP joint may be congruous and maloriented, although there have been no published anatomic studies on this aspect of the deformity. The issue of MTP joint congruity is reminiscent of that seen in the opposite direction with juvenile hallux valgus and, as with the latter condition, requires an operative approach that preserves joint congruity.

Natural History. In the absence of treatment, shoe fitting becomes increasingly difficult or impossible (255).

Treatment. There is no role for conservative management of this deformity. Surgical management is mandatory and depends on the individual pathoanatomy. The literature is not particularly helpful in providing direction for operative treatment because of the historical failure to appreciate the frequency with which a longitudinal epiphyseal bracket is associated with the hallux varus. The issues to be considered are correction of polydactyly if present; correction of the soft-tissue tether on the medial side of the foot and the widened web space between the great and second toes; correction of metatarsal–phalangeal joint incongruity, if present; and resection of the metatarsal longitudinal epiphyseal bracket (259).

Soft-tissue release and resection procedures with or without syndactylization, as described by McElvenny (254) and Farmer (260), are appropriate when the metatarsal is normal. Mills and Menelaus (255) found that soft-tissue realignment procedures alone were often unsatisfactory because of the shortness and progressive further shortening of the first metatarsal. In the soft-tissue reconstruction of this deformity, lengthening the medial tethers is mandatory. This requires resection of the fibrous band and, in some cases, Z-plasty of the skin along the medial border of the foot. The abductor hallucis and the medial capsule of the metatarsophalangeal joint must be released.

The redundant skin in the web space between the first and second toes often requires resection. Caution must be exercised to avoid injury to the lateral digital neurovascular structures of the great toe, because the medial digital neurovascular structures of the hallux will at least be stretched if not inadvertently damaged by the medial release. The metatarsophalangeal joint often benefits from temporary retrograde alignment and pinning with a K-wire.

The second issue to be dealt with is the bony deformity of the metatarsal. Mubarak et al. (257) demonstrated that resection and interposition grafting of a longitudinal epiphyseal bracket is an effective technique that leads to gradual correction of the varus deformity of the first metatarsal and allows longitudinal growth of the bone to resume.

Longitudinal epiphyseal bracket of the metatarsal is analogous to a delta phalanx of the thumb. Although this condition has been described in several bones of the hand and foot, Mubarak et al. (257) have highlighted this malformation in the first metatarsal. The condition is characterized by a shortened and angulated first metatarsal. The medial diaphysis and metaphyses of the bone are bracketed by a continuous epiphysis. There is a variable degree of angulation deformity and shortening of the bone. This condition can occur in the phalanx, metatarsal, or metacarpal bones but appears limited to those bones that ordinarily have a proximal physis. It also occurs frequently in association with polydactyly. The surgeon, therefore, should be especially aware of this condition when excising an extra hallux adjacent to a shortened first metatarsal.

The continuous nature of the physis is not apparent on plain radiographs until the child is older, and there has been ossification of the bracket. In young children, it can be documented, if necessary, with magnetic resonance imaging. Early identification and treatment before it ossifies is important. The bracket almost always lies on the plantar-medial side of the metatarsal.

Resection of the abnormally positioned epiphysis along the medial shaft of the first metatarsal with local fat interposition is an effective treatment in young children before the epiphysis ossifies (Figs. 29-68 to 29-69). Mubarak et al. (257) have recommended that polymethyl methacrylate be used as an interposition material to prevent regrowth of the physis in the older child in whom ossification of the epiphyseal bracket already exists. It is yet to be demonstrated that this is necessary.

The interposition material can be fat, Silastic, or methyl methacrylate. With adequate resection of the abnormal epiphysis and good anchoring of the graft, fat is an excellent choice and avoids the risks and potential complications of the foreign materials. This procedure is combined with distal soft-tissue release and resection of duplicated parts as indicated. Hypercorrection of the first MTP joint should be avoided to prevent the creation of joint incongruity and progressive hallux valgus.

Late onset of degenerative arthrosis of the first metatarsal–phalangeal joint, if it were to occur, can be managed by arthrodesis (255). Alternative treatments for pain in the adolescent and adult with residual shortening and deformity include metatarsal lengthening (Fig. 29-70) and amputation. Amputation is a particularly valuable alternative in the management of severe congenital hallux varus deformity in Apert syndrome (256).

Congenital Overriding Fifth Toe

Definition. Congenital overriding fifth toe is a dorsomedial subluxation of the fifth toe at the MTP joint that is present at birth. The entire toe is dorsally and medially displaced,

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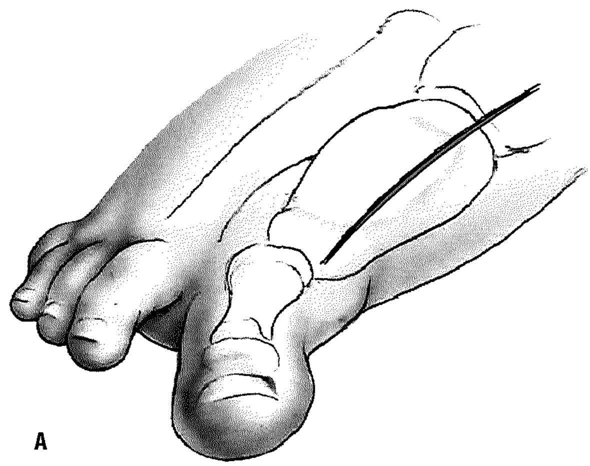
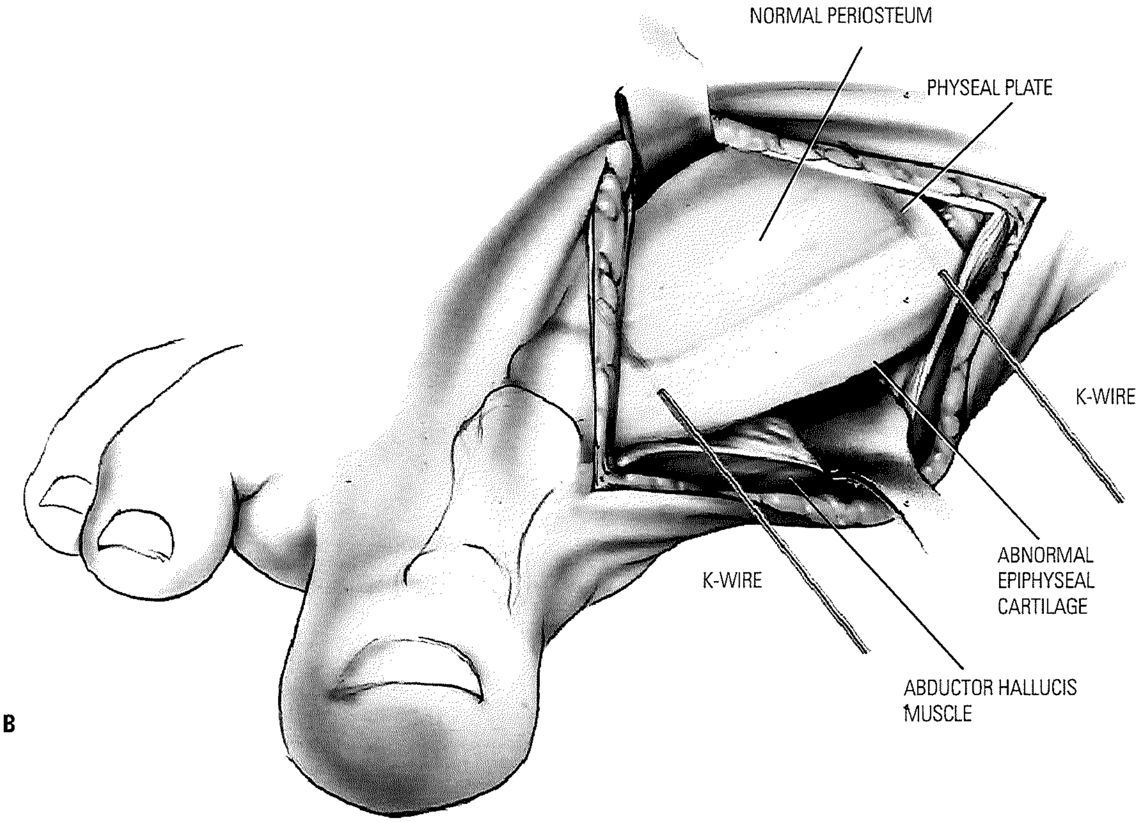
Physiolysis and Metatarsal Osteotomy in the Treatment of Longitudinal Epiphyseal Bracket of the First Metatarsal (Figs. 29-68 to 29-70)



A



B

FIGURE 29-68. Physiolysis in the Treatment of Longitudinal Epiphyseal Bracket of the First Metatarsal. The incision for resection of a longitudinal epiphyseal bracket is longitudinal along the medial length of the metatarsal **(A)**. The abductor hallucis muscle is released from its distal attachment because it will be tight and limit correction. The bracket epiphysis starts proximally in its normal location articulating normally with the articular cartilage of the medial cuneiform. It then extends along the medial aspect of the shaft of the metatarsal before ending distally with reexpansion to a normal articular cartilage surface that articulates with the normal articular cartilage of the proximal phalanx of the hallux. The abnormally present cartilage along the shaft is primarily medial and extends both dorsomedially and plantar-medially to about the midsagittal plane of the metatarsal. The periosteum and bony cortices are normal laterally. The bone deep to the abnormal cartilage on the medial shaft has the histologic characteristics and gross appearance of metaphyseal bone, as exists adjacent to a normal physeal plate. The metatarsal shaft is exposed extraperiosteally **(B)**. Steinmann pins or small gauge needles can be inserted as guide pins at the proximal and distal extents of the planned resection segment with guidance from an image intensifier (see Fig. 29-67B).

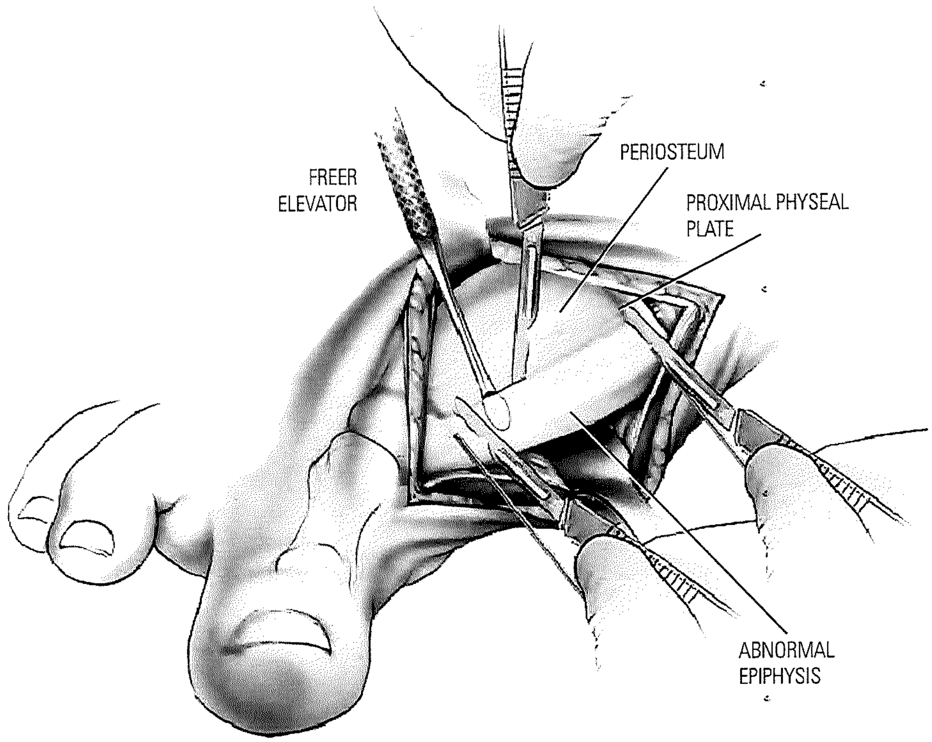


FIGURE 29-69. A scalpel is used to incise the cartilage down to bone adjacent to the guide pins. It is then possible to separate the abnormal growth plate from the underlying bone of the shaft with a Freer elevator. Ensure that normal periosteum is visualized on the dorsal and plantar surfaces beyond the area of cartilage resection. Failure to do so might result in persistence of abnormal growth. Local subcutaneous fat is an excellent, readily available, and appropriate interposition material for resections performed in young children. Simply reapproximating the subcutaneous tissues and skin edges accomplishes this task. Expect spontaneous angular deformity correction and resumption of longitudinal growth when this procedure is performed in children under 1 to 2 years of age (see Fig. 29-67B,C).

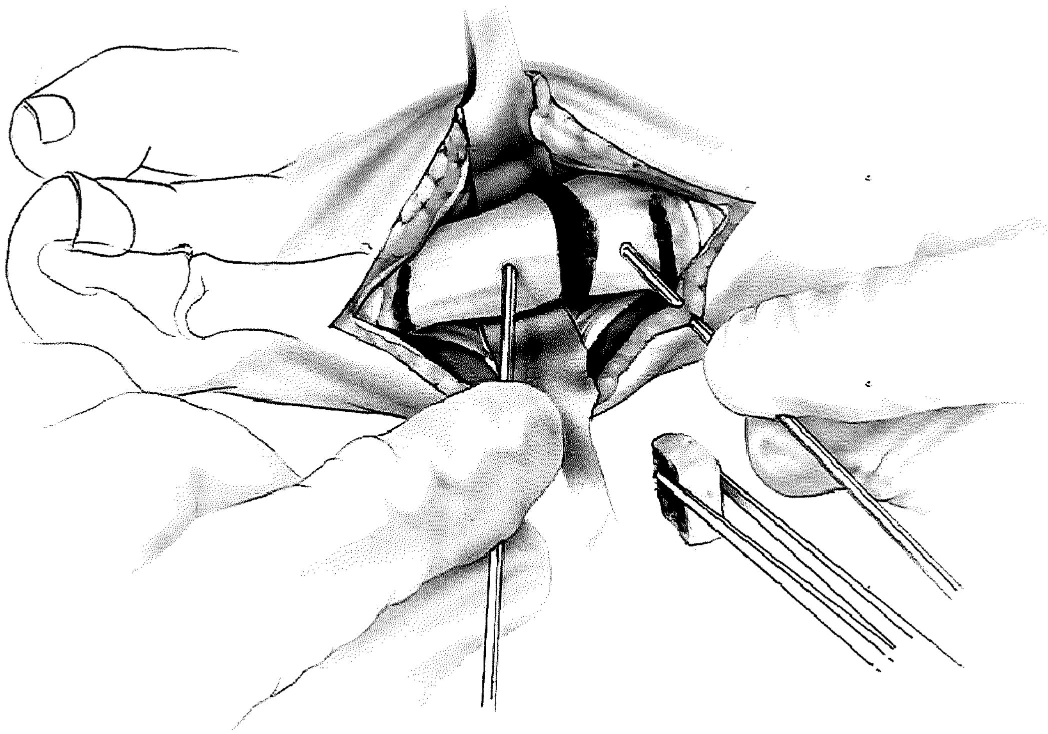


FIGURE 29-70. Metatarsal Osteotomy in the Treatment of Longitudinal Epiphyseal Bracket of the First Metatarsal. In an older child, an osteotomy can be performed to correct angulation and lengthen the metatarsal either as an isolated procedure or concurrent with resection of an epiphyseal bracket. To perform an osteotomy, the bone is divided at the site of its most acute angle (the CORA). To manipulate the fragments, it may be necessary to put small Steinmann pins in the proximal and distal fragments. Using these pins to realign the distal fragment, tight soft-tissue structures can be identified and released. It may also be desirable to correct any true hallux varus by release of the medial capsule of the metatarsophalangeal joint. A small piece of autogenous or allograft bone is inserted into the opening. A longitudinal pin is then passed through the phalanges into the metatarsal, fixing the graft and both of the fragments.

adducted, and externally rotated, lying across the base of the fourth toe (Fig. 29-71).

Epidemiology. The incidence is unknown, but congenital overriding of the fifth toe is a common condition. There is no sex predilection. Bilateral involvement is seen in 20% to 33% of cases (261–263).

Etiology. There is a familial predilection for this deformity, but the etiology is unknown (262).

Clinical Features. The toe has a characteristic appearance that is different from other congenital and developmental deformities of the toes. The interphalangeal joints are in normal full extension. The skin in the web between the fourth and fifth toes is out of alignment with the other web spaces, yet there is no stress or tension on the skin. The toe was created in that position, not secondarily contracted. The toenail is normal, and the toe flexor and extensor muscles function normally. Except for possible bilaterality, this is an isolated deformity.

Radiographic Features. Though difficult to image, radiographs merely show dorsomedial angulation/subluxation at the MTP joint.

Pathoanatomy. There is congenital contracture of the dorsomedial capsule of the fifth MTP joint with subluxation at the joint, but with maintenance of contact of the articular surfaces. The toe is not clawed. Specifically, there are no deformities at the interphalangeal joints. There is also shortening of the extensor tendons to the fifth toe that matches the degree of proximal positioning of the toe. The toe seems to have emerged from the end of the foot translated more proximally and dorsally than the other toes. The skin is not stretched or stressed.

Natural History. It has been stated that approximately half of affected individuals will experience symptoms from this deformity, generally due to pressure from shoe wear (262). However, that is likely an overestimate because of the unknown incidence of the deformity.

Treatment. Conservative measures such as stretching, taping, and strapping have no proven efficacy. This is not surprising considering the pathoanatomy. Therefore, education about the reasonably good prognosis is the recommended early treatment.

Surgery is indicated for the roughly 50% of adolescents and adults who experience pain with shoe wear (262). The toe in its medially deviated and dorsiflexed state will overlie the fourth metatarsal–phalangeal joint creating excessive height in the toe box of the shoe. Many surgical procedures have been proposed. Those involving partial and complete excision of the proximal phalanx with syndactylization to the fourth toe have had only fair success and have created secondary deformities (264). Amputation should be considered a salvage procedure. The Butler procedure (261, 263), originally reported by Cockin (262), is a very successful procedure for the management of this condition (Figs. 29-71 to 29-75).

Congenital Vertical Talus

Definition. A congenital vertical talus is a dorsolateral dislocation of the talonavicular joint, and occasionally the calcaneocuboid joint, associated with extreme and rigid plantar flexion of the talus, eversion of the subtalar joint, and fixed dorsiflexion of the midfoot on the hindfoot (265, 266). Other historic terms used to describe this deformity include congenital rocker-bottom foot, congenital convex pes valgus, and congenital flatfoot with talonavicular dislocation.

Epidemiology. The incidence of congenital vertical talus is unknown, but it is considered to be exceedingly rare. It occurs as an isolated congenital abnormality in approximately half of the cases and is associated with neuromuscular and genetic disorders in the rest (267–272). Fifty percent of children have bilateral involvement, and there is no sex predilection (269).

Etiology. There are probably multiple etiologies for this deformity. There is evidence that some cases of the isolated deformity are transmitted as an autosomal dominant trait with incomplete penetrance (270, 273). Cases associated with neural tube defects, such as myelomeningocele, sacral agenesis, and diastematomyelia, are due to neurologically mediated muscle imbalance (274). Sharrard and Grosfield (275) identified vertical talus in 10% of their patients with myelomeningocele (275). Myoplastic muscle imbalance creates the deformity in children with arthrogryposis. Given the frequency with which this deformity is associated with neuromuscular disorders, a thorough neuromuscular evaluation is indicated in patients with congenital vertical talus with the possible inclusion of an MRI of the neuroaxis.

Clinical Features. The congenital vertical talus has a rigid, convex plantar surface giving the foot the appearance of a Persian slipper (Fig. 29-76). Lloyd-Roberts and Spence (276) described the clinical appearance as "a prominence in the sole from which the heel and forefoot rise in a gentle curve." The Achilles tendon is contracted, and the hindfoot is in a fixed equinovalgus position. There are few posterior heel skin creases. The head of the talus is palpable on the plantar-medial aspect of the midfoot. The midfoot is abducted and dorsiflexed on the hindfoot, that is, severely everted. It cannot be adducted and plantar-flexed, that is, inverted, to neutral. There is a crease overlying the narrow, concave sinus tarsi. The hallmark finding in congenital vertical talus is that none of the deformities is correctable by manipulation. The longitudinal arch cannot be created, the head of the talus cannot be covered by the navicular, and the ankle cannot be dorsiflexed.

Congenital oblique talus is a term often mentioned in discussions of congenital vertical talus, usually indicating a milder

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The Butler Procedure for Overlapping Fifth Toe (Figs. 29-71 to 29-75)

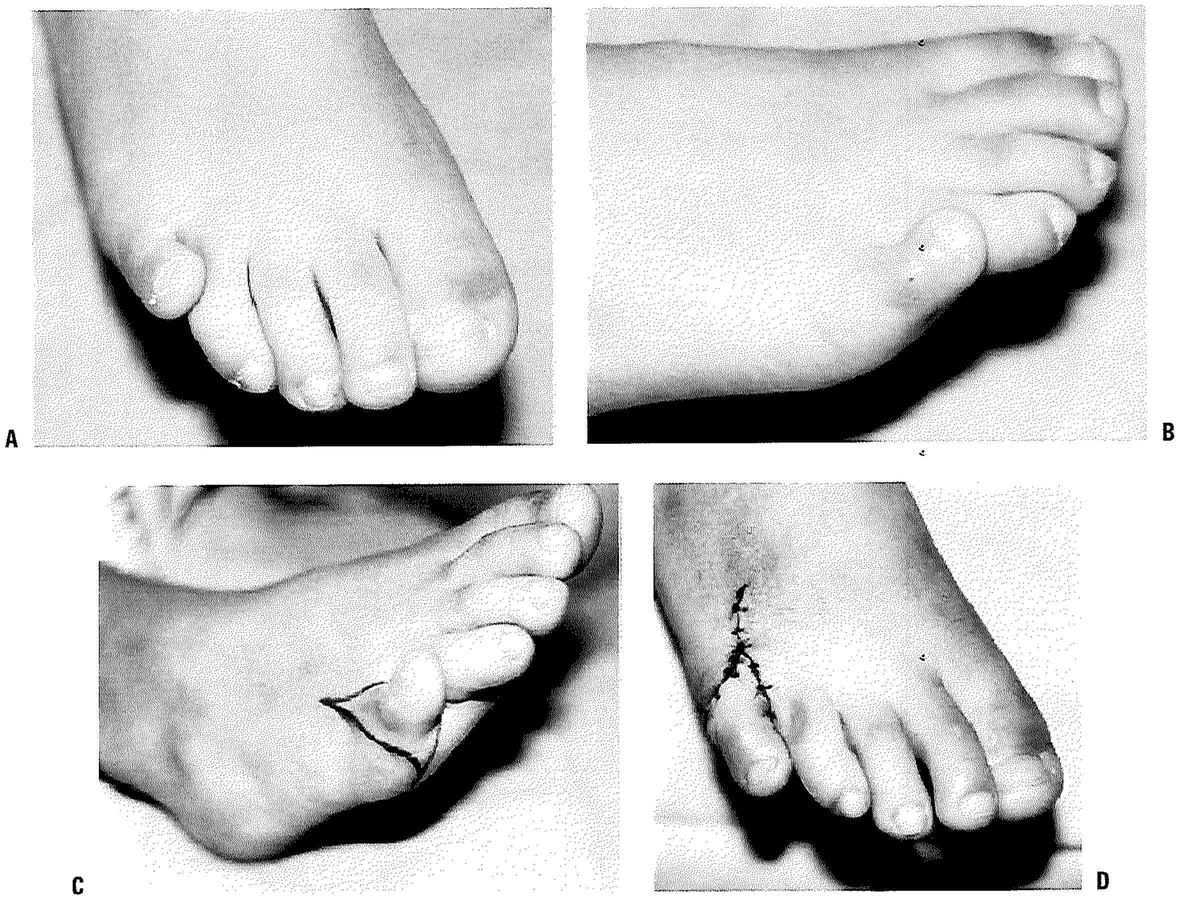

FIGURE 29-71. The Butler Procedure for Overlapping Fifth Toe. A, B: Congenital overriding fifth toe. **C–E:** The Butler procedure for congenital overriding fifth toe. Double racket-handle incision with dorsal V to Y and plantar Y to V advancement. (From the private collection of Vincent S. Mosca, MD.)

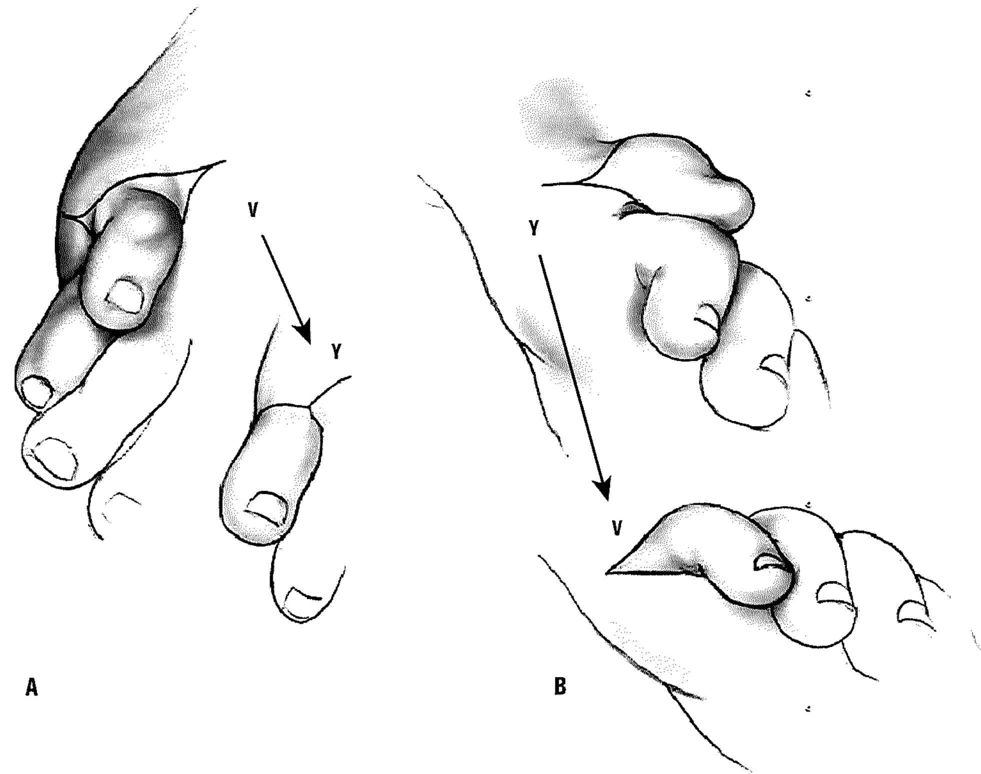

FIGURE 29-72. The incision for correction of a congenital overriding fifth toe is a double racket incision. The plantar handle should be longer than the dorsal and should be directed more laterally. The reason for this is apparent when it is understood that the dermodesis is accomplished by a V-to-Y advancement of the dorsal incision **(A)** and a Y-to-V advancement of the plantar incision **(B)**.

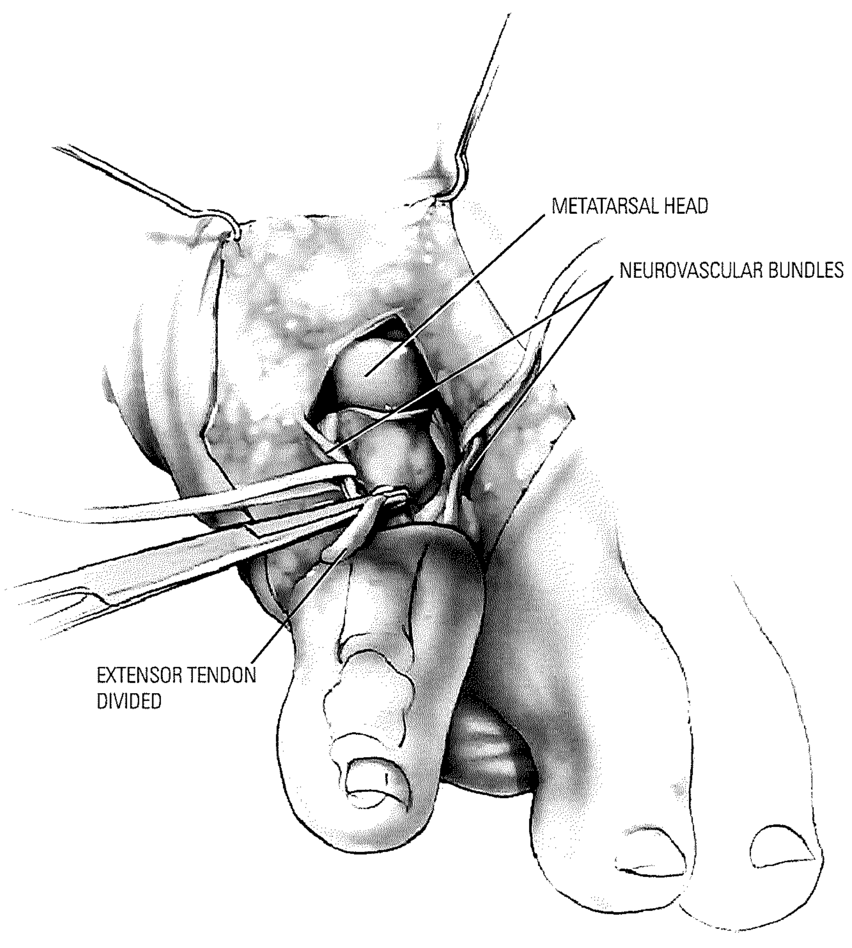

FIGURE 29-73. After the skin incisions are made, they are carefully deepened through the subcutaneous tissue by sharp and blunt dissection to mobilize the skin. Care should always be taken to avoid injury to the neurovascular bundles. Starting dorsally by the extensor tendon (which can be tensed by flexing the toe), a small hemostat is used to separate the tissue off the capsule, both medially and laterally. Here, the neurovascular bundles are illustrated as having been isolated for clarity; however, this is not necessary if care is taken to stay close to the capsule and bone. The extensor tendon is divided along with the dorsal aspect of the capsule. With the capsule now exposed on both sides, it is a simple matter to divide it safely medially and laterally down to the plantar aspect.

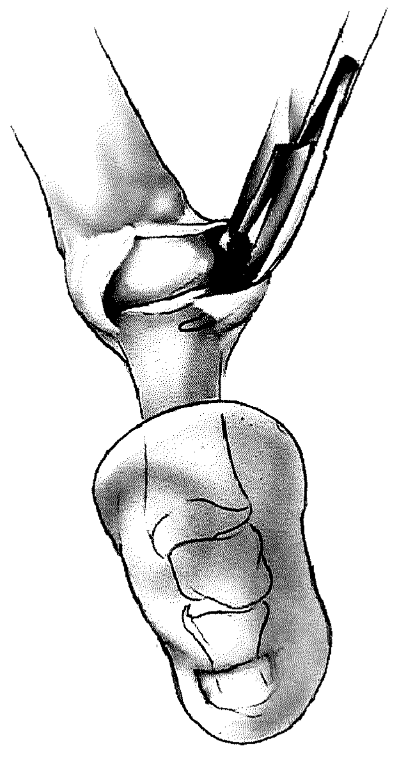

FIGURE 29-74. If the toe does not lie in a normal position after this release, it is most likely because of adherence of the capsule to the plantar aspect of the metatarsal head. This can be freed by inserting a small, curved hemostat around the head and spreading it. The toe should rest in anatomic alignment. If unstable, a temporary retrograde K-wire can be inserted.

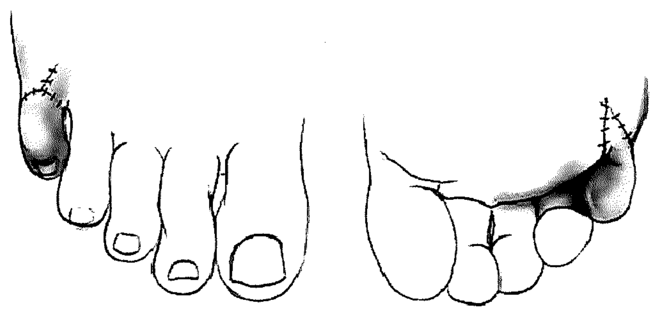

FIGURE 29-75. The skin is closed, advancing the plantar flap into the racket incision that was extended somewhat laterally. This is the Y-to-V advancement. The dorsal skin flap now will not fit as it did before, leaving a longer linear incision. This is the V-to-Y advancement. The remainder of the incision is closed. Fine absorbable sutures are used in the skin to obviate the difficult problem of removal (see Fig. 29-71C–E). A short leg cast is applied. The patient may walk with the aid of crutches. After 3 to 4 weeks, healing should be sufficient to remove the cast and permit full weight bearing.

class of deformity. To my knowledge, there is no consensus definition of this deformity or any primary literature on the subject (268, 277, 278). The justification for any classification system should be to direct differential treatment and to assign prognosis, based upon the natural history of the condition and the proven efficacy of treatment. Hamanishi (268) attempted to differentiate congenital vertical talus from congenital oblique talus based upon a specific clinical examination finding and his new radiographic measurement system, but he did not clearly document a difference in prognosis or the efficacy of differential treatment based upon his definitions. He also stated that, despite his definitions, there is a large overlap between the two conditions.

Though not etiologically or pathophysiologically related, I believe that severity and rigidity of the deformities should be used to differentiate valgus, or eversion, deformities of the hindfoot. At one end of the spectrum is the congenital vertical talus, a severe and rigid deformity in which the subtalar joint cannot be inverted to even near-anatomic alignment, and the talus remains maximally plantar-flexed despite attempts to dorsiflex the ankle. At the other end of the spectrum is the normal physiologic flexible flatfoot without Achilles tendon contracture in which the subtalar joint can be inverted beyond neutral, and the ankle can be fully dorsiflexed above neutral. According to Harris and Beath (279), the subtalar joint of a flexible flatfoot with a short Achilles tendon can likewise be inverted beyond neutral alignment, but the ankle cannot be fully dorsiflexed. My belief is that a congenital oblique talus is a milder and more flexible form of a congenital vertical talus, but is a more severe and rigid deformity than a flexible flatfoot with a short Achilles tendon. I generally define a congenital oblique talus as one in which the subtalar joint can be inverted to near, but not complete, anatomic alignment, and the talus can be partially dorsiflexed, though perhaps less so than in a flexible flatfoot with a short Achilles tendon. This definition is obviously subjective and possibly no more or less meaningful than any in the literature. Therefore, the best approach is probably to differentiate congenital oblique and vertical talus deformities from the flexible flatfoot with a short Achilles tendon, based on the definition of the latter by Harris and Beath (279). Oblique and vertical talus deformities can then be grouped under the single term congenital vertical talus (or congenital pes valgus, or other) and considered along a continuum of severity and rigidity, an approach that would then be analogous to the classification systems for clubfoot (121–123).

It is important to differentiate the congenital vertical talus from positional calcaneovalgus, congenital posteromedial bowing of the tibia, and equinovalgus foot deformity associated with fibula hemimelia, conditions sometimes confused with congenital vertical talus.

Radiographic Features. An AP radiograph of the foot is helpful, but the diagnosis is confirmed on lateral radiographs that are obtained with the foot in maximum plantar flexion and maximum dorsiflexion (274) (Fig. 29-77). The talus, calcaneus, and metatarsals are ossified at birth, and the cuboid

FIGURE 29-76. Congenital vertical talus in an infant. **A:** Medial. **B:** Lateral. (From the private collection of Vincent S. Mosca, MD.)

generally ossifies within the first month of life. These centers of ossification enable one to confirm the diagnosis radiographically soon after birth. The maximum dorsiflexion view shows persistence of plantar flexion of the talus and calcaneus caused by contracture of the Achilles tendon and posterolateral joint capsules (Fig. 29-77A). In a normal foot, the talus dorsiflexes to a right angle with the tibia, and the calcaneus dorsiflexes at least 20 degrees above a right angle with the tibia (Fig. 29-77B). The maximum plantar flexion view shows persistent dorsal translation of the forefoot on the hindfoot caused by fixed dorsal dislocation of the navicular on the head of the talus (Fig. 29-77C). In a normal, unstressed foot, the axes of the talus and first metatarsal create a nearly straight line. In a normal foot that is maximally plantar-flexed, those

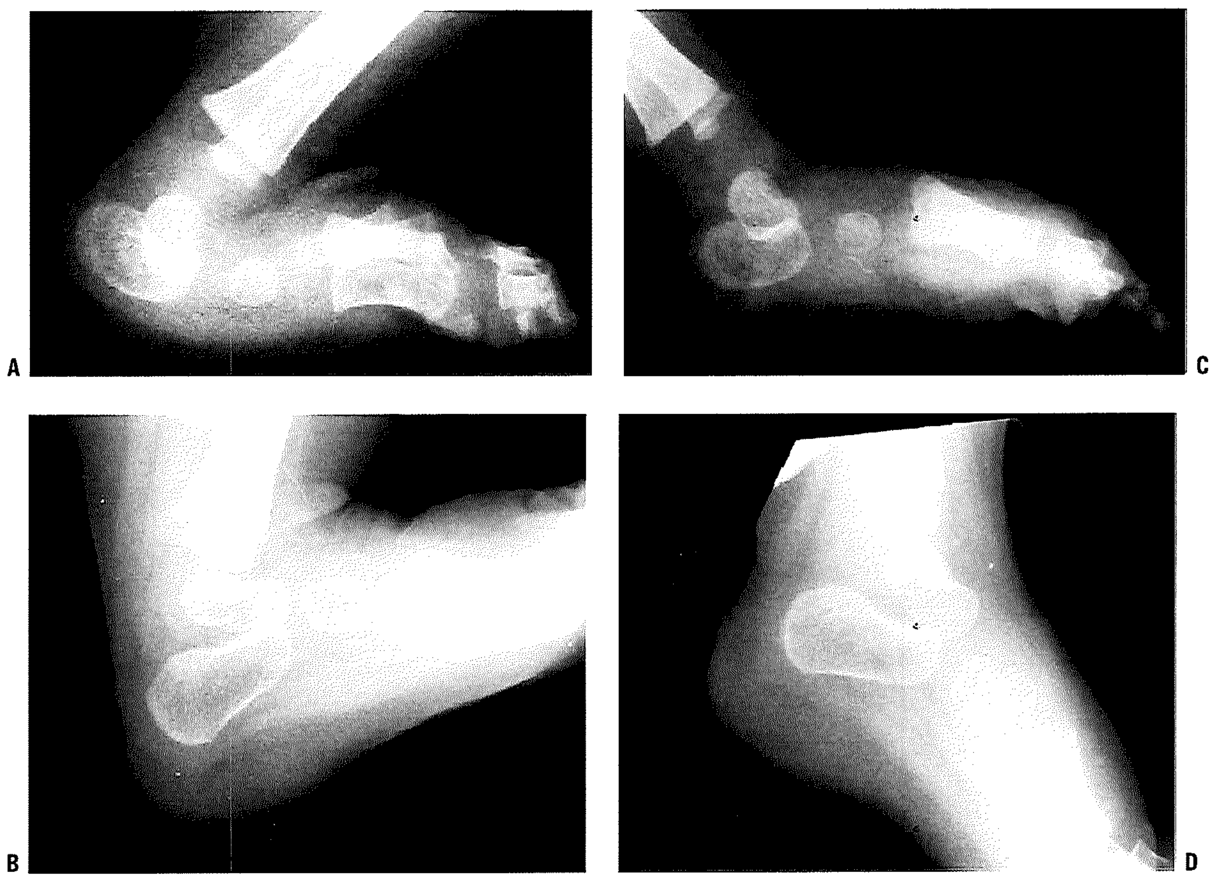

FIGURE 29-77. **A:** Lateral dorsiflexion radiograph of congenital vertical talus, showing persistent plantar flexion of the talus and calcaneus. **B:** Lateral dorsiflexion radiograph of a healthy foot, showing full dorsiflexion of the talus and calcaneus. **C:** Lateral plantar-flexion radiograph of the congenital vertical talus, showing persistent dorsal translation of the forefoot on the hindfoot. **D:** Lateral plantar-flexion radiograph of a healthy foot, showing good alignment of the forefoot on the hindfoot. (From the private collection of Vincent S. Mosca, MD.)

lines intersect in the midfoot creating an apex dorsal angle (Fig. 29-77D). The position of the cuboid in relation to the calcaneus should also be noted, as it may be dorsally subluxated to varying degrees in the congenital vertical talus.

There is clearly a spectrum of flexibility in severe and rigid congenital equinovalgus hindfoot deformities that can be identified both clinically and radiographically. Hamanishi (268) introduced the talar axis–first metatarsal base angle and the calcaneal axis–first metatarsal base angle to define and differentiate congenital vertical from congenital oblique talus, but the validity of these angles has not been verified. In fact, there are no universally accepted clinical or radiographic measurements that can be used to clearly differentiate congenital vertical talus from the so-called congenital oblique talus. Nevertheless, there are congenital equinovalgus hindfoot deformities in which the talus is in exaggerated plantar flexion and will partially dorsiflex, and the forefoot is in exaggerated dorsiflexion and will partially plantar-flex to near-anatomic alignment with the hindfoot. For that reason, it makes the most sense to eliminate the term congenital oblique talus, and consider a continuum of congenital vertical talus deformities that includes a more flexible variety, stopping short of including the flexible flatfoot with a short Achilles tendon.

Pathoanatomy. Autopsy and surgical findings have confirmed consistent pathoanatomic findings in congenital vertical talus (280–283). Most have found contractures of the tibialis anterior, extensor hallucis longus, extensor hallucis brevis, peroneus tertius, peroneus longus, peroneus brevis, and the Achilles tendon. The peroneus longus and peroneus brevis may be anteriorly subluxed over the lateral malleolus, and the posterior tibial tendon may be subluxed anteriorly over the medial malleolus. The severe plantar flexion of the talus results in contact of only the most posterior aspect of the talar dome with the distal tibial articular cartilage. There is dorsal extension of the articular cartilage of the talar head to accommodate the proximal articular contact with the navicular, which is wedge shaped with a hypoplastic plantar segment. The head of the talus generally protrudes below the posterior tibial tendon, and the calcaneonavicular, or spring ligament, is markedly attenuated. The calcaneus is severely externally rotated and everted, with its posterolateral border in proximity to the fibula. The sustentaculum tali and anterior facet of the subtalar joint are exceedingly hypoplastic or absent in the most severe cases. The dorsal capsule of the talonavicular joint is thickened and contracted.

Natural History. Congenital vertical talus persists and causes disability if untreated. The rigidly plantar-flexed head of the talus becomes the predominant weight-bearing surface of the foot with the development of pressure-induced callosities and pain. The heel does not contact the ground. There is no push-off. The gait simulates that of a Syme amputation, but without the well-cushioned heel pad under the weight-bearing bone. If one accepts my definition of a congenital oblique talus as existing on a continuum between a congenital vertical talus and a flexible flatfoot with a short Achilles tendon (but closer to the vertical talus), the prognosis for the untreated congenital oblique talus is poor. The reason for that conclusion is that the untreated congenital vertical talus always causes disability and the flexible flatfoot with a short Achilles tendon is frequently associated with pain and disability, according to Harris and Beath (279).

Treatment. Historically, the belief was that most clubfeet and all congenital vertical talus deformities required extensive surgical releases at some time within the first year of life. In 1995, Cooper and Dietz (184) published the impressive long-term follow-up results of the Ponseti casting method for correction of idiopathic clubfoot. With increasing universal application of the Ponseti method since that time, the role for surgical management of the idiopathic clubfoot has decreased dramatically and has been essentially eliminated in some centers. A reliably effective casting method for the correction of the congenital vertical talus was not demonstrated until 2006. In that year, Dobbs et al. (284) reported the first study showing short-term maintenance of good correction in 19 idiopathic congenital vertical talus deformities treated with a reverse-type Ponseti casting followed by minimally invasive surgery. Long-term follow-up is lacking, and Dobbs has already modified the method since publication. Nevertheless, it makes sense to use the reverse-Ponseti casting technique even if only to more effectively stretch the dorsal soft tissues to render the surgical treatment less extensive.

Casting has been considered important by nearly all who have studied this condition (269, 270, 274, 282). Historically, it was expected that the casts would achieve only minimal correction of the deformities, perhaps only stretching of the skin, and that extensive surgery would be necessary to achieve full correction. Proposed surgical options have included one-stage release (270, 274, 282, 285–289), two-stage release (269, 290, 291), talectomy (265), naviculectomy (292, 293), subtalar arthrodesis (294–297), triple arthrodesis, and lateral column lengthening (personal experience).

Talectomy was recommended by Lamy and Weissman in 1939 (265) and was soon abandoned. It is a destructive, rather than a reconstructive, procedure that does not directly address the pathology. Additionally, it leaves no options for future problems that may arise, such as recurrence of deformity.

The primary choice for operative treatment of a congenital vertical talus in a child under the age of approximately 2 years is either the one-stage or the two-stage circumferential release and reduction procedure. The first stage of the two-stage approach consists of lengthening the contracted dorsolateral tendons, releasing the contracted dorsolateral joint capsules, and reducing the subtalar joint with plication of the talonavicular joint capsule and the tibialis posterior tendon. The second stage consists of a posterolateral release of the contracted capsules and lengthening of the Achilles and peroneal tendons. The traditional one-stage procedure simply combines the two stages into one. A newer and perhaps less commonly used one-stage procedure was reported by Seimon in 1987 (282). Mazzocca et al. (285) compared Seimon's dorsal approach to the traditional posteromedial–lateral approach and found it to be associated with shorter operative times, better clinical scores, and fewer complications. Most recent authors recommend a one-stage procedure (270, 274, 282, 285–289), reporting results that are comparable to or better than those reported with the two-stage approach (269, 290, 291).

Several authors have reported the addition of a full or split transfer of the tibialis anterior to the head or neck of the talus. Although the efficacy of these transfers has not been scientifically proven, the split transfer adds little time and no morbidity, and it makes theoretic sense. The peroneus longus, the plantar flexor of the first ray of the foot, is congenitally contracted and strong. Complete transfer of the tibialis anterior, the dorsiflexor of the first ray, could lead to muscle imbalance with the progressive development of a cavus foot deformity. The split transfer leaves some dorsiflexion power on the first ray while adding supplemental support to the head of the talus.

It is not clear if there is an upper age limit for this reconstructive approach. There is disproportionate growth of the medial and lateral columns of a foot with a chronically unreduced vertical talus. Physiologic compression that is normally associated with a reduced talonavicular joint is lacking. Longitudinal overgrowth of the medial column occurs according to the Hueter-Volkmann law. Excessive compression along the lateral column of the foot inhibits normal longitudinal growth. This phenomenon may be seen as early as age 2 to 3 years. It is manifest either as an inability to fully reduce the deformity or as residual deformity despite full reduction of the talonavicular joint. Shortening the medial column and lengthening the lateral column of the foot are two approaches to management. Several authors (292, 293) have recommended naviculectomy as both a primary and salvage procedure for congenital vertical talus. It is an effective technique for shortening the medial column of the foot. The proximal articular surfaces of the three cuneiform bones have a combined configuration identical to the distal articular surface of the navicular and almost identical to the proximal articular surface of the navicular. They create a reasonably congruous articulation with the talar head, which is further improved over time by the Hueter-Volkmann law. A posterolateral release is combined with naviculectomy for full deformity correction in this group of slightly older children (Fig. 29-78). The upper age limit for this procedure is unknown. I have used lateral column lengthening for select cases of congenital oblique and vertical talus in older children with variable success. The congenitally contracted skin along the lateral border of the foot limits the applicability of this technique in most cases.

Early diagnosis and treatment should eliminate the need for other surgical options in young children. Nevertheless, subtalar (294–297) and triple arthrodesis have been reported for this condition, as they have been for almost every major foot deformity in the child. The literature clearly shows that these techniques are associated with a high rate of complications including the development of degenerative arthritis at the ankle and midtarsal joints (19–27). Napiontek (297) reported overcorrection of the valgus deformity in half of his patients who underwent peritalar reduction combined with subtalar arthrodesis. Arthrodeses of the joints of the hindfoot should, therefore, be reserved as salvage procedures for the adolescent and adult who have painful recurrent deformity or painful degenerative arthritis.

Curly Toe

Definition. Curly toe is a congenital deformity of one or more of the lesser toes in which there is flexion, varus deformity, and lateral rotation of the phalanges and interphalangeal joints causing the toe to curl under the adjacent more medial toe. The metatarsophalangeal joint has normal alignment (Fig. 29-79).

Epidemiology. Curly toe is a very common deformity, although the true incidence is not known. It is very frequently bilateral and symmetric, with high familial incidence (298, 299).

Etiology. The cause is unknown.

Clinical Features. The third and fourth toes are most frequently involved. The distal phalanx or the distal and middle phalanges underride the more medial toe because of the flexion, varus, and external rotation deformities of the distal and/or PIP joints. The nail plate of the affected toe faces laterally. Contrary to the situation seen with congenital overriding fifth toe, the skin in the web spaces is normally aligned, and there is no deformity at the MTP joint. The deformity is flexible in early childhood. The interphalangeal joints can be extended fully when the MTP joint and the ankle joint are plantar-flexed. This maneuver indicates that the deformity is due to contracture of the flexor tendons to the affected toe and not due to capsular contractures.

Radiographic Features. Radiographs are neither needed nor helpful in the young child.

Pathoanatomy. The FDL and/or the flexor digitorum brevis tendons to the affected toe are contracted (300). Joint capsules are generally not affected. A trapezoid-shaped deformity of one or more phalanges is often present.

Natural History. Curly toes are generally asymptomatic in young children. Many improve in shape spontaneously (299, 300). They may become symptomatic in older children, adolescents, or adults, because of exaggerated pressure on the skin and nails of malaligned toes. The nail of the underlying toe may cut the plantar surface of the overlying toe, causing symptoms.

Treatment. Stretching and taping have no proven efficacy in the treatment of curly toes (299) but may help in mild cases. The family should be educated that, in general, symptoms are rare and long-term disability is unlikely, even with mild residual deformity. Some patients do experience pain and problems from curly toe deformity. If associated with a tight toe flexor, stretching exercises might be of benefit prior to embarking on surgical treatment.

Surgery is indicated for pain, callosities, and blistering resulting from pressure on the tip of the curly toe or over the

FIGURE 29-78. Radiographs before (**A, B**) and after (**C, D**) naviculectomy for congenital vertical talus in an older child. *Arrow* indicates the navicular. (From the private collection of Vincent S. Mosca, MD.)

interphalangeal joints of the more medial toe that overrides the curly toe. Another indication is an unacceptable problem with growth of the nail on either or both toes.

Tenotomy of the flexor digitorum longus (FDL) with or without tenotomy of the flexor digitorum brevis (FDB) has been successful in 95% to 100% of cases (298, 300). A double-blind, randomized prospective study comparing simple tenotomy of the long toe flexor to the Girdlestone-Taylor transfer of the FDL to the extensor mechanism showed no difference in outcome (301). In this study, 19 patients with bilateral deformity involving the third and fourth toes were operated on, using a flexor tenotomy release on one side and the flexor transfer procedure on the other. At 4-year follow-up, there was no difference between the two procedures, indicating that simple tenotomy of the flexor tendon is sufficient treatment for the symptomatic curly toe.

Flexible Flatfoot

Definition. Flatfoot is the term used to describe a weight-bearing foot shape in which the hindfoot is in valgus alignment, the midfoot sags in a plantar direction with reversal of the longitudinal arch, and the forefoot is supinated in relation to the hindfoot. Flexibility refers to the mobility of the subtalar

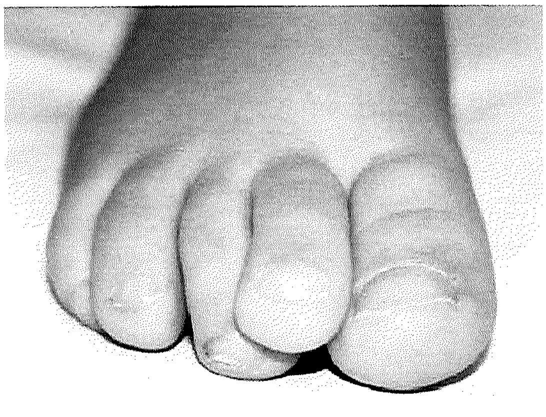

FIGURE 29-79. The curly toe deformity generally results from a tight toe flexor as seen in the third toe in this patient. Another possible etiology is an abnormally shaped phalanx that may result in fixed deformity and require osteotomy or arthrodesis for correction of painful persistent deformity. (From the private collection of Vincent S. Mosca, MD.)

joint and longitudinal arch and the ability of both to reverse their alignments.

Epidemiology. The true incidence of flexible flatfoot is unknown primarily because there is no agreement on strict clinical or radiographic criteria for defining a flatfoot. At the root of this dilemma is the lack of a universally accepted definition of a "normal," in contrast to an "average height," longitudinal arch. Nevertheless, it is believed that most children (9, 10) and at least 20% of adults (8) have flatfeet, most of which are flexible, strong, stable, and comfortable. Harris and Beath (8) used their own criteria when they identified flatfoot in approximately 23% of the 3619 adults whom they examined. They classified them into three types and emphasized that the flatness of the arch in weight bearing is of less importance than the mobility of the joints and tendons. The flexible, or hypermobile, type of flatfoot was characterized by good mobility of the joints and tendons. It accounted for two-thirds of the flatfeet and was found to be of little or no clinical concern as a potential cause of disability. Contracture of the Achilles tendon was associated with a flexible, or hypermobile, flatfoot in 25% of the total. This type was found to be a cause of pain and disability (8, 279). The least common type was the rigid flatfoot, which was characterized by restricted mobility of the subtalar joint. This type was usually caused by a tarsal coalition and painful disability was sometimes observed. Flexible flatfeet are said to run in families, although there are, to my knowledge, no data to support this statement. The frequency of flatfeet may be the basis of this apparent observation.

According to a study by Reimers et al. (302) carried out in Danish schoolchildren, the proportion of feet with decreased longitudinal arches declined from 42% in the 3- to 5-year age group to 6% in the teenagers. In this, as in all studies of the longitudinal arch, the definition of flatfoot was unique to the study and not universally accepted. Therefore, the percentages are circumspect. Nevertheless, the study confirmed what other studies have shown, which is that there are more flat-footed young children than older children and adolescents. They also found a strong relation between a short Achilles tendon and persistence of flatfoot deformity in the teenagers.

Staheli et al. (9) used the footprint technique to evaluate the shape of the plantar surface in 882 asymptomatic feet in normal people aged 1 to 80 years (Fig. 29-80A). He demonstrated that most infants are flatfooted, that the arch develops spontaneously during the first decade of life in most children, and that flatfeet are within the normal confidence limits for arch height in adults as well as children. Vanderwilde et al. (10) confirmed these findings with the first comprehensive study on normative radiographic measurements of the foot in children (Fig. 29-80B). Average values and 2 standard deviation ranges for several AP and lateral measurements were determined from radiographs of normal feet in children aged 6 months to 10 years. It was found that there is a large spectrum of normal values for children of different ages, that these normal values are different from adult normal values, and that these normal values change spontaneously with age into the adult norms.

More recently, Kanatli et al. (303) have confirmed an excellent correlation between footprint and radiographic analysis of flexible flatfeet in children, indicating that clinical exam alone is sufficient to follow the development of the longitudinal arch.

Etiology. There are two main theories explaining the etiology of flexible flatfoot. Duchenne (304) utilized faradic stimulation of the peroneus longus muscle to produce a longitudinal arch in a child's flatfoot. He felt that subclinical muscle weakness was responsible for the flexible flatfoot, a theory that has been supported by other authors. That theory was fairly decisively refuted by Basmajian and Stecko (36), who demonstrated little or no electromyographic activity in the muscles of the foot and ankle when physiologic loads were applied to the static plantigrade foot in his study subjects. He concluded that the bone–ligament complex determines the height of the longitudinal arch, whereas the muscles maintain balance, accommodate the foot to uneven terrain, protect the ligaments from unusual stresses, and propel the body forward. Mann and Inman (305) confirmed this theory. They also found that the intrinsic muscles are the principle stabilizers of the foot during propulsion, and that greater intrinsic muscle activity is required to stabilize the transverse tarsal and subtalar joints in a flatfooted individual than in one with an average height arch.

Harris and Beath (279) and others supported the theory that the shape and function of the foot is dependent on the design, configuration, and relative position of the tarsal bones. They were unable to determine whether the abnormal shape of the bones and joints was primary or secondary to the lax ligaments.

It is not known whether the short Achilles tendon associated with some flatfeet is a primary pathologic feature or a secondary deformity. Harris and Beath (8) believed that flexible

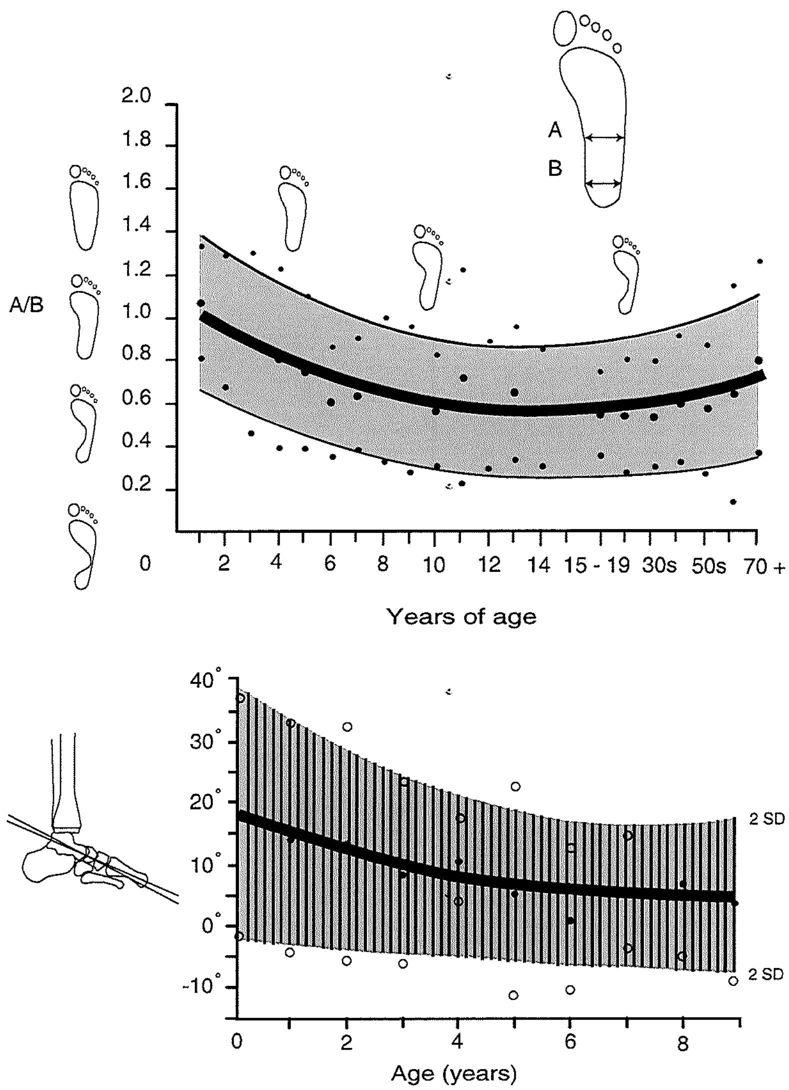

FIGURE 29-80. **A:** Footprints from individuals of all ages show that children are more flat-footed than adults, that there is a wide range of normal arch heights, and that the arch generally elevates spontaneously during the first decade of life. (From Staheli LT, Chew DE, Corbett M. The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. *J Bone Joint Surg Am* 1987;69:426–428, with permission.) **B:** Radiographs from children of all ages confirm the footprint data. The drawing and graph represent the lateral talus-first-metatarsal angle. (From Vanderwilde R, Staheli LT, Chew DE, et al. Measurements on radiographs of the foot in normal infants and children. *J Bone Joint Surg Am* 1988;70:407–415, with permission.)

flatfeet and flexible flatfeet with short Achilles tendons are separate entities, although documentation of early clinical differentiation has not been reported.

The effect of extrinsic factors on the shape and development of the longitudinal arch is suggested by studies from developing countries. Sim-Fook and Hodgson (191), in China, and Rao and Joseph (192), in India, found a higher prevalence of flatfeet among those children who wore shoes compared with those who did not. Echarri and Forriol (306), in applying Staheli's index of arch development, found boys to have a higher tendency for flatfoot than girls, and wearing of shoes to have no influence on the height of the longitudinal arch or morphology of the foot.

Clinical Features. The clinical assessment should consist of a general examination of the musculoskeletal system in addition to the specific foot and ankle exam. The general examination is aimed at assessing ligament laxity, torsional and angular variations of the lower extremities, and the walking pattern. Assessment of the foot and ankle begins with the recognition that a flatfoot is not a deformity. It is a combination of deformities that includes a valgus deformity of the hindfoot and a supination deformity of the forefoot. There is a lateral rotational deformity as well. The axis of the subtalar joint complex is in an oblique plane such that eversion creates valgus, external rotation, and dorsiflexion of the so-called AP around the talus. The mobility, or flexibility, of the subtalar joint in a flexible flatfoot is revealed by toe standing (Fig. 29-81) and by the Jack toe-raise test (307) (Fig. 29-82). These two maneuvers take advantage of the windlass action (53, 308) of the plantar fascia to mobilize the subtalar joint into inversion and create a longitudinal arch (Fig. 29-8). Supination deformity of the forefoot on the hindfoot is revealed when the hindfoot deformity is passively corrected by inversion. Functional motion of the ankle joint, as assessed by excursion of the Achilles tendon, is important yet difficult to evaluate accurately. A component of eversion of the subtalar joint is dorsiflexion of the calcaneus in relation to the talus. Therefore, the subtalar joint must be held inverted to neutral in order to isolate and assess motion of the talus at the ankle joint. The knee is then flexed, and the ankle is dorsiflexed. Dorsiflexion is measured as the angle between the lateral border of the foot and the anterior tibial shaft. Less than 10 degrees of

FIGURE 29-81. The arch elevates and the heel corrects from valgus **(A)** to varus **(B)** in a flexible flatfoot during toe standing, because of the windlass effect of the plantar fascia. (From Mosca VS. Flexible flatfoot and skewfoot. In: Drennan JC, ed. *The child's foot and ankle.* New York, NY: Raven Press, 1992:355, with permission.)

dorsiflexion indicates contracture of the soleus muscle, which equates to contracture of the entire Achilles tendon. The knee is then extended while trying to maintain maximum dorsiflexion of the ankle and without allowing the subtalar joint to evert. Dorsiflexion is again measured as the angle between the lateral border of the foot and the anterior tibial shaft. If more than 10 degrees of dorsiflexion was possible with the knee flexed, but <10 degrees of dorsiflexion is possible with the knee extended, the gastrocnemius alone is contracted. One should differentiate contracture of the gastrocnemius from contracture of the entire triceps surae (Achilles tendon), because both can cause pain that justifies surgical management, but the surgical technique obviously varies between them.

Finally, the weight-bearing pattern on the plantar aspect of the foot should be viewed, as callosities under the head of the talus are associated with symptoms, greater severity of flatfoot deformity, and Achilles or gastrocnemius tendon contractures. Sequential footprint measurements can be made in order to determine the natural history of the foot deformity.

A family history of flatfeet should be ascertained with particular attention paid to the existence of pain or other disability in affected individuals.

In summary, in evaluating a patient with flatfoot deformity, a complete physical examination must be done, testing muscle strength of all lower extremity muscles and ruling out spinal pathology by physical examination. Range of motion and alignment as well as muscle strength and sensation should be evaluated in the lower extremities. Tightness of the Achilles tendon and flexibility of the foot deformity must be determined.

Radiologic Findings. Radiographs of the flatfoot are not necessary for diagnosis, but may be indicated for the assessment of pain or decreased flexibility, and for surgical planning. Weight-bearing anteroposterior and lateral views are generally sufficient to evaluate the flexible flatfoot, whereas the addition of the oblique and axial, or Harris, views is necessary to evaluate the rigid flatfoot. Without weight bearing, or at least simulated weight bearing, the radiographic relationships between the bones will not represent the true clinical deformities. Radiographs can define the static relationships between bones, but cannot provide information on flexibility or function. They should not be used as an indication for treatment. This was the conclusion of the study on radiographs of the adult foot by Steel et al. (309) and the study on radiographs of the child's foot by Vanderwilde et al. (10).

The lateral radiograph of a flatfoot reveals plantar flexion of the calcaneus, measured by the calcaneal pitch (CP), and an even greater degree of plantar flexion of the talus, measured by the talohorizontal angle (Fig. 29-83). Dorsiflexion of the navicular on the head of the plantar-flexed talus creates a midfoot sag with lowering of the longitudinal arch that can be quantified using the talus–first metatarsal angle. Meary (51) determined that the normal talus–first metatarsal angle is zero

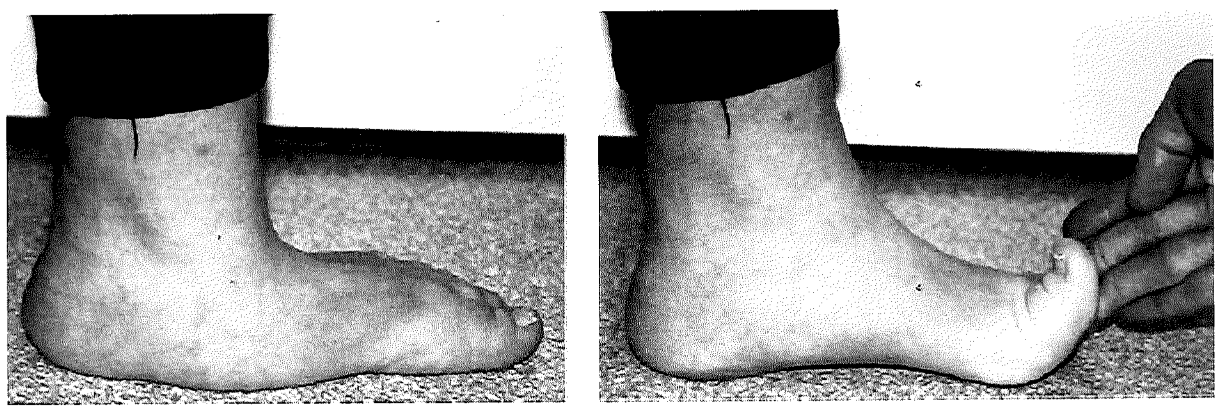

FIGURE 29-82. The arch elevates **(B)** in a flexible flatfoot **(A)** with the Jack toe-raise test because of the windlass effect of the plantar fascia. (From Mosca VS. Flexible flatfoot and skewfoot. In: Drennan JC, ed. *The child's foot and ankle.* New York, NY: Raven Press, 1992:355, with permission.)

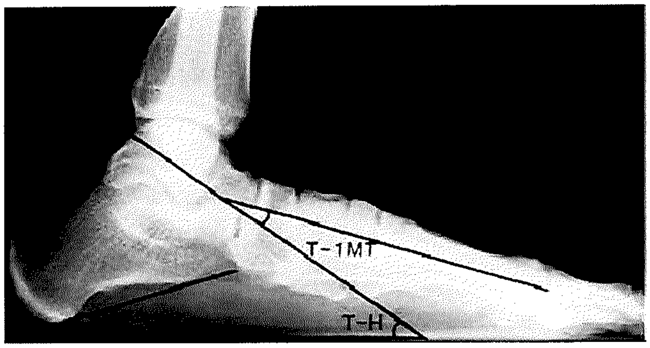

FIGURE 29-83. Weight-bearing lateral radiograph. The CP and the talus–horizontal angle (*T-H*) are the best measurements to assess valgus deformity of the hindfoot. The talus–first metatarsal angle (*T-1MT*) is known as the Meary angle. A plantar-flexed apex is seen in a valgus foot. (From Mosca VS. Calcaneal lengthening for valgus deformity of the hindfoot. Results in children who had severe, symptomatic flatfoot and skewfoot. *J Bone Joint Surg Am* 1995;77:500–512, with permission.)

degrees, or a straight line, but there is in fact a range of normal values. The site of intersection of the axis of the talus and that of the first metatarsal in a flatfoot is most often located in the head of the talus or at the talonavicular joint, which indicates the midfoot sag is at the talonavicular joint (Fig. 29-83). This CORA (52) can exist at other sites along the medial column of the foot. The location has important implications if surgery is undertaken.

The AP radiograph is less helpful in quantifying flatfoot deformity in a child. The subtalar complex in a flatfoot is excessively everted, a malalignment that combines external rotation and dorsiflexion of the calcaneus in relation to the talus with abduction and dorsiflexion of the navicular on the head of the talus. The axis of the calcaneus is frequently difficult to assess on the AP radiograph due to technical considerations. Therefore, assessment of the relationship at the talonavicular joint is critical. Unfortunately, the child's navicular ossifies eccentrically beginning laterally, making it unreliable for positional assessment. The AP talus–first metatarsal angle has been used as an alternative means for evaluating that relationship, but it is unreliable as well. In a pure flatfoot deformity, the CORA for the talus–first metatarsal angle should be in the head of the talus or at the talonavicular joint, which indicates eversion of the subtalar joint that is manifest as abduction at the talonavicular joint (Fig. 29-84). Adduction at the tarsometatarsal joint, as occurs in a skewfoot, will falsely minimize the apparent deformity at the talonavicular joint if assessed using the talus–first metatarsal angle (237).

Natural History. Flatfeet are ubiquitous in infants. Footprint (9) and radiographic (10) studies have confirmed that the average and normal range of arch heights is lower in the child than the adult. The height of the longitudinal arch generally increases spontaneously during the first decade of life in most children. And there is a wide range of normal arch heights at all ages (particularly in young children) (Fig. 29-80).

Lin et al. (310) showed that preschool children with flatfoot deformity tended to perform physical tasks poorly and walked more slowly than controls with "healthy" feet. They also found that flatfoot deformity was associated with valgus knees and generalized ligamentous laxity to some degree. This observation has not been confirmed in older children, adolescents, or adults. Harris and Beath (8, 279) found that the flexible flatfoot in their Canadian soldiers was the normal contour of a strong

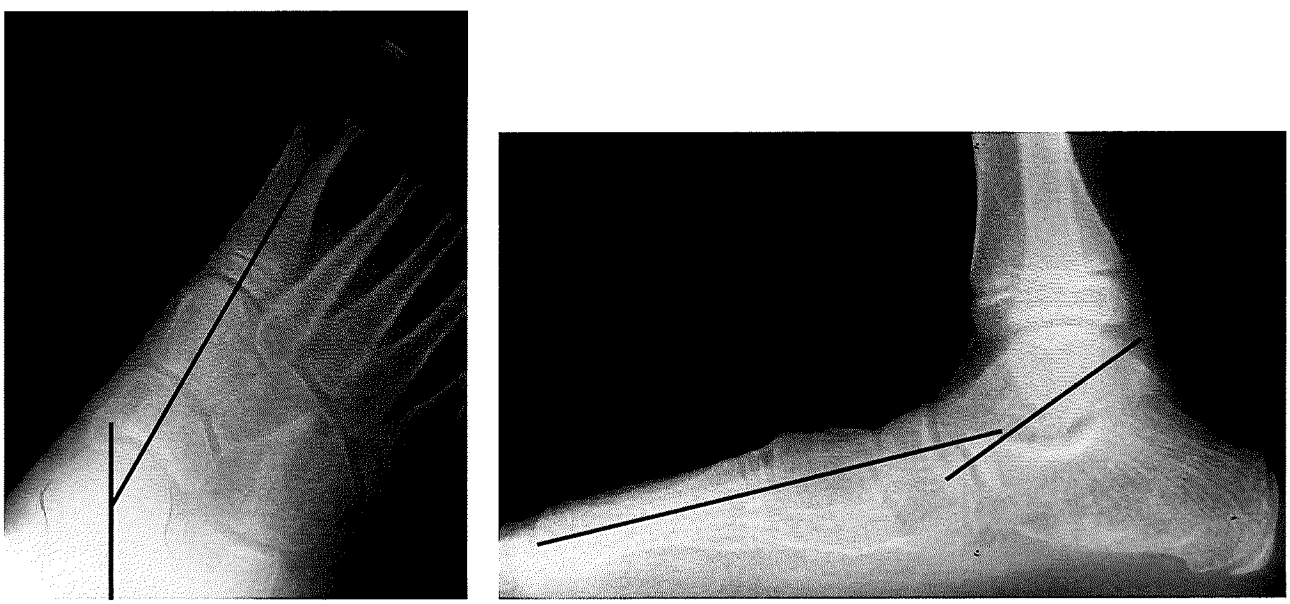

FIGURE 29-84. Anteroposterior **(A)** and lateral **(B)** radiographs of a flatfoot demonstrating abduction and dorsiflexion of the navicular on the head of the talus. (From Mosca VS. Flexible flatfoot and skewfoot. In: McCarthy J, Drennan JC, eds. *The child's foot and ankle.* 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 2009;144, with permission.)

and stable foot and was not the cause of pain or disability. Giladi et al. (534) found that military recruits with flatfeet had significantly less risk of stress fractures than those with average or high arches. And Cowan et al. (311) reported a study of prospective Army recruits in which they found that low-arched individuals had no increase in the risk of injury. Conversely, Kaufman et al. (312) reported an increased risk of overuse injuries in patients with dynamic pes planus, particularly those with restricted ankle dorsiflexion. This finding confirms Harris and Beath's (279) observations regarding flexible flatfeet with short Achilles tendons. Based on the evidence in the literature, longer term follow-up assessment of Lin et al.'s study patients is needed before conclusions can be drawn from their data.

Pathoanatomy. The functions of the foot include provision of a stable, but supple, platform that adapts to the ground during the early stance phase of gait, followed by conversion to a rigid lever during push-off (313–317). Several authors have represented the complex interrelationships between the bones of the mid- and hindfoot as a mitered hinge (313, 314, 316–318), though that analogy is too simplistic. Using that as a first approximation or basic foundation, one must add a thorough understanding of the shape, structure, relationships, and motions of the subtalar joint complex to truly understand the biomechanics of the foot.

The subtalar joint complex is comprised of three bones (possibly four, if one includes the cuboid), several important ligaments, and multiple joint capsules that function together as a unit. Almost 200 years ago, Scarpa (14) saw similarities between the subtalar joint complex and the hip joint. He compared the femoral head to the talar head, and the pelvic acetabulum to his so-called acetabulum pedis (AP). The latter is a cup-like structure made up of the navicular, the spring ligament, and the anterior end of the calcaneus and its facets. Although it is not a perfect comparison, I believe that the two anatomic areas share certain features that make the comparison both valid and worthwhile.

The subtalar joint has an axis of motion that is in an oblique plane that is not frontal, sagittal, or coronal, thus creating motions that are best described with the unique terms inversion and eversion. Inversion is comprised of plantar flexion, supination, and internal rotation of the AP around the head of the talus (15). Eversion is a combination of dorsiflexion, pronation, and external rotation of the AP around the talar head. The static position of inversion of the subtalar joint is called hindfoot varus and is found in cavovarus feet and clubfeet. Hindfoot valgus is the static position of the everted subtalar joint and is seen in flatfeet and skewfeet.

The tibia and talus internally rotate during the first half of the stance phase of the gait cycle while the subtalar joint complex everts. The talar head plantar-flexes because of the lost support from the AP. The foot becomes quite supple, or unlocked, and flattens. During the latter part of the stance phase, the tibia and talus externally rotate while the subtalar joint complex inverts and the AP once again supports the head of the talus. The talus dorsiflexes, and the entire foot becomes more rigid, or locked. This diminishes stress on the muscles and ligaments during push-off.

The flexible flatfoot begins stance in an unlocked, everted position, and does not completely invert to a rigid lever during the latter portion of stance. Theoretically, this should lead to muscle fatigue and pain; however, this seems to occur only in some flatfooted individuals (319).

Treatment. There are no long-term, prospective clinical studies on the natural history of flexible flatfoot. The information that has been presented is cross-sectional and inferential. Much of our understanding of the benign nature of flexible flatfoot has only recently been elucidated. Most authorities now agree that the flexible flatfoot is an anatomic variant and not a potentially disabling deformity (8, 308, 309). Nevertheless, controversy abounds.

Earlier, uncontrolled studies indicated an efficacy of orthoses and shoe modifications in the development of the arch in the child's foot (320). More recent prospective, randomized, and controlled studies revealed no benefit from shoe modifications and inserts over spontaneous development of the longitudinal arch (277, 321, 322). In a study by Garcia-Rodriguez et al. (323), the prevalence of flexible flatfoot was evaluated in children between the ages of 4 and 13 years. They found no positive treatment effect for those who were undergoing orthopaedic treatment versus those who were not. An interesting finding of their study was that overweight children were found to be at greater risk of flatfoot deformity. Caution against the rate and expense of overtreatment of a physiologic, self-limiting deformity was raised. Driano et al. (324) reported long-term negative psychological effects on adults who had worn shoe modifications as children compared with controls. Therefore, one must conclude that the management for the asymptomatic flexible flatfoot is education of the child and family.

Some children with flexible flatfoot have activity-related pain in the leg or foot. The pain is usually diffuse and nonlocalized, and it is believed to represent an overuse, or fatigue, syndrome. This is consistent with the findings of Mann and Inman (305) that flatfooted individuals demonstrate greater intrinsic muscle activity than normal. Over-the-counter and custom-molded shoe inserts have been shown to relieve or diminish symptoms and to increase the useful life of shoes without a simultaneous permanent increase in the height of the arch (325). Although arch supports do seem to provide relief in a number of cases, Miller et al. (326) were unable to show any change in ground reaction forces relating to the use of orthotic devices. Whether or not the ground reaction forces can be altered by an orthotic device, it appears that symptoms can be significantly decreased.

Some children with flexible flatfoot have pain with weight bearing and callosities under the head of the plantar-flexed talus. The Achilles tendon or the gastrocnemius tendon alone is almost routinely contracted in these children. The contracted tendon prevents normal dorsiflexion of the ankle joint during the midstance phase of gait and shifts the dorsiflexion stress to the subtalar joint complex. The talus remains rigidly