plantar-flexed. The soft tissues under the head of the talus are subjected to excessive direct axial loading and shear stress. Firm or hard arch supports exaggerate these pressures. An aggressive stretching program for the Achilles tendon, performed with the subtalar joint inverted, may relieve the symptoms in this clinical situation. Failure to relieve this localized pain with prolonged attempts at conservative management is an indication for operative reconstruction of the foot (237).

An operation is rarely, if ever, indicated for flexible flatfoot. Nevertheless, an extensive list of surgical procedures to correct flatfoot has been proposed during the last century. The indications for these procedures, whether for correction of deformity, relief of symptoms, or prophylaxis, are difficult to ascertain from review of the articles. The procedures can be categorized as soft-tissue plications, tendon lengthenings and transfers, osseous excisions, osteotomies, arthrodesis of one or more joints, and interposition of bone or man-made materials into the sinus tarsi. Any procedure should be judged by its ability to achieve and maintain correction of even severe deformity while maintaining mobility of the subtalar joint, and by its ability to achieve and maintain relief of pain. There have been very few long-term outcome studies on any of these procedures. Nevertheless, those that have been reported have helped to narrow the surgical choices. Mosca (327) recently reviewed the literature and can be referenced for more detail on these procedures.

Procedures that rely entirely on soft-tissue plications and tendon transfers fail in the short term. Osseous excisions were abandoned years ago because of their obvious destructive nature. Arthrodesis of one or more of the joints in the subtalar complex has been abandoned because of the detrimental effect of eliminating the shock-absorbing function of that important joint complex. Subtalar and triple arthrodesis shift stress to the ankle and midtarsal joints leading to premature degenerative arthrosis at those sites (19–27).

The most popular procedures used during the last 60 to 70 years are the many modifications of Hoke's limited midtarsal arthrodesis (16–18, 307, 328–330). These procedures combine arthrodesis of one or more midtarsal joints with soft-tissue plication across the talonavicular joint. Favorable short-term results have been consistently reported, but unsatisfactory long-term results were reported in 49% to 70% of cases (16–18). The unsatisfactory feet in these series frequently showed degenerative changes at the talonavicular joints in addition to persistence or recurrence of pain and deformity. Furthermore, the originators of these procedures acknowledged that these procedures were not capable of correcting severe valgus deformities. They recommended triple arthrodesis for those feet. Though not known at the time of those recommendations, we now know the long-term results of triple arthrodesis to be the significant risk of developing degenerative arthritis and pain at adjacent joints (19–27). Therefore, present surgical recommendations focus on preservation of subtalar motion. Pseudoarthrodesis, or so-called arthroereisis, procedures were introduced between 1946 and 1977 as variations on a method to restrict excessive subtalar joint eversion by placing a bone block in the sinus tarsi (331–334). The bone grafts occasionally underwent resorption with recurrence of the deformity or remained and resulted in restriction of subtalar motion (essentially a pseudoarthrodesis) with its associated problems. Arthroereisis by means of synthetic implants was started in the late 1970s because of the reported problems and complications associated with the bony arthroereisis procedures. No less than 10 types of synthetic implants and methods for insertion have been reported, most with follow-up of <2 years (335–349). Reported problems and complications have led to an ongoing search for a better implant and a better method for implanting it. The variety and succession of past implant materials and designs have prevented a validation study from being performed to determine the overall effectiveness of the procedure or even to validate the concept of the procedure (346).

There is no clear consensus among proponents on the indications for arthroereisis. Nevertheless, many are performed, and the reported complication rate with the use of synthetic implants is 3.5% to 30%, with the most recent studies reporting rates of 3.5% to 11% (337–341, 343–349). The complications include those associated with inappropriate implantation (obviously not counted, but certainly a major issue, especially if one considers the often-reported indication of performing the operation in an asymptomatic physiologic FFF in a young child), surgeon error (malpositioning, overcorrection, undercorrection, extrusion of implant, wrong size of implant), biomaterials problems (breakage, degradation), and biologic problems (foreign body reaction, synovitis, infection, persistent and recurrent pain, implant-induced sinus tarsi impingement pain, intraosseous ganglion cyst within the talus, osteonecrosis of the talus, peroneal spasm, calcaneus fracture) (337–341, 343–349). Black et al. (337) and Verheyden et al. (338) both recommended abandonment of this procedure because of the high rate of negative outcomes.

The Maxwell Brancheau arthroereisis (MBA) implant, a large cylinder-shaped titanium screw (343, 344), and the Giannini Flatfoot Expanding Implant, a Teflon/stainless steel expansion drywall anchor design (339, 340), are perhaps the most commonly used implants at the present time, based on the number of articles in the literature. According to published descriptions, both are inserted into the sinus tarsi anterior to the posterior facet along the trajectory of the tarsal canal between the posterior and middle facets. The originators of these implants (339, 340, 343, 344), as well as other authors (341, 345–349) and even the product technique manuals, are evasive regarding the depth to which the implants enter the tarsal canal, though they certainly appear to enter it. Nevertheless, proponents consider them to be extra-articular, if inserted properly, because they do not technically touch articular cartilage, though they clearly encroach upon it. The arthroereisis implants have been shown to mechanically block eversion and also decrease total subtalar joint motion (342, 349), indicating that their effect is in fact intra-articular.

In published studies on subtalar and triple arthrodeses, stress transfer to adjacent joints with the development of degenerative arthrosis was not seen for at least 10 years, which is longer than the follow-up in any of the reports on arthroereisis. Additionally, these implants, not surprisingly, lead to resorption of the adjacent cortical surfaces of the talus and calcaneus (Fig. 29-85), the long-term effects of which are unknown.

Both the MBA and Giannini arthroereisis implants are now offered as bioabsorbable implants made of poly-L lactic acid (PLLA), but the original metal designs seem to be used most often, and the bioabsorbable implants have even shorter follow-up than the original designs. Saxena and Nguyen (348) found MRI evidence of residual bioabsorbable implant at >4 years after implantation. These authors stated that there were no cystic changes noted in the bones, but acknowledged that granuloma formation from PLLA can appear in a delayed fashion. Additionally, their MRI study of the subtalar joint in adults with these implants found that the tarsal canal is smaller in height and length than the implant sizes generally used. They felt that this was a particular problem for the metal implants and less so for the bioabsorbable ones, unless one considers that children and adolescents have an even smaller canal than the ones they studied. Finally, they questioned the benefit of the bioabsorbable implants since half of their patients required or were recommended to have explantation.

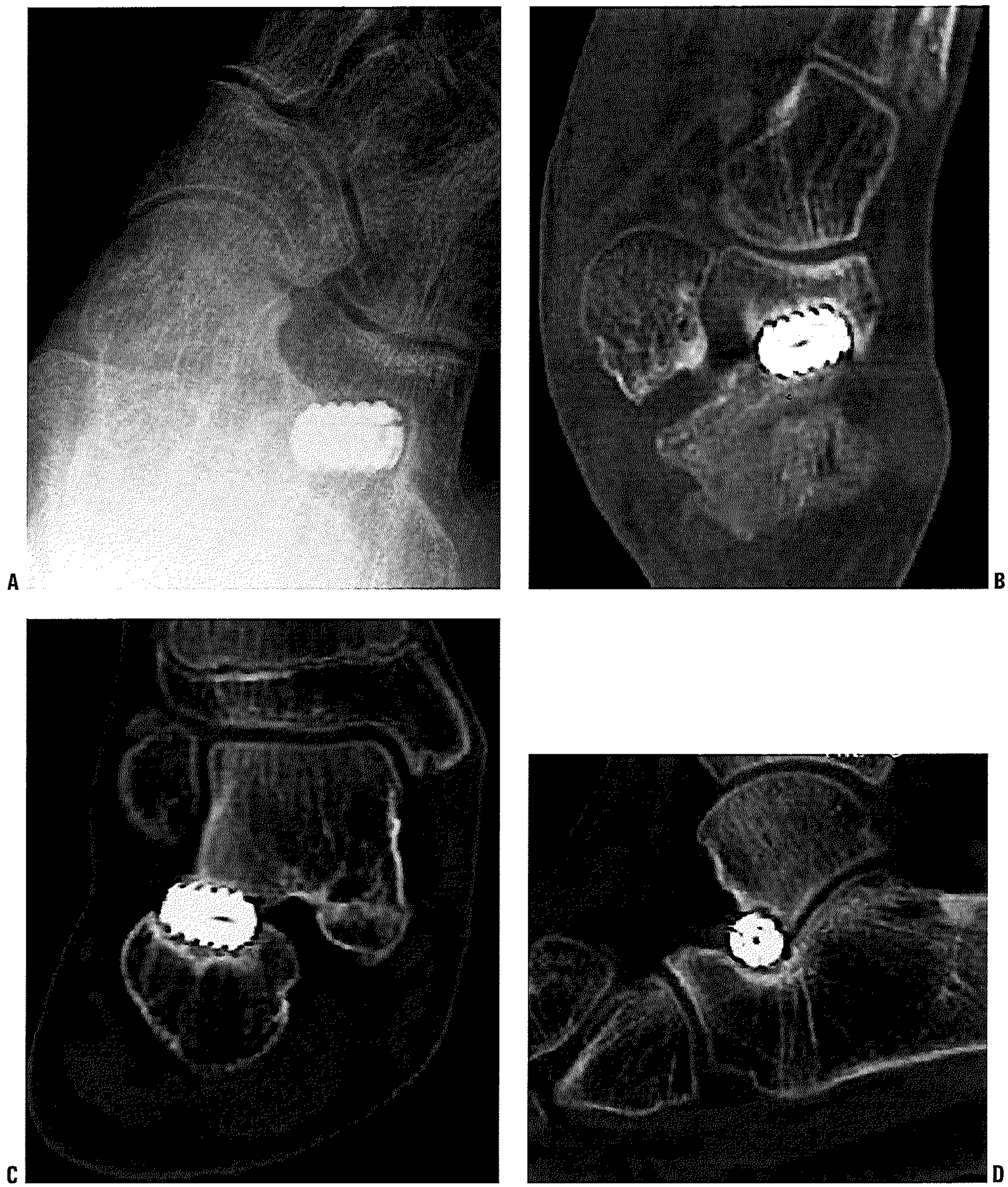

FIGURE 29-85. X-ray and CT scan images showing bone resorption around an MBA implant. **A:** AP x-ray. **B:** Transverse plane CT scan image. **C:** Coronal plane CT scan image. **D:** Sagittal plane CT scan image. (From Mosca VS. Flexible flatfoot and skewfoot. In: McCarthy J and Drennan JC, eds. *The Child's Foot and Ankle.* 2nd ed. Lippincott Williams & Wilkins, 2009:147, with permission.)

The bottom line seems to be that more information and, in particular, long-term studies are needed before arthroereisis can be recommended for children with painful flatfeet. And even more important is the need for the proponents of arthroereisis to clarify surgical indications based on the best scientific evidence available.

Osteotomy is the last category of procedures that has been used to treat flatfeet. This is a biologic approach that does not depend on soft tissues, that are known to stretch out, and it avoids arthrodeses/arthroereisis and the known complications of those procedures.

Numerous osteotomies of the calcaneus to correct heel valgus have been described. The most popular original osteotomy was that described by Dwyer (80). However, wound problems resulting from the opening wedge and collapse of the graft have limited the use of this procedure. These potential problems are solved and the same goals are achieved by a medial displacement osteotomy of the posterior calcaneus (Figs. 29-86 to 29-90). The operation was first described by Koutsogiannis (235) but attributed to Pridie.

The posterior calcaneus displacement osteotomy does not actually correct the malalignment of the subtalar joint, but merely creates a compensating deformity to improve the valgus angulation of the heel. Recalling Scarpa's analogy to the hip (14), I believe the posterior calcaneal displacement osteotomy is the Chiari osteotomy of the AP. Koutsogiannis reported successful "correction" of valgus deformity in 30 of 34 feet, but arch restoration rarely occurred. Other authors confirmed these same results in FFF (350) as well as in paralytic flat feet (351). The posterior calcaneus osteotomy does not correct the multiple components of subtalar joint eversion, such as external rotation and dorsiflexion of the AP. Rathjen and Mubarak (352) reported good correction of flatfoot deformities by combining a modification of this osteotomy (medially based closing wedge with medial displacement) with a closing-wedge osteotomy of the medial cuneiform, an opening-wedge osteotomy of the cuboid, and medial reefing of the talonavicular joint.

The other osteotomy for correction of valgus deformity of the hindfoot is the calcaneal lengthening osteotomy, conceptualized by Evans (236) and elaborated by Mosca (237, 238) (Figs. 29-91 to 29-98). Evans believed that the lateral column of the flatfoot was shorter than the medial column, a situation exactly opposite to that found in a cavovarus foot. For painful flatfeet, he equalized the length of the columns by inserting a corticocancellous graft into an osteotomy of the anterior calcaneus that was made 1.5 cm proximal to, and parallel with, the calcaneocuboid joint. That was the entire extent of his description. By lengthening the calcaneus in this way, he showed that the heel valgus, talonavicular sag, and lateral subluxation of the navicular on the head of the talus could all be simultaneously corrected. Armstrong and Carruthers (353) recommended the technique and highlighted its advantages to be correction of hindfoot valgus without need for arthrodesis, preservation of some subtalar motion, versatility for pronated and abducted feet of different etiologies, and simplicity of execution. Phillips (354) reported a 7 to 20 year (average 13 years) follow-up of Evans' patients. Seventeen of the twenty-three feet had good to very good results when assessed by strict criteria. Anderson and Fowler (355) also reported very good results with this procedure in 9 feet followed for an average of 6½ years. They reaffirmed the correction of all components of the hindfoot deformity by this simple technique and advised performing the procedure between ages 6 and 10 years in appropriate individuals to allow remodeling of the tarsal joints, a consideration not mentioned by Evans.

In 1995, Mosca (237) reported the short-term results of calcaneal lengthening for valgus deformity of the hindfoot from various underlying etiologies in 31 feet in 20 children. He reported correction, at the site of deformity, of all components of even severe eversion of the subtalar joint complex, including dorsiflexion, pronation, and external rotation of the AP around the talar head. Function of the subtalar joint was restored, symptoms were relieved, and, at least theoretically, the ankle and midtarsal joints were protected from early degenerative arthrosis by avoiding arthrodesis. He stressed the need for strict indications for surgery, specifically a flexible or rigid flatfoot with Achilles or gastrocnemius contracture and intractable pain in the medial midfoot and/or sinus tarsi despite prolonged attempts at conservative management.

As noted above, Evans provided very little information on the technique, which made interpretation difficult and surgical success inconsistent by those who read his article. Mosca thoughtfully considered Evans' concept and applied an understanding of foot biomechanics and the principles of foot deformity-correction surgery to develop a reliable method for achieving consistently good surgical outcomes. His published contributions (15, 237, 238, 356) include the location of the skin incision (modified Ollier), the specific location and direction of the osteotomy (exiting medially between the anterior and middle facets), the shape of the bone graft (trapezoidal), management of the soft-tissue constraints along the plantar-lateral border of the foot (lengthened) and the soft-tissue redundancy along the plantar-medial border (plicated), stabilization of the calcaneocuboid joint to prevent subluxation (using a Steinmann pin), the need to recognize and concurrently manage rigid forefoot supination deformity if present (plantar-based closing-wedge osteotomy of the medial cuneiform), and the importance of lengthening the Achilles or gastrocnemius tendon if contracted (which is usually the case in the symptomatic FFF).

It must be stressed that the calcaneal lengthening osteotomy does not correct flatfoot deformity. It corrects valgus/eversion deformity of the hindfoot. In all flatfeet, the forefoot is supinated. In young children and adolescents, the forefoot supination deformity will often spontaneously pronate to neutral after the hindfoot deformity is corrected with the calcaneal lengthening osteotomy. In most older adolescents, the forefoot supination deformity does not correct and must be identified and operatively corrected under the same anesthetic. A plantar-based closing-wedge osteotomy of the medial cuneiform, that is internally fixed with a wire staple, is an effective procedure to correct this deformity. And

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Posterior Osteotomy of Calcaneus for Valgus (Figs. 29-86 to 29-90)

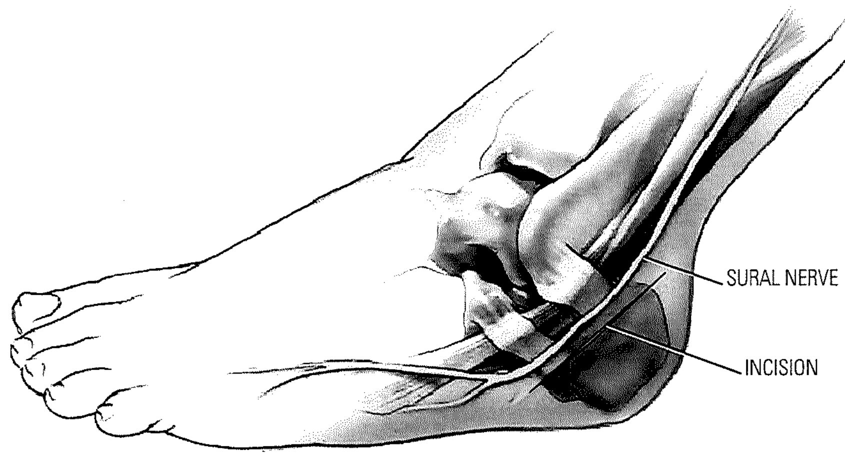

FIGURE 29-86. Posterior Osteotomy of Calcaneus for Valgus. An oblique incision is made over the lateral side of the calcaneus for a posterior calcaneus medial displacement osteotomy. The incision is posteroinferior to the peroneal tendons. It should be long enough to allow exposure of the inferior and dorsal surfaces of the tuber of the calcaneus, which actually means that it does not have to be very long. It is important to avoid damage to the sural nerve, which runs slightly inferior to the peroneal tendons.

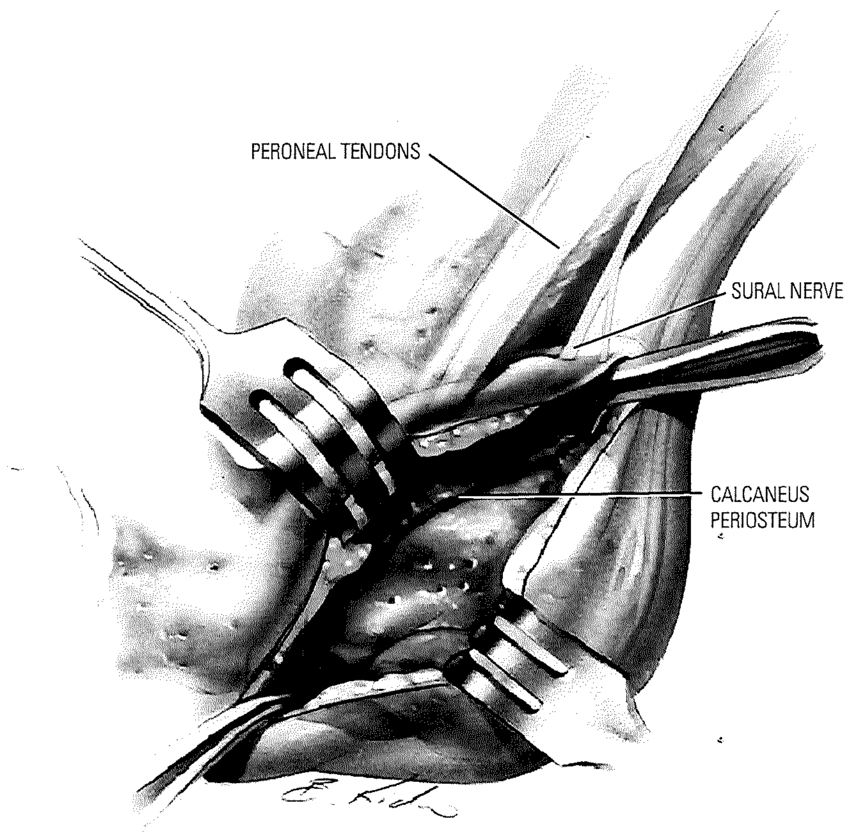

FIGURE 29-87. The incision should reach the periosteum of the calcaneus with a minimum of undermining. A narrow curved retractor (e.g., a Joker or a Crego) is slid extraperiosteally over the dorsal surface of the calcaneus, anterior to the Achilles tendon and adjacent to the capsule of the posterior facet of the subtalar joint. It continues extraperiosteally on the medial side of the calcaneus deep to the posterior tibial neurovascular bundle. A similar retractor is slid extraperiosteally under the calcaneus at a position slightly more anterior than the dorsally placed retractor. It, likewise, remains deep to the neurovascular bundle. Curved Crego elevators are useful here for the purposes of dissection, retraction, and soft-tissue protection. A straight incision is made in the periosteum dorsally, laterally, and plantarward. It is elevated for about 5 mm on each side of the incision. The capsule of the posterior facet of the subtalar joint should be seen but not disturbed. This ensures that the osteotomy is anterior enough to prevent the creation of too small a posterior calcaneal fragment.