TRIPLE ARTHRODESIS

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Introduction

Triple Arthrodesis has been widely used since originally introduced by Ryerson in 1923. It has been variously designated as a stabilizing procedure by some while viewed as a salvage procedure by others. Some have acclaimed the procedure as one of great merit while others insist that the procedure is fraught with too many concomitant complications. How does one rationalize the divergent views?

Several facts should be recognized with regard to triple arthrodesis. First, the procedure does eliminate motion at the subtalar and midtarsal joints. Hence, pronation and supination of the foot are effectively eliminated in both the forefoot and rearfoot once solid arthrodesis is achieved. This being the case it is imperative to recognize that the arthrodesis must be done with the rearfoot and the forefoot in slight valgus. A rigid valgus foot can be readily accommodated to a comfortable functional foot. On the other hand, a foot that is fused with either a varus rearfoot or forefoot can rarely be made comfortable. The authors have seen dozens of painful feet following triple arthrodesis purely because the surgeon placed the foot in a varus position. Lack of understanding of this simple fact has caused many to become disenchanted with the procedure.

Triple arthrodesis should be performed with full knowledge that dorsiflexion and plantarflexion will henceforth take place only at the ankle joint. In many severely pronated feet a great deal of dorsiflexion occurs at the midtarsal joint. Once arthrodesis is accomplished dorsiflexion will only be possible at the ankle joint. It is therefore wise to assess the adequacy of ankle joint motion before performing the procedure. If inadequate dorsiflexion is available one can expect jamming of the anterior ankle joint and the development of chronic synovitis and degenerative joint changes. Additionally, any limitation in ankle motion results in severe repetitive strain at the lesser tarsal and tarsometatarsal joints. Failure to consider the adequacy of ankle motion has resulted in many surgeons becoming disenchanted with the procedure.

Delayed union or nonunion of the arthrodesis site has been responsible for a great deal of disillusionment. The healing of a triple arthrodesis is much like that of any fracture or arthrodesis elsewhere. Good healing requires good surgical execution of resections, accurate fitting of the margins of the arthrodesis, stable internal fixation, appropriate external support by casting for an adequate time, prevention of all weightbearing until solidly healed and good patient compliance. The authors are often consulted to revise a triple arthrodesis in which healing has not occurred or has occurred in an undesirable position. Review of the immediate post operative x-rays usually demonstrates evidence of poorly fitted margins of the attempted arthrodesis or poor fixation or both. Occasionally the patient will volunteer that they were permitted weightbearing during healing. Any one or a combination of these factors can virtually guarantee poor results of attempted triple arthrodesis.

The complex effects of joint resections in triple arthrodesis have discouraged many surgeons. For example, when one resects the subtalar joint if more bone is resected posteriorly than anteriorly it will have the effect of relaxing or relative lengthening of the achilles tendon. But at the same time, such resection will necessitate more excursion of anterior trochlear surface into the ankle joint with each step. In the event that there is no reserve anterior trochlear surface available an osseous equinus results. Failure to understand this relationship can result in disillusionment of both the patient and the surgeon.

In positioning the talus on the calcaneus after resection of the joint surfaces, moving the talus anteriorly on the calcaneus will tend to plantarflex the forefoot whereas moving the talus posteriorly on the calcaneus will tend to dorsiflex the forefoot. Here again, if one creates plantarflexion of the forefoot on the rearfoot it is necessary to recognize that additional ankle dorsiflexion will be required. If the motion is available there will be no difficulty encountered. If not a painful ankle equinus as well as severe lesser tarsal strain may result.

Failure to adequately derotate the forefoot in relation to the rearfoot causes many unnecessary complaints. As indicated earlier a varus forefoot or rearfoot can create a painful foot. A forefoot which remains in mild varus following triple arthrodesis will result in painful concentration of weight on the base and head of the fifth metatarsal. This is generally impossible to adequately relieve with biomechanical devices.

Arthrodesis in an adducted or abducted position becomes a permanent characteristic. The surgeon should be alert to the position of the limb in regard to the line of progression before surgery is performed. He should not be mislead into lining the foot up in perfect position with the knee in a patient who may have considerable femoral anteversion. Such can result in a permanently adducted foot with no mechanism to compensate.

In addition to the above potential complications, and others, the authors have frequently heard speakers refer to difficulty with the knee, the hip, or the back following triple arthrodesis. In our experience patients requiring triple arthrodesis generally have multiple structural weaknesses and would develop the same or often far greater symptoms with adjacent joints were the triple arthrodesis not performed. An excellent example is seen in the patient with a collapsing pes valgus deformity. If no arthrodesis is performed one can expect severe degenerative changes in the knee joint as a result of the increased bending and torsional stresses. If triple arthrodesis is performed at the appropriate time the subsequent knee changes may be mild to non existent.

While the complexity of performing an accurate well fixated triple arthrodesis continues to be a challenge the appropriate use of the procedure today offers very predictable results.

Indications

Triple arthrodesis is usually performed to correct deformity, to increase stability, or to improve function. Some of the indications which follow will necessarily overlap because of the nature of the conditions for which the procedure is used.

Valgus Foot Deformity

Valgus foot deformities may be associated with a number of different etiologies. But if the deformity is severe enough the foot may begin to break down medially at the subtalar and midtarsal joints. Such feet cause extreme fatigue to the patient and often force the patient to accept a highly limited lifestyle. Additionally such feet may cause deterioration of the knees and lumbar spine. A variety of foot conditions are included among the valgus foot deformities.

Collapsing Pes Valgus Deformity

The collapsing pes valgus deformity typically represents an advanced stage of the flexible pes valgo planus foot which has been progressive from birth. Often an untreated congenital calcaneovalgus deformity will progressively worsen throughout development until eventual degenerative changes produce a collapsed rearfoot with subtalar pronation and extreme abduction of the forefoot at the midtarsal joint. The first ray is often likewise unstable.

This foot type is quite amenable to stabilization by triple arthrodesis. Important considerations prior to surgery include determination of available ankle range of motion and ankle stability as well as any tilt of the ankle joint.

Ruptured Tibialis Posterior Tendon

Rupture of the tibialis posterior tendon in a severely pronated foot results in collapse of any remaining arch along with severe abduction of the forefoot at the midtarsal joint. While the condition is often designated as spontaneous pes valgus deformity it is in fact anything but spontaneous. Rupture of the tibialis posterior tendon occurs as a result of chronic long term synovitis of the tibialis posterior which is caused by excessive loading in an already pronated foot. Often the pronation is present as a compensation for equinus. Tenosynovitis weakens the tendon and eventually results in rupture.

It should be pointed out that in this type deformity the first ray is hypermobile, often with a forefoot varus or supinatus and occasionally presenting a complete breach at the naviculocuneiform or cuneometatarsal joint.

While this type foot lends itself to correction by triple arthrodesis it should be pointed out that the forefoot must be derotated and tilted into sufficient declination to bring the medial side of the foot into stable weightbearing. If such derotation is not adequate then stabilization arthrodesis and plantarflexion of the first ray may be necessary as a part of the same surgery. To neglect this latter maneuver may result in the forefoot functioning as though it had been left in a fixed varus position, a painful and difficult condition at best.

Tarsal Coalition

Tarsal coalitions may result in a foot with either a fixed varus or valgus condition. Most often the patient with a painful coalition presents with peroneal spastic pes valgus deformity. The foot is severely pronated, the sub talar joint is everted, the midtarsal joint is severely abducted and the head of the talus protrudes medially and plantarly. There is typically a decrease of absence of motion in the involved joint even when peroneal spasm is relieved. Where calcaneonavicular coalitions are discovered in the young patient with minimal boney adaptations resection of the coalition may be quite adequate. In calcaneonavicular coalitions with considerable boney adaptation and in most chronically painful talocalcaneal coalitions triple arthrodesis offers a far more plausible surgical correction.

Tarsal coalition is another condition in which one should be particularly alert to the reduction of the medial column of the foot to a stable weight bearing position. The forefoot must not be allowed to retain a forefoot varus or supinatus. To do so can result in a foot which bears weight only along the lateral column of the forefoot.

Tarsal Arthritis

Tarsal arthritis may result from rheumatoid arthritis or from degenerative changes associated from severe pronation, especially when compensating for equinus. Trauma to the tarsal area, especially compression fractures of the calcaneus, produce a high incidence of painful tarsal arthritis.

While tarsal arthritis is not limited to the pronated foot it is by far more common in the severe valgus foot deformity.

Triple arthrodesis offers permanent relief of pain while correcting the deformity and restoring stability to the foot. The presence of equinus must not be ignored in correcting the foot deformity.

Varus Foot Deformity

Varus foot deformities tend to be associated with the high arched and more rigid foot type. The etiologies are varied and may in a few instances be repetitious of those found with the valgus foot.

Cavus Foot

Severe cavus foot may be associated with neuromuscular disease or may be idiopathic. Often the foot functions in fixed varus and is incapable of pronation to the perpendicular. The foot may be prone to recurring ankle sprains as well as knee and lumbar spine symptoms. As the foot becomes progressively deformed in the direction of rearfoot varus one sees increasing clawtoe deformities.

Triple arthrodesis offers a mechanism to lower the arch, evert the rearfoot at the subtalar joint, and abduct the forefoot at the midtarsal joint. Additionally the forefoot can be derotated in relation to the rearfoot.

Cavoadducto Varus

Cavoadducto varus deformity may be idiopathic though it is often found associated with neurologic diseases in which muscle imbalance is etiologic.

As in the cavus foot triple arthrodesis offers an approach through which we are able to correct the principle deformity, stabilize the foot, and offer increased function and mobility to the patient.

Talipes Equino Varus

Recalcitrant talipes equino varus is best treated by triple arthrodesis combined with appropriate soft tissue releases. It should, however, be stressed that resection of boney wedges from the subtalar and midtarsal joints often does not release the foot. Soft tissue releases and tendon transfers must of necessity be combined with triple arthrodesis. This is not a good foot on which to perform ones first such operation.

Lateral Ankle Instability

Lateral ankle instability associated with fixed varus of the rearfoot and adductus of the forefoot is especially susceptible to correction by triple arthrodesis. It is necessary that the rearfoot be reoriented into a valgus attitude and that the forefoot be mildly abducted. Additionally, the talofibular ligament should be repaired if ruptured.

Ankle Equinus

Osseous equinus of the ankle is often susceptible to correction by triple arthrodesis. To effect such correction necessitates resection of more bone from the anterior aspect of the under side of the talus than from the posterior facet. This results in dropping the anterior end of the talus which effectively places the tibia in articulation with the more posterior part of the trochlear surface of the talus. Such change results in an increase in anterior trochlear surface reserve.

Neuromuscular Disease

Neuromuscular diseases and disorders of the spinal cord and brain can produce any and all of the deformities heretofore enumerated as treated by triple arthrodesis. Cerebral Palsy often produces spastic pes valgus deformity. Spina bifida is often responsible for cavo adducto varus deformity. Charcot Marie Tooth disease causes cavo adducto varus deformity. And poliomyelitis causes varying rearfoot deformities depending on the muscles affected.

As detailed in earlier paragraphs triple arthrodesis allows for correction of deformity of the rearfoot while restoring reasonable stability. In many of these latter conditions muscle tendon transfers are combined with triple arthrodesis to restore function and supplement stability.

ANATOMIC DISSECTION IN TRIPLE ARTHRODESIS

Application of the techniques of anatomic dissection to triple arthrodesis has significantly expanded and enhanced the execution of this classic surgical procedure. Anatomic dissection is a fundamental surgical skill or technique based upon the use of natural tissue plane separation and the relationship of individual anatómic structures. The technique has been thoroughly illustrated in its application to the first metatarsophalangeal joint in both film and text (*Anatomic Dissection in Hallux Abducto Valgus Surgery*, available from Doctors Hospital Podiatry Institute).

The fundamental components of anatomic dissection involve:

1. skin incision
2. dissection through the superficial fascia (subcutaneous layer)
3. identification of the deep fascia
4. separation of the superficial fascia from the deep fascia
5. execution of the deep fascial incision and manipulation of deeper structures based upon specific procedure or technique
6. closure

General and specific goals can be outlined when the basic skills of anatomic dissection are applied to the procedure of triple arthrodesis. The application of these skills will enable the surgeon to more effectively and efficiently execute the surgical procedure.

Purpose

The general goals of anatomic dissection in triple arthrodesis include:

1. Exposure
2. Hemostasis
3. Atraumatic technique.

While these few goals may appear to be rather simple in form, they are both complex and far reaching when expanded to their fullest potential.

Exposure

The primary purpose of surgical exposure in any surgical procedure is to provide for unrestricted visualization and manipulation of critical structures and tissues. Historically triple arthrodesis has been performed through a single lateral Ollier incision. This relatively transverse incision ran from the tip of the fibular malleolus across the sinus tarsi to the dorsal region of the talonavicular joint. Dissection was carried in some fashion through the deeper tissues to expose the subtalar, calcaneocuboid, and talonavicular joints. All joint surfaces were resected through this single approach and fixation and closure followed.

The use of the classic Ollier incision poses obvious potential hazards to specific vital structures including sensory nerve, extensor tendons, and deeper neurovascular structures. While this incision may be rather effective in a cavovarus foot deformity, adequate exposure especially of the talonavicular joint in a severe pes valgus foot deformity could be rather challenging. Excessive tissue retraction and violation of vital neurovascular structures would often lead to wound slough, dehiscence, and infection. Hence the connotation of poor blood supply to the lateral aspect of the foot.

While full exposure continues to be a primary goal, we have found the two incision approach more advantageous not only to this goal but also to the other general goals in the dissection approach to triple arthrodesis. The two incision technique uses a lateral and a medial approach to the rearfoot.

The lateral incision extends from the tip of the fibular malleolus distally to the region of the base of the fourth and fifth metatarsals. This incision gives direct access to the subtalar joint and calcaneocuboid joint with minimal disruption or transection of vital structures. The medial incision extends from the region of the medial malleolus distal to the level of the naviculocuneiform joint and provides exposure of the talonavicular joint, as well as access for fixation of the subtalar joint.

There are several significant and important advantages of the two incision technique.

1. Direct access to the subtalar and calcaneocuboid joints laterally and talonavicular joint medially for joint resection and fixation.

2. Direct visualization through medial and lateral approaches minimizes excessive tissue retraction and

related wound complications.

3. The longitudinal orientation of the incisions runs parallel to most vital structures and tissues. Combination of the orientation of the incision and the techniques of anatomic dissection then significantly minimizes violation of the major blood and nerve supply to the tissues of the foot. Communication of the medial surgical approach and the lateral approach through subperiosteal dissection across the dorsum of the midtarsal region preserves the relationship and viability of the important soft tissues.

An anatomic plan for exposure and manipulation of both soft tissues and osseous structures is very important to the success of the procedure. Accurate and delicate execution of these techniques will greatly facilitate the execution of the procedure and minimize damage to the vital supportive soft tissues. All of these techniques will lead to decreased pain and swelling and minimize wound complications such as hematoma, dehiscence, tissue slough, and infection.

Hemostasis

Hemostasis for the traditionally performed triple arthrodesis was typically a mid-thigh pneumatic tourniquet. While this technique adequately controlled bleeding during the surgical procedure, it was common to see a blood soaked cast within the first few hours following the surgical procedure.

Hemostasis implies more than just the control or "damming" of bleeding during a surgical procedure. The techniques of anatomic dissection not only provide control of bleeding during surgery but also the reduction and control of bleeding following surgery and the release of the tourniquet.

Anatomic dissection may be so effective that a tourniquet is not even necessary during some surgical procedures. However, the tourniquet is a surgical tool and can be put to good use if safely employed in the execution of a triple arthrodesis.

A mid-thigh pneumatic tourniquet is usually inflated at the start of the surgical procedure. Commonly accepted parameters are used for pressure and duration.

The primary use of the tourniquet in triple arthrodesis is to speed the surgical procedure especially during the initial phases of dissection and exposure of the osseous structures. Even with the tourniquet elevated, superficial and penetrating vessels are identified and secured. One of the primary areas of bleeding however, comes with the reflection of soft tissues from bone or sub-periosteal dissection. Bleeding from the bone surface cannot be clamped and tied and the use of the tourniquet greatly facilitates this phase of the surgical dissection.

Another phase of the procedure which creates active bleeding is the resection of the primary joint surfaces. Exposure of the cancellous bone of the greater tarsals can create some significant bleeding. Execution of this phase of the procedure without the use of the tourniquet is exceptionally difficult because of constant bleeding which obscures vision and requires continuous suctioning. It is highly recommended that the tourniquet be inflated for the primary resection of articular surfaces during the execution of triple arthrodesis.

In most cases the tourniquet may be safely inflated for 1.5 to 2.0 hours. This length of time is usually sufficient for completion of the phases of initial dissection, joint exposure and resection, and finally joint apposition and temporary fixation. In a rapidly moving and uncomplicated case even the permanent fixation can be accomplished within the two hour time frame. If permanent fixation can be accomplished within the initial tourniquet application it is strongly recommended that the tourniquet be released before wound closure. The medial and lateral wounds can be packed with moist saline sponges and a temporary compression dressing applied. The tourniquet is released and five to ten minutes is allowed to pass to permit normal return of blood flow, reflex hyperemia to subside, and normal coagulation of bleeding tissues to occur. The wounds are then carefully inspected to identify and coagulate any actively bleeding vessel or tissue. The wounds can then be closed in layers over standard closed suction tubing (TLS).

If final fixation has not been accomplished within the initial tourniquet application, the tourniquet may be released with the wound packed and dressed as above. A standard period of "breathing" can be allowed and the tourniquet can be reinflated for completion of the procedure or the procedure can be continued without tourniquet if bone bleeding is not a major obstacle.

The use of Topical Thrombin may be considered if there is general tissue and bone oozing that cannot be easily controlled.

The use of closed suction drainage systems (TLS) is standard in the execution of triple arthrodesis. It is not uncommon to produce 100 to 200 cc's of hemorrhage following wound closure even in a completely secured wound. Cancellous bone bleeding is responsible for this portion of the surgical hemorrhage and may continue in some form for as long as two to three days.

A uniform and firm compression dressing, elevation of the extremity, and application of ice are also helpful and important in reducing the immediate postoperative bleeding, hematoma, and edema.

Anatomic dissection has a major role in triple arthrodesis. Hemostasis through anatomic dissection has direct bearing on many phases of the surgical procedure:

1. Anatomic incision placement and tissue plane dissection techniques avoid major vessels and nerves.

2. Individual vessels that may cross the surgical course are specifically handled.

3. Anatomic dissection planes preserve the primary longitudinal orientation of vital blood supply to major tissue areas.

4. Postoperative bleeding is minimized and controlled to reduce wound complications.

Atraumatic Technique

When the topic of atraumatic techniques is discussed, the initial thoughts include gentle tissue handling, proper types of instruments, and a general sense of delicateness to avoid bruising and extra insult to the soft tissues. The Swiss surgical philosophy discusses "atraumatic technique" from a somewhat different point of view. The primary emphasis of atraumatic technique in an "AO" context refers to the preservation of vascular supply to the osseous and soft tissues. Obviously, one of the primary requirements for primary bone healing is viable vascularized bone.

We share the same appreciation of vascularized bone and soft tissues and suggest that the techniques of anatomic dissection to be detailed are a primary skill that will ensure preservation of the viability of both the bone and adjacent soft tissues.

The previously discussed points of exposure and hemostasis are directly responsible for the preservation of vascular supply. Proper incision placement, tissue plane dissection, hemostasis techniques, and subperiosteal dissection lead to minimized tissue trauma and preservation of blood supply. The technique basically employs identification and separation rather than laceration, shredding, and tearing of tissues.

This type of approach literally allows the soft tissues over the entire dorsum of the foot and ankle to be elevated as a complete and intact layer which includes its primary neural and vascular supply. With the vital soft tissues cleanly separated and retracted, the individual joints of the rearfoot may be freely resected and fixated. Essentially, all osseous work is done within the protective envelope of the periosteum of the tarsal bones. Upon completion of the osseous work, the periosteum and other soft tissues are reapplied to the bony surfaces to allow additional revascularization of the underlying bone.

The techniques of anatomic dissection can be an extremely valuable tool in the execution of triple arthrodesis. The procedure is technically difficult and demanding on both the surgeon and the targeted tissues. A logical and meticulous technique based on anatomy will greatly enhance the execution of the procedure and minimize the potential morbidity and complications of the procedure.

Technique

The patient is initially placed in a slight lateral position to facilitate the approach to the lateral aspect of the foot. A pneumatic-suction back pack is helpful for positioning of the patient. A mid-thigh pneumatic tourniquet is inflated and routine cautery and suction is available.

Lateral Incision

The lateral incision is utilized for exposure of the subtalar and calcaneocuboid joints (Fig. 1). The key landmarks for placement of the incision include tip of the fibular malleolus, the sinus tarsi, and the calcaneocuboid joint. Other key landmarks that may be appreciated by palpation include the peroneal tendons, the lateral process of the talus, the lateral margin of the floor of the sinus tarsi, and the lateral wall of the calcaneus and the bases of the fourth and fifth metatarsals.

The incision runs from just inferior to the distal tip of the fibular malleolus along the lateral margin of the floor of the sinus tarsi, across the calcaneocuboid joint to the junction of the fourth and fifth metatarsal bases. This incision placement will give direct access to the subtalar and calcaneocuboid joints and run longitudinally between the course of the intermediate dorsal cutaneous nerve and the sural nerve. Occasionally, a communicating branch from sural nerve to the intermediate dorsal cutaneous nerve may be encountered and may need to be sacrificed.

A controlled depth incision technique is used to separate the skin layer and avoid laceration of underlying veins that may cross the surgical incision.

Dissection Through the Superficial Fascia

Once the skin edges have been freely separated,

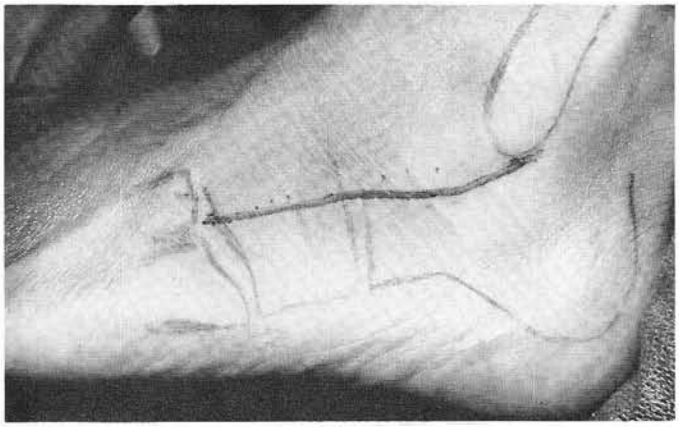

Fig. 1. Skin incision for lateral approach to subtalar and calcaneocuboid joints.

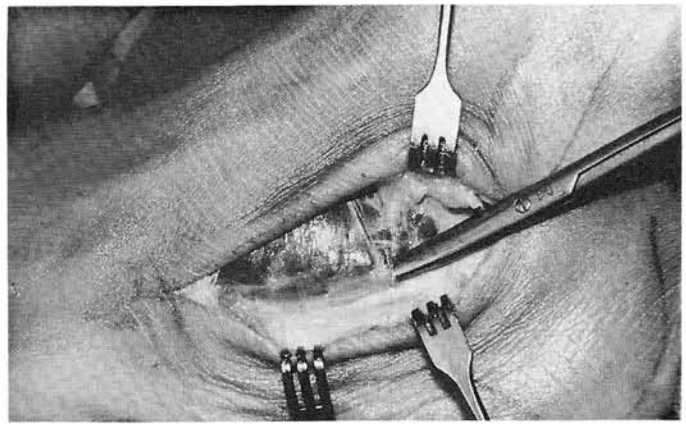

Fig. 2. Demonstration of deep fascia overlying junction of extensor digitorum brevis muscle belly and peroneal tendons.

dissection is carried through the subcutaneous layers to the level of the deep fascia. The technique is performed with sharp or blunt dissection and any superficial vessel that crosses the incision is isolated, clamped, cut, and coagulated. Electrocautery or hand ties may be used.

Occasionally, a communicating branch of the sural nerve to the intermediate dorsal cutaneous nerve will be identified crossing the line of dissection. If the nerve can be safely retracted, it is preserved; if not, it is sacrificed. The sural nerve and the intermediate dorsal cutaneous nerve should be safely protected within the subcutaneous tissues below and above the primary incision.

Separation of the Superficial Fascia from the Deep Fascia

The deep fascia is exposed through the full length of the incision. A moderate degree of separation of the two tissue layers is then created before the deep fascia is incised. The primary purpose of separation of the superficial fascia from the deep fascia in the lateral incision is to facilitate wound closure by making tissue layer identification more readily visible at the completion of the procedure.

The superficial fascia or subcutaneous layer is easily separated from the deep fascia especially over the extensor digitorum brevis muscle belly. This maneuver is readily performed merely by peeling the tissues away from the deep fascia with the use of a surgical sponge. This separation becomes more difficult over the sinus tarsi and may require a spreading technique with the use of a Metzenbaum scissor. Clean separation should be carried proximally to identify deep fascia over the tip of the fibular malleolus and inferiorly over the peroneal retinaculum at the proximal extent of the wound.

The inferior margin of the incision is rather firmly affixed to the underlying deep fascia. Minimal separation is required at this level and care should be taken to avoid laceration of the peroneal retinaculum and sheath specifically over the peroneus brevis tendon as it crosses from the tip of the fibular malleolus to the base of the

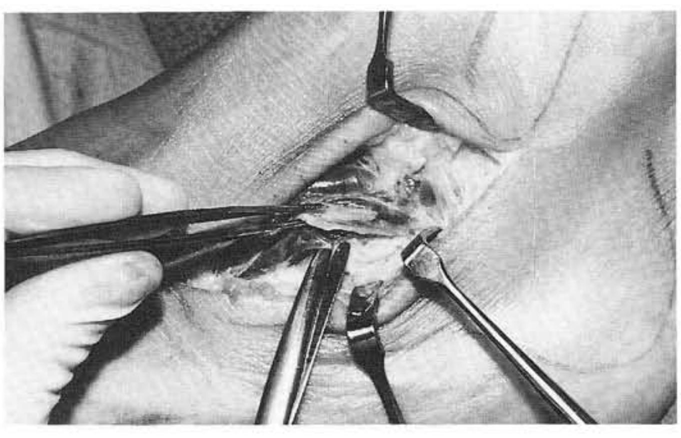

Fig. 3. Elevation of extensor digitorum brevis muscle belly from dorsal surface of calcaneocuboid joint.

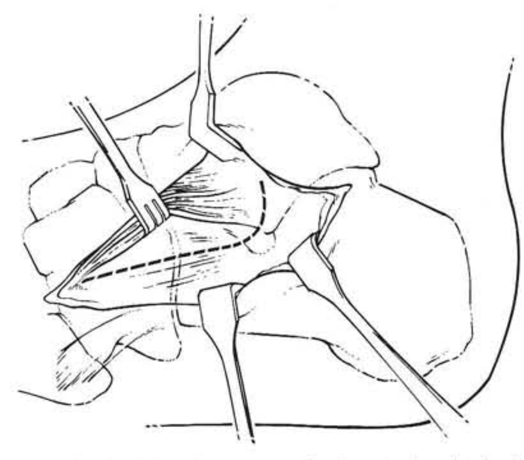

Fig. 4. Capsular incision into posterior facet of subtalar joint and calcaneocuboid joint.

fifth metatarsal. The course of the peroneus brevis tendon along the lateral aspect of the calcaneus will be a key dissection landmark for incision and progression to deeper tissues.

Deep Fascial Incision

The primary relationship which determines the deep fascial incision is the junction of the inferior edge of the extensor digitorum brevis muscle belly and the peroneus brevis tendon (Fig. 2). The deep fascia is initially penetrated at the distal extent of the wound over the EDB muscle belly just superior to the retinaculum and sheath that protect the peroneus brevis tendon.

The incision is carried proximally along the inferior border of the muscle belly to the level of the fibrous plug at the entrance of the sinus tarsi. Minimal dissection across the sinus tarsi is necessary at this time as the primary tissues within the sinus tarsi will be evacuated with the sub-periosteal dissection technique.

At this point, a Metzenbaum scissor is used to gently tease and lift the inferior edge of the EDB muscle belly from capsular tissues over the dorsal region of the calcaneocuboid joint and neck of the calcaneus (Fig. 3). This technique clearly reveals the capsular and ligamentous covering over the calcaneocuboid joint and periosteum over the dorsal lateral aspect of the neck of the calcaneus. The peroneus brevis tendon should still be totally ensheathed.

Lateral Periosteal and Capsular Incision

The lateral periosteal and capsular incision exposes the subtalar and calcaneocuboid joints.

The tip of the fibular malleolus is easily palpated at the proximal end of the incision. Another prominent projection of bone is palpable just anterior to the tip of the fibular malleolus. This prominence is the anterior lateral corner of the lateral process of the talus and is an important landmark for the capsular and periosteal incision used to expose the subtalar joint.

The lateral process of the talus is a key structure for orientation within the realm of the subtalar joint. The lateral process forms the primary portion of the talus which articulates with the calcaneus to form the posterior facet of the subtalar joint. The anterior surface of the lateral process of the talus forms the posterior wall of the sinus tarsi. The anterior and inferior edge of the lateral process of the talus defines the anterior margin of the posterior facet. Intimate familiarity with the contours of the lateral process of the talus will greatly facilitate exploration and exposure of the subtalar joint.

The lateral capsular and periosteal incision is an inverted "L" incision beginning on the lateral process of the talus (Fig. 4). The incision courses inferiorly along the lateral process to the lateral margin of the calcaneus and then runs distally along the dorsolateral edge of the calcaneus. The incision is carried across the calcaneocuboid joint out to the level of the metatarsal-cuboid articulation.

The sub-periosteal dissection will then follow two different directions to fully expose the osseous structures on the lateral aspect of the foot. The dorsal route will lift all soft tissues from the dorsal surface of the cuboid, the calcaneocuboid joint, and clean all tissues from the floor of the sinus tarsi. These tissues will include the periosteum and capsule, the origin and main mass of the extensor digitorum muscle belly, and the contents of the sinus tarsi.

The incision over the lateral process of the talus is actually a lateral capsular incision to the posterior facet of the subtalar joint (Fig. 5). The anterior edge of the capsule can be reflected with a pick-up and the anterior margin of the posterior facet is clearly visualized. The sub-periosteal dissection technique can begin with a clean intra-capsular approach. The knife blade can be inserted across the anterior surface of the lateral process of the talus and directed inferiorly and then anteriorly to shell the origin of the EDB muscle belly and other soft tissues from the floor of the sinus tarsi (Fig. 6).

A similar intra-capsular technique can begin reflection of soft tissues from the region of the calcaneocuboid joint. Proximal extension of this dissection will communicate with the dissection of the sinus tarsi and begin elevation of the dorsal tissues over the calcaneocuboid joint and sinus tarsi as an intact and viable tissue flap (Fig. 7).

Dissection across the dorsal surface of the cuboid should be carried medially until the lateral surface of the navicular is contacted (Fig. 8). Proximal and medial extension across the neck of the calcaneus and into the sinus tarsi will expose the inter-tarsal ligament and elevate the proximal attachment of the bifurcate ligament from the dorsal surface of the calcaneus.

Care must be taken to follow the contour of the calcaneus to cleanly evacuate the sinus tarsi. The inferior attachment of the inter-tarsal ligament must be freed from the calcaneus to allow separation of the subtalar joint and more importantly, entrance into the middle facet of the subtalar joint (Fig. 9).

Excess fibro-ligamentous tissue from evacuation of the sinus tarsi may be resected to aid in visualization of the region. Resection of muscle tissue should be avoided.

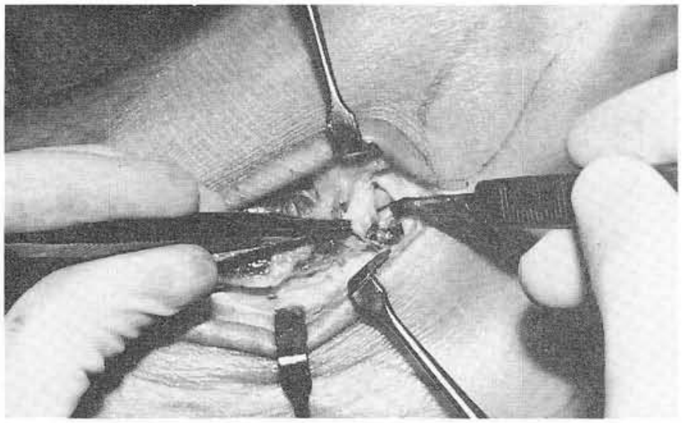

Fig. 5. Proximal portion of lateral capsular incision demonstrating posterior facet of subtalar joint. Superior joint structure — articular surface of lateral process of talus. Inferior joint structure — articular surface of posterior facet of calcaneus.

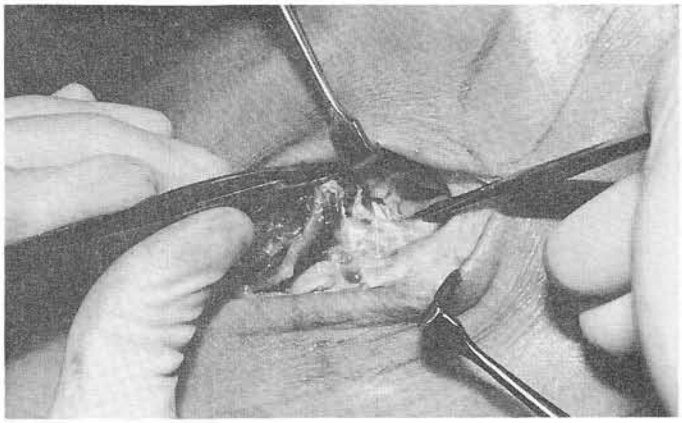

Fig. 6. Initial dissection elevating capsule, periosteum, and extensor digitorum brevis muscle belly from superior surface of sinus tarsi and calcaneocuboid joint region.

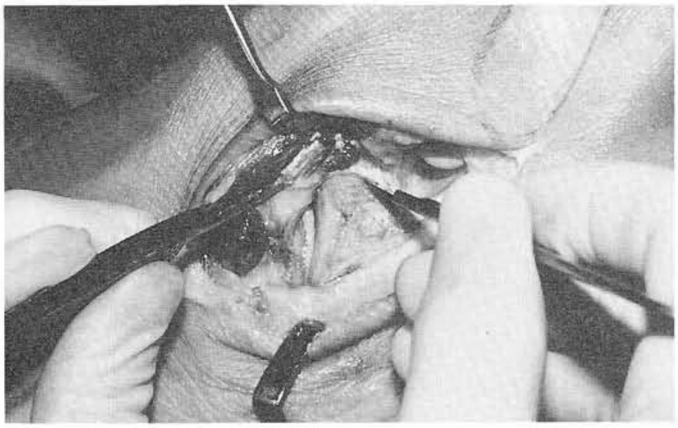

Fig. 7. Additional dorsal dissection exposing the calcaneocuboid joint.

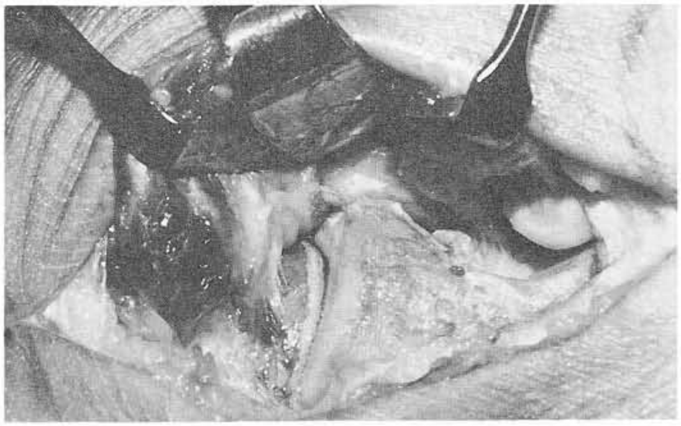

Fig. 8. Closeup view of calcaneocuboid joint, the sinus tarsi, and posterior facet of subtalar joint. Note talocalcaneal ligament deep in sinus tarsi.

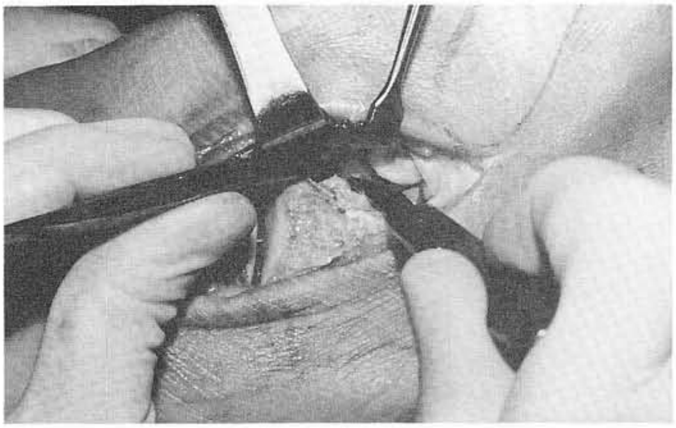

Fig. 9. Sectioning of talocalcaneal ligament.

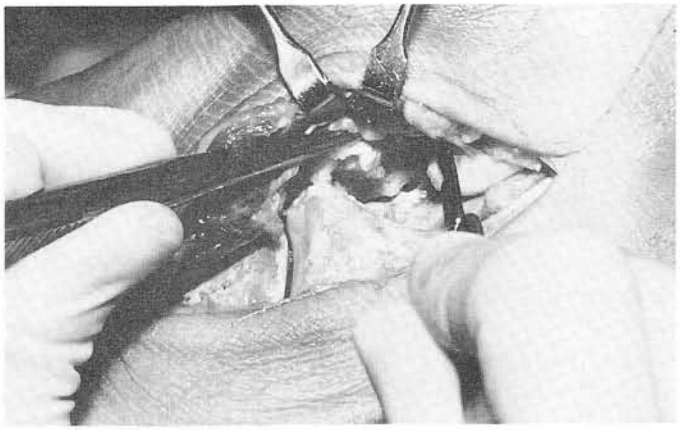

Fig. 10. Initiation of dissection across anterior surface of lateral process of talus and up lateral surface of head and neck of talus.

Once the confines of the middle facet have been visualized the sub-periosteal dissection process is carried up the lateral side of the head and neck of the talus (Fig. 10). Soft tissue along the anterior surface of the lateral process of the talus and the lateral aspect of the head and neck of the talus must be cleanly reflected to fully expose the subtalar joint and aid in exposure of the talonavicular joint by communication with the subperiosteal dissection from the medial approach (Fig. 11).

At this point the subtalar joint is easily visualized and the lateral tissues of the calcaneocuboid region must be reflected to fully deliver the calcaneocuboid joint.

The soft tissues over the lateral aspect of the calcaneocuboid joint and subtalar region are essentially intact from the skin down to the level of the periosteum. There has been minimal separation of the subcutaneous tissues from the deep fascia and retinaculum over the peroneal tendons. The sural nerve and the lesser saphenous vein should be safely protected within these inferior and lateral tissues.

The peroneus brevis tendon now becomes the primary structure used for orientation and preservation of tissue relationships as the capsule and periosteum are reflected from the lateral aspect of the calcaneocuboid joint and lateral surface of the calcaneus. The peroneus brevis tendon should still be completely ensheathed within the retinaculum and sheath of the peroneal tendons. The internal surface of that sheath is actually tissue that includes periosteum of the lateral wall of the calcaneus.

A sub-periosteal dissection technique extended inferiorly from the primary capsular and periosteal incision will cleanly expose the lateral surface of the calcaneocuboid joint and still protect the peroneal tendons totally within their soft tissue covering (Fig. 12). Inferior release of the calcaneocuboid joint should be performed with a curved periosteal elevator such as the Crego elevator (Fig. 13).

Proximal reflection of periosteum from the lateral wall of the calcaneus will begin to expose the saddle shaped portion of the calcaneal margin of the posterior facet.

Full exposure of the posterior facet requires reflection of the peroneal tendons. The peroneal sheath is entered just inferior to the distal tip of the fibular malleolus and an incision is extended proximally around the tip of the malleolus sectioning the anterior portion of the peroneal retinaculum (Fig. 14). The peroneus brevis and longus tendons are then retracted posteriorly with the blade of a Senn retractor (Fig. 15).

Retraction of the peroneal tendons reveals the lateral capsular tissues covering the posterior facet of the subtalar joint. Two primary structures included in these lateral tissues are the calcaneofibular ligament and the lateral talo-calcaneal ligament.

Full exposure and visualization of the subtalar joint for accurate joint resection is aided by the ability to open the joint with inversion of the foot. "Opening" of the subtalar joint would be significantly hindered by the in tact lateral ligamentous structures. Earlier techniques utilized the insertion and spreading of a small lamina spreader to open the subtalar joint.

The lateral capsular tissues of the posterior facet of the subtalar joint can be cleanly incised including the calcaneofibular ligament (Figs. 16, 17). This maneuver allows the joint to be easily opened with the lamina spreader and the ligament may be primarily repaired at the time of closure.

A Crego elevator may be passed intra-capsularly around the posterior rim of the posterior facet to appreciate the contour and extent of the joint (Figs. 18, 19).

The subtalar and calcaneocuboid joints are now fully exposed (Fig. 20). The surgeon should evaluate the integrity of the joints and any related pathology. The procedure is now continued with the medial incision.

Medial Incision

The medial incision provides direct access to the talonavicular joint and direct exposure of the dorsal surface of the neck of the talus for the fixation process of the talocalcaneal joint. The sub-periosteal dissection from the medial incision is also extended laterally around the lateral contour of the head and neck of the talus and the lateral surface of the navicular. The soft tissues over the dorsal aspect of the midtarsal region can then be cleanly retracted and protected as an intact and viable tissue layer.

The landmarks for the incision include the medial malleolus, the prominence of the navicular, and the naviculocuneiform joint (Fig. 21). The incision begins at the notch formed by anterior medial junction of the medial malleolus and the medial aspect of the dome of the talus. The incision is carried inferiorly across the prominence of the navicular to the lower margin of the naviculocuneiform joint. The angulation of this incision allows for three specific technical executions:

1. direct access to the talonavicular joint,

Once the confines of the middle facet have been visualized the sub-periosteal dissection process is carried up the lateral side of the head and neck of the talus (Fig. 10). Soft tissue along the anterior surface of the lateral process of the talus and the lateral aspect of the head and neck of the talus must be cleanly reflected to fully expose the subtalar joint and aid in exposure of the talonavicular joint by communication with the subperiosteal dissection from the medial approach (Fig. 11).

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1. direct access to the talonavicular joint,

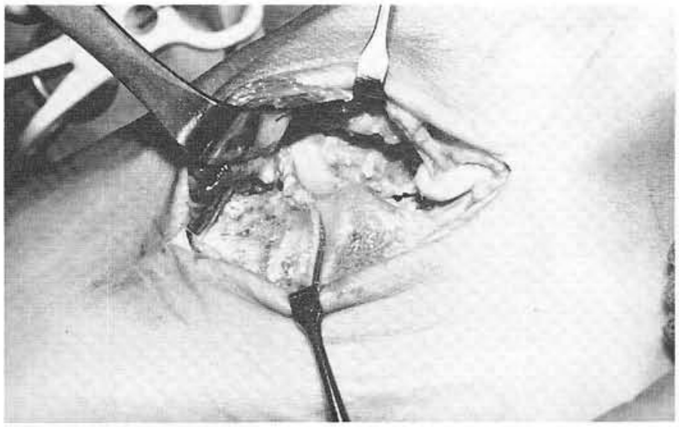


Fig. 11. Lateral exposure with demonstration of:
-calcaneocuboid joint
-posterior facet of subtalar joint
-middle facet of subtalar joint
-head and neck of talus and
-talonavicular joint.

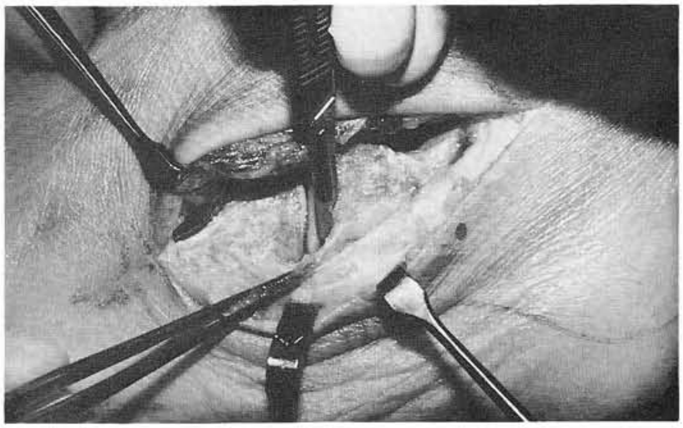


Fig. 12. Reflection of periosteum and capsular tissues from lateral aspect of calcaneocuboid joint.

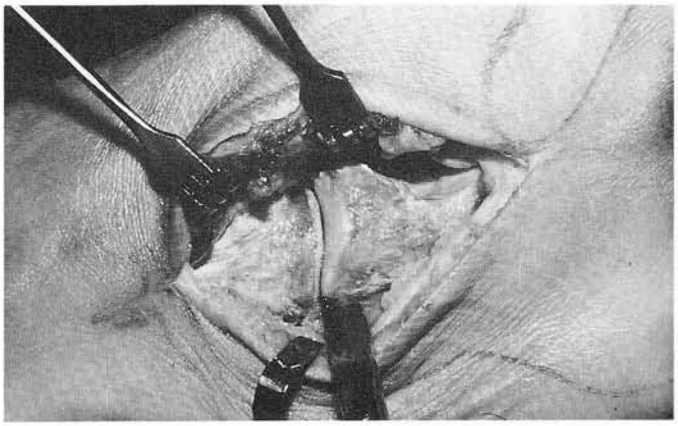


Fig. 13. Full exposure of calcaneocuboid joint.

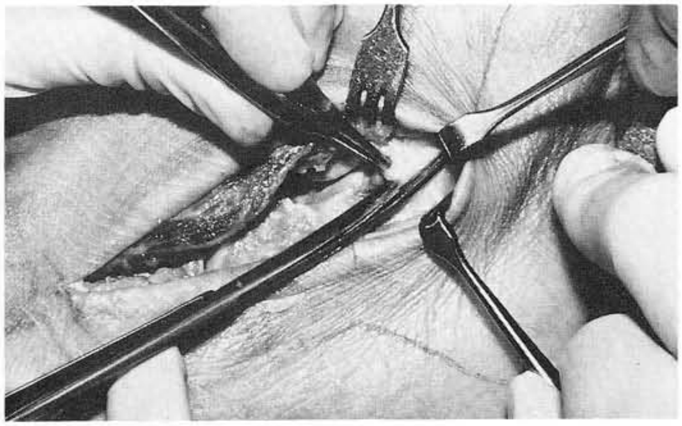


Fig. 14. Incision through peroneal retinaculum at distal tip of fibular malleolus.

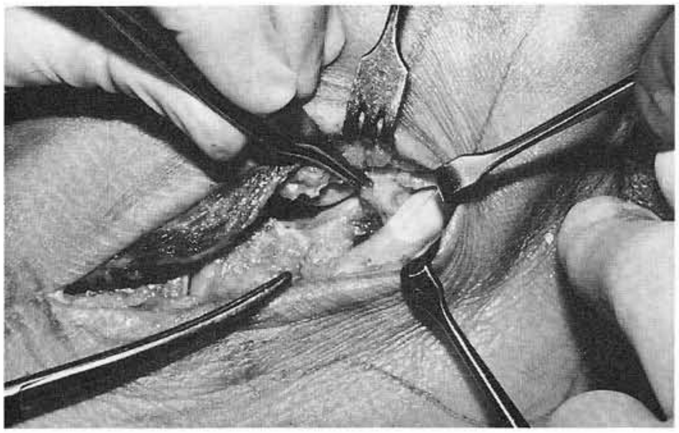


Fig. 15. Exposure of peroneal tendons before retraction.

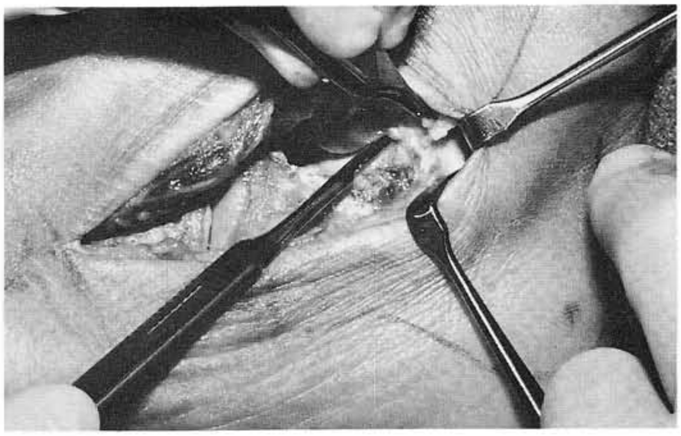


Fig. 16. Incision of lateral capsule of posterior facet of subtalar joint including calcaneofibular ligament.

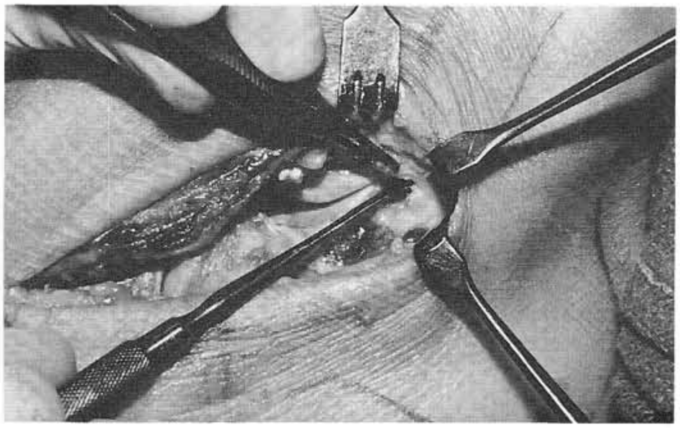


Fig. 17. Demonstration of sectioned calcaneofibular ligament.

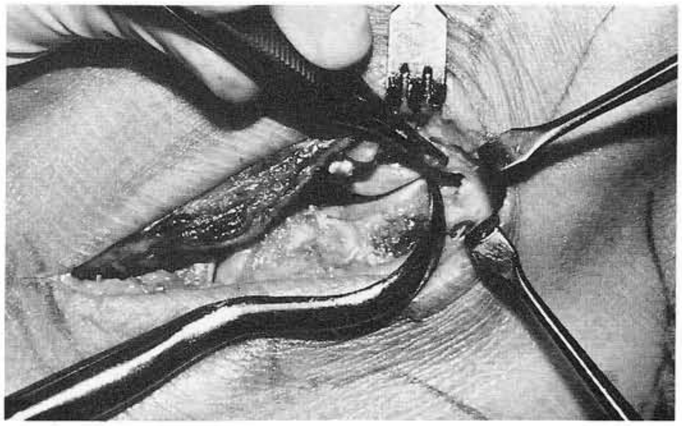


Fig. 18. Insertion of Crego elevator intracapsularly around posterior contour of posterior facet of subtalar joint.

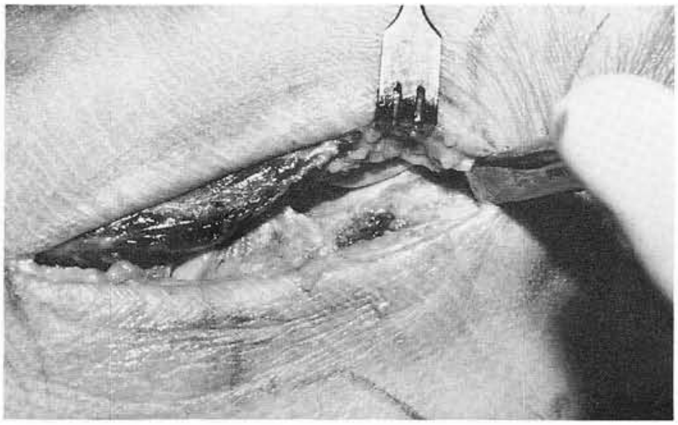


Fig. 19. Full exposure of posterior facet of subtalar joint.

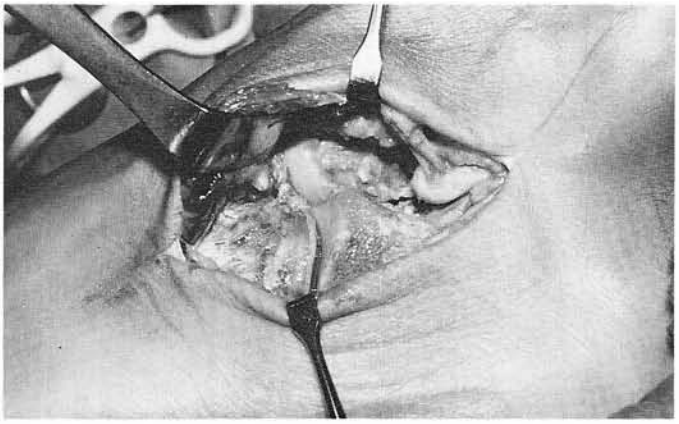


Fig. 20. Completed lateral exposure with demonstration of:
-calcaneocuboid joint
-posterior facet of subtalar joint
-middle facet of subtalar joint
-head and neck of talus and
-talonavicular joint.

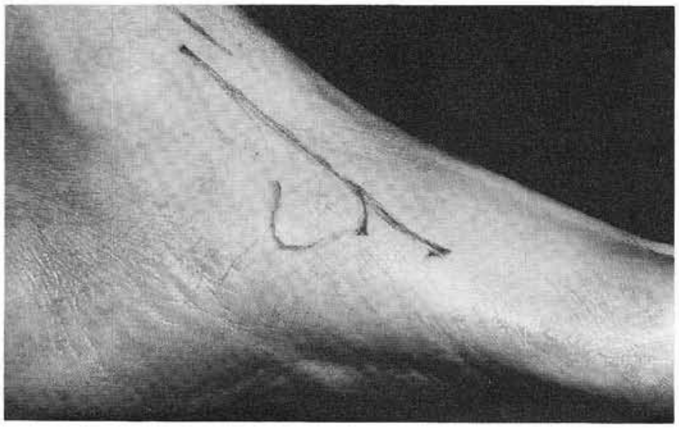


Fig. 21. Medial skin incision for exposure of talonavicular joint.

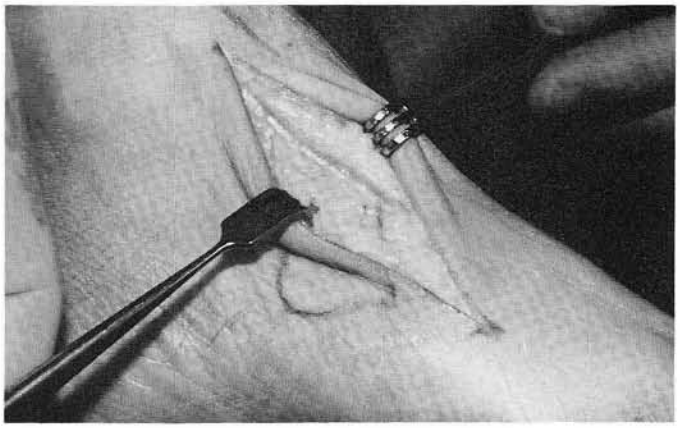


Fig. 22. Demonstration of medial marginal vein.

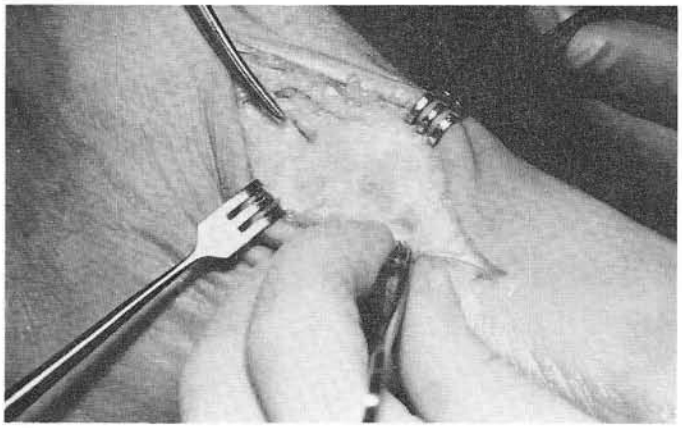


Fig. 23. Retraction of medial marginal vein and exposure of capsule over talonavicular and ankle joints.

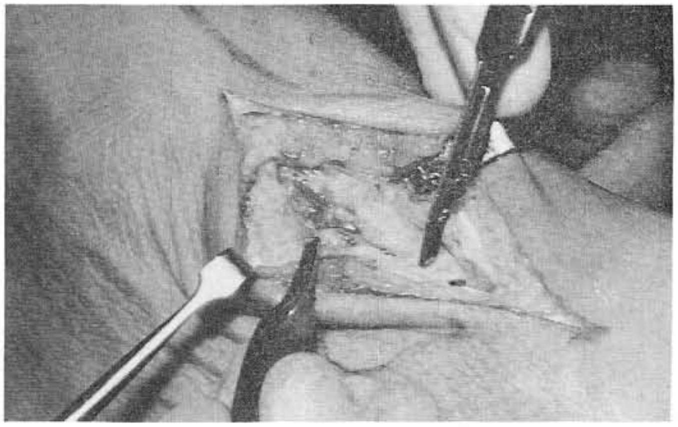


Fig. 24. Capsular incision into talonavicular and ankle joints.

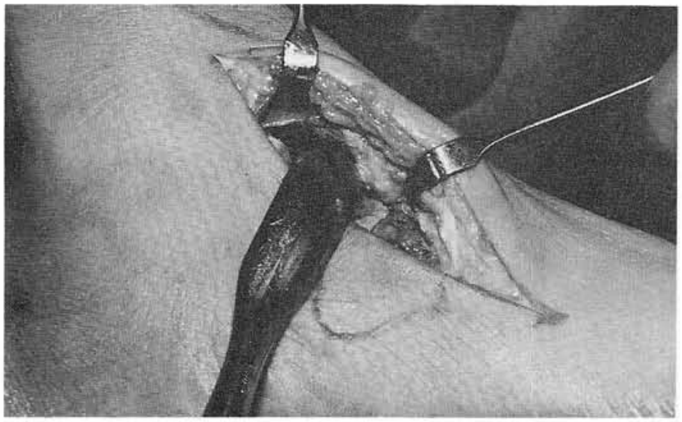


Fig. 25. Insertion of Crego periosteal elevator to elevate periosteum and capsular tissues from dorsum and lateral surfaces of talonavicular joint.

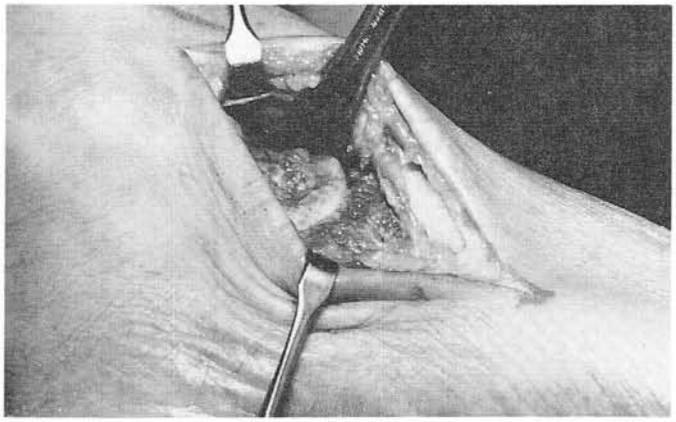


Fig. 26. Full exposure of talonavicular joint.

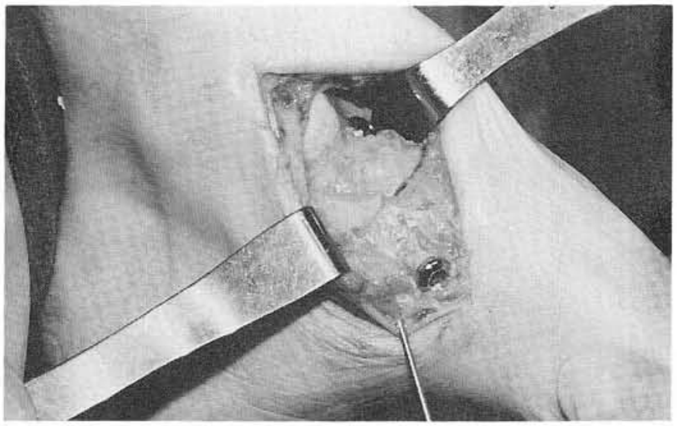


Fig. 27. Subperiosteal communication of medial and lateral incisions with elevation and protection of dorsal tissue island by ribbon retractor.

2. a superior approach to the dorsal surface of the neck of the talus for instrumentation and fixation of the talocalcaneal joint, and
3. An inferior approach to the distal surface of the navicular for instrumentation and fixation of the talonavicular joint.

The incision should also lie longitudinally between the tibialis anterior tendon and the tibialis posterior tendon. At the proximal extent of the incision dissection will come directly upon the extension of the greater saphenous vein, the medial marginal vein. As the incision courses inferiorly it passes below the level of the medial marginal vein and it is usually possible to retract this major vessel laterally without transection.

Subcutaneous Dissection

Dissection is extended through the subcutaneous tissues, over the anterior aspect of the ankle, and across the dorsal region of the talonavicular joint and the medial and inferior aspect of the naviculocuneiform joint. Large communicating veins from the inferior aspect of the medial marginal vein should be isolated, clamped, cut, and tied (Figs. 22, 23). The medial marginal vein can then be retracted laterally within the subcutaneous tissues. Dissection is carried again to the level of the deep fascia. The superficial tissues are gently separated from the surface of the deep fascia over the anterior aspect of the ankle and the medial and inferior aspect of the talonavicular region.

Deep Fascial Incision

The incision through the deep fascia is made along the medial border of the tibialis anterior tendon. The tendon is then retracted laterally.

From the level of the talonavicular joint distally there is minimal aereollar tissue between the deep fascia and the underlying joint capsule and periosteum. However, from the talonavicular joint proximally across the level of the ankle joint, there is a significant layer of subcutaneous tissues and a rather extensive network of vessels including tributaries of the anterior medial malleolar artery and the deep venous complex or anteromedial malleolar veins. These rather large vessels must be individually isolated and secured to avoid significant bleeding upon release of the tourniquet.

Medial Periosteal and Capsular Incision

The deep incision through joint capsule and periosteum actually crosses two joints, the ankle joint and the talonavicular joint (Fig. 24). The line of incision essentially follows the skin incision. It begins proximally at the medial notch of the ankle mortise, courses distally over the dorsomedial aspect of the head and neck of the talus and talonavicular joint to the inferior aspect of the naviculocuneiform joint.

An intra-articular dissection technique then readily peels the capsular tissues from the dorsal surface of the neck of the talus. This subperiosteal plane reveals the talonavicular joint and is carried distally to expose the dorsal surface of the navicular. This intra-capsular dissection across the anterior aspect of the ankle and subperiosteal dissection technique across the dorsal surface of the mid-tarsal region elevates the vital soft tissues from the anterior aspect of the ankle and dorsum of the foot. This also does protects the deep vessels which include the dorsalis pedis artery.

The contour of the head and neck of the talus and navicular is followed laterally and inferiorly with the use of a Crego elevator as periosteum and capsule are stripped from the lateral aspect of the mid-tarsal level (Figs. 25, 26). As the dissection is carried laterally it communicates with the subperiosteal dissection from the lateral incision which has come across the dorsal surface of the calcaneocuboid joint and sinus tarsi and over the lateral aspect of the head and neck of the talus.

This communication of dissection planes across the mid-tarsal region is of primary significance in providing full exposure of the mid-tarsal joints. It also preserves the viability of the dorsal soft tissue island that has been created between the medial and lateral incisions. A malleable retractor can be passed across the dorsal level to protect the soft tissues during joint resection and fixation (Fig. 27).

Inferior dissection completes exposure of the medial incision. The capsular tissues including the primary insertion of the tibialis posterior tendon are reflected from the navicular out to the level of the naviculocuneiform joint. This inferior exposure not only allows for resection of the talonavicular joint but also its fixation. The use of a large cancellous bone screw in fixation of the talonavicular joint requires penetration of the navicular at its distal and inferior surface as the course of the screw channels up the angle of the neck of the talus.

Joint Resection and Fixation

Once complete exposure of all joint areas has been accomplished the process of joint resection and fixation is performed. The details of this procedure are in the following section of this paper.

Wound Closure

Once fixation has been completed the medial and lateral incisions are closed in anatomic layers. Usually the tourniquet is released and any active bleeding is secured. The wounds are generously irrigated as has been done repeatedly during the entire procedure. Large TLS closed-suction drains are placed in both the medial and lateral incisions to provide effective evacuation of internal bleeding from resected joint surfaces. The capsular and periosteal layers are closed over the drain tubes and the tubes are exited through the superficial tissues and skin with the use of the trochar.

The remaining tissue layers; deep fascia, subcutaneous, and skin are then closed individually. The incisions are cleansed and covered with moist saline soaked sponges and a surgical dressing is applied. The foot and lower extremity are then placed in a Jones compression dressing and cast and postoperative management is initiated.

Joint Resection, Positioning, Internal Fixation

Traditionally, the triple arthrodesis procedure involved resecting wedges of bone from the joint surfaces of the tarsal area. Fixation was not commonly employed. The patient was usually casted with the resected tarsal bones placed in alignment to correct for the deformity, hoping the pieces would fall together much like a puzzle. Common postoperative complications included nonunion, pseudoarthrosis, malalignment, residual deformity or a short fat foot with the possibility of reoperation at a later time.

The triple arthrodesis performed by members of the Institute combines anatomic dissection with minimal bone resection and rigid internal fixation.

Prior to performing the procedure the surgeon needs a mental picture of the end result. The procedure is employed to correct many deformities that exhibit markedly varied pathology such as rigid cavovarus, rigid equinovarus, severe pes valgo planus, flexible cavovarus, etc. The surgeon visualizes the resected joint surfaces as apposing triangles or rhomboid wedges sliding upon each other to achieve flush joint surfaces and alignment. An important consideration to alignment of triple arthrodesis is the angle of gait.

The normal foot compensates for abnormal hip position either internal or external, via functional subtalar and midtarsal joints. After triple arthrodesis this compensatory mechanism is no longer available. This mandates the need to determine knee position prior to surgery. If the knee functions internally rotated 15 degrees then it would be desirable to abduct the foot on the leg 30 degrees thus resulting in a 15 degree abduction from the line of progression. Consideration of foot position is important. It is not advisable to abduct a foot if the individual already posses 15-30 degrees external position of the knee in gait. In the latter instance the foot may align directly with the direction of the knee (Fig. 28).

Joint Resection, Wedging and Bony Realignment

The principles of wedging and sliding of the involved bones to achieve correction through triple arthrodesis are relatively simple. But because of the number of in teracting considerations it is probably worthwhile to review all of them.

Minimal Resection

It is wise to resect as little bone as can possibly achieve the desired realignment. To resect excessive bone results in a short wide foot which can make proper shoeing impossible. If resection is combined with appropriate sliding of bones then minimal resection of wedges is usually necessary. Resection is based upon the anticipated realigned positions (Fig. 29).

Midtarsal Joint Resection First

Resection of the midtarsal joint is done first (Fig. 30). This provides relaxation of the tissues and allows the forefoot to be manipulated or retracted such as to provide easier access to the subtalar joint. Where possible it is wise to have an assistant hold the forefoot appropriately aligned on the rearfoot while performing both the calcaneocuboid and the talonavicular resections. By holding the forefoot appropriately realigned

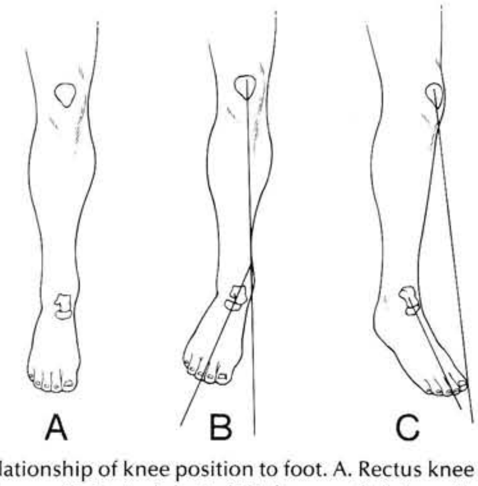


Fig. 28. Relationship of knee position to foot. A. Rectus knee and foot. B. Rectus knee with foot abducted 30 degrees. C. Internal knee position with adducted foot 25 degrees.

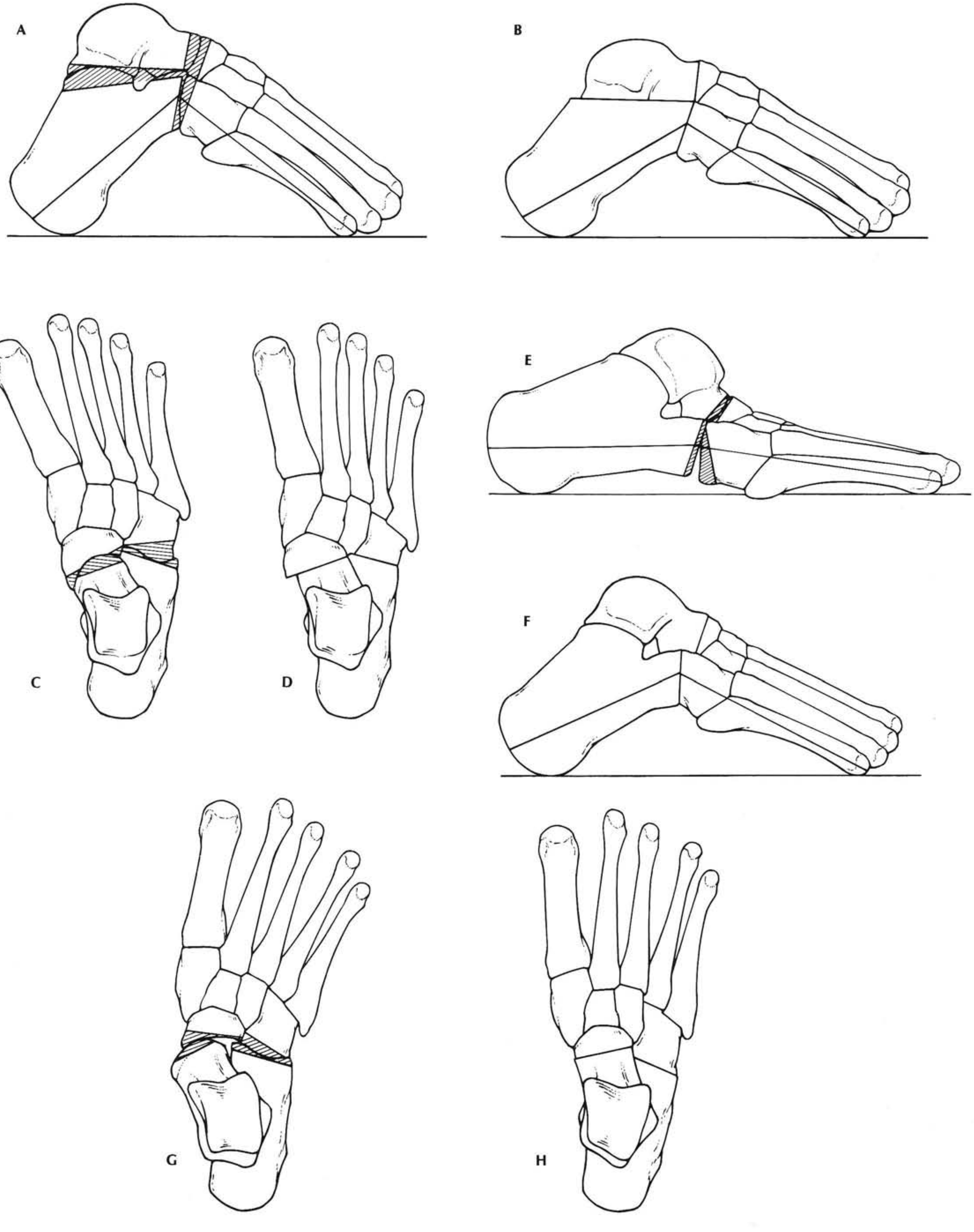


Fig. 29. Minimal bone resection illustrated in both pes cavus (A-D). Pes valgus (E-H).

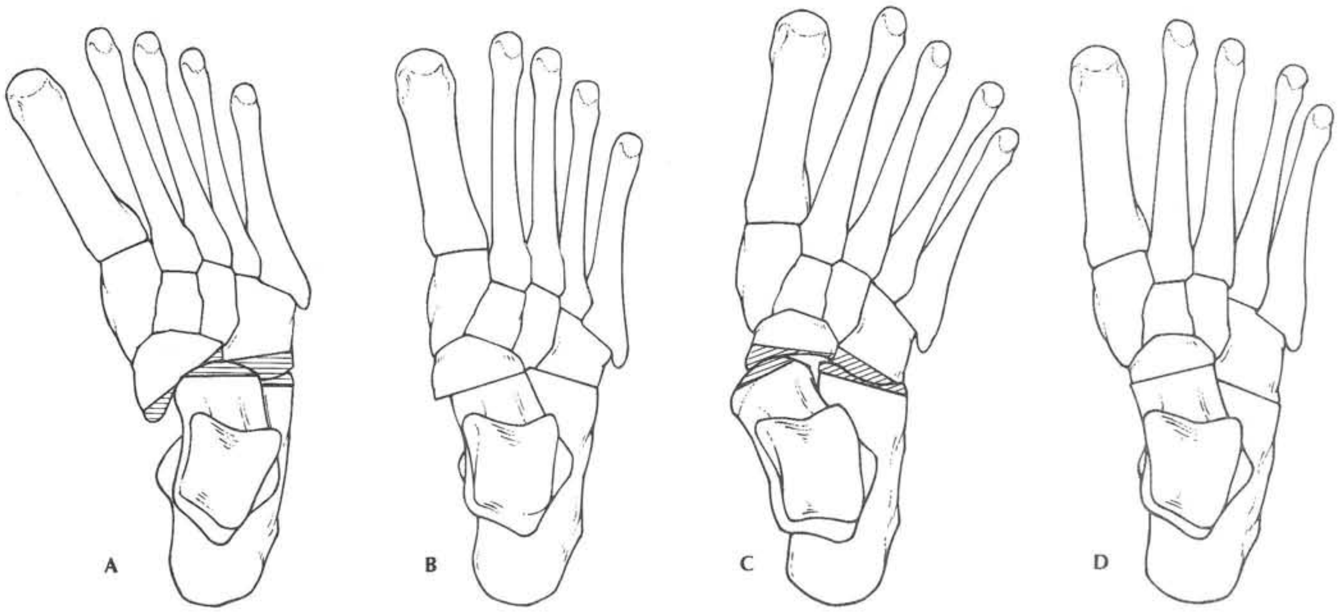


Fig. 30. Midtarsal joint resection. A & B. Adducted forefoot with resection parallel to joint surfaces with minimal wedging and final position. C & D. Abducted forefoot with minimal resection and final position.

one need only make the cuts of the midtarsal joint parallel to the articulation. Minimal resection is carried out. Additional resection or wedging can be carried out at the midtarsal joint after the subtalar joint has been resected and temporarily fixated.

Subtalar Joint Wedging

Wedging of the subtalar joint should also be minimal. Thick resections can so shorten the heel as to result in constant irritation of the malleoli against the top of the shoe when the patient returns to foot gear. As a rule of thumb, resect only the minimal amount of bone that will allow realignment. The calcaneus can be slid laterally to change the transfer of weight more medially in the cavus foot. Or in the pes valgus foot one may wish to move the calcaneus slightly medially beneath the talus (Fig. 31).

Forefoot Derotation

Often a severe pathologic forefoot varus or valgus may be present (Fig. 32). In a pathologic pes valgus deformity one may encounter a forefoot varus of 30-40 degrees. Or in a severe forefoot valgus extreme eversion of the forefoot in relation to the rearfoot may be encountered. In either instance the forefoot may be derotated on the rearfoot before fixation.

Frequently after derotation the surfaces of the midtarsal joint may no longer fit properly. In such instances the foot may be held in the corrected alignment and the large oscillating saw used back and forth within the involved joints as a file until the surfaces fit perfectly, a maneuver known as reciprocal planing.

Plantarflexion or Dorsiflexion of Forefoot

While most texts recommend resection of wedges to effect dorsiflexion of the forefoot (usually to lower the arch) or plantarflexion (usually to restore an arch) sliding of the subtalar joint is often overlooked (Fig. 33). Sliding the calcaneus posteriorly on the talus results in plantarflexion of the forefoot in relation to the rearfoot (increasing arch height). Sliding the calcaneus anteriorly on the talus results in dorsiflexion of the forefoot on the rearfoot (decreasing arch height) (Fig. 34). This often affects the fitting of the midtarsal joint and may necessitate some filing of the joint with the large oscillating blade (reciprocal planing) to restore perfect fitting. Sliding of bone to effect correct alignment effects correction without substantial shortening of a foot or distorting its dimensions.

Abduction of Forefoot or Rearfoot

Abduction of the forefoot can usually be effected by small wedge resections from the lateral distal end of the calcaneus after temporary fixation of the subtalar joint. It is important that the subtalar joint be stable before planning such wedges. Otherwise one does not have a stable benchmark against which to judge (See Fig. 30).

Temporary Fixation

Temporary fixation is done with large Kirschner wires or small Steinmann pins. The subtalar joint is first fix-

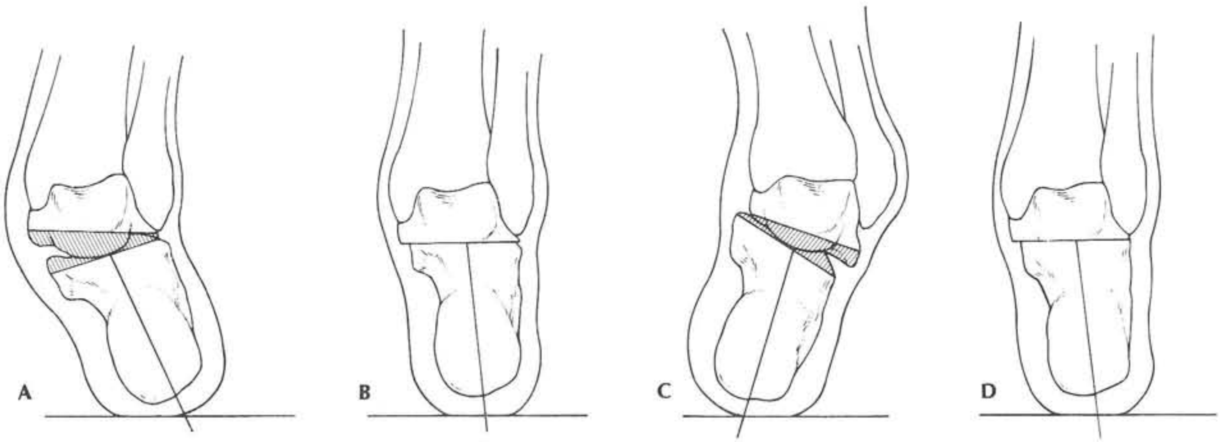


Fig. 31. Subtalar joint resection. A & B. Pes valgus foot type with resection of joint surfaces and sliding of calcaneus medially. C & D. Pes cavus foot type with resection of joint surfaces and sliding of calcaneus laterally.

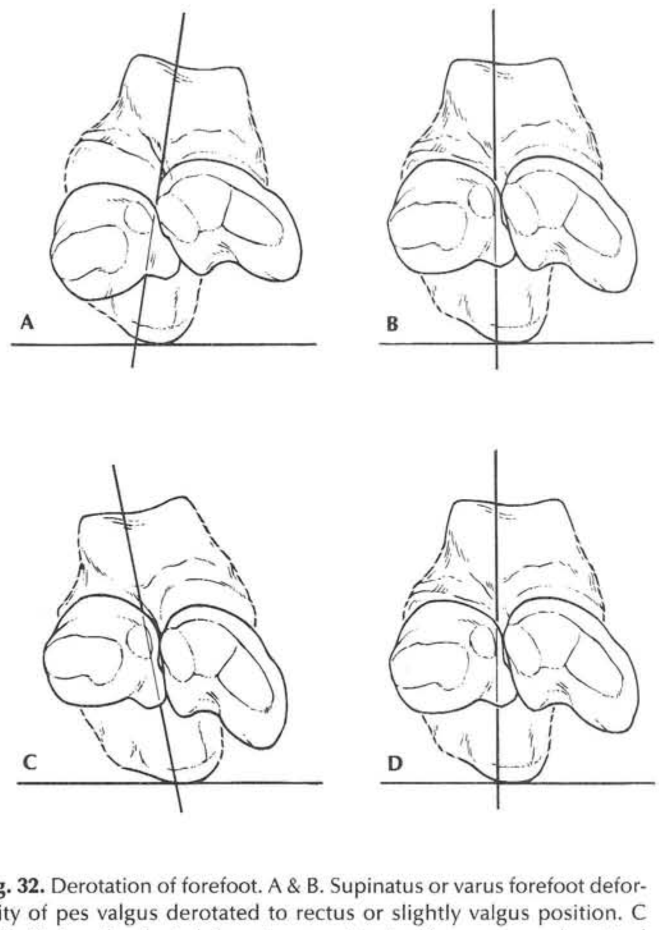


Fig. 32. Derotation of forefoot. A & B. Supinatus or varus forefoot deformity of pes valgus derotated to rectus or slightly valgus position. C & D. Valgus forefoot deformity associated with pes cavus derotated to rectus or slight valgus position.

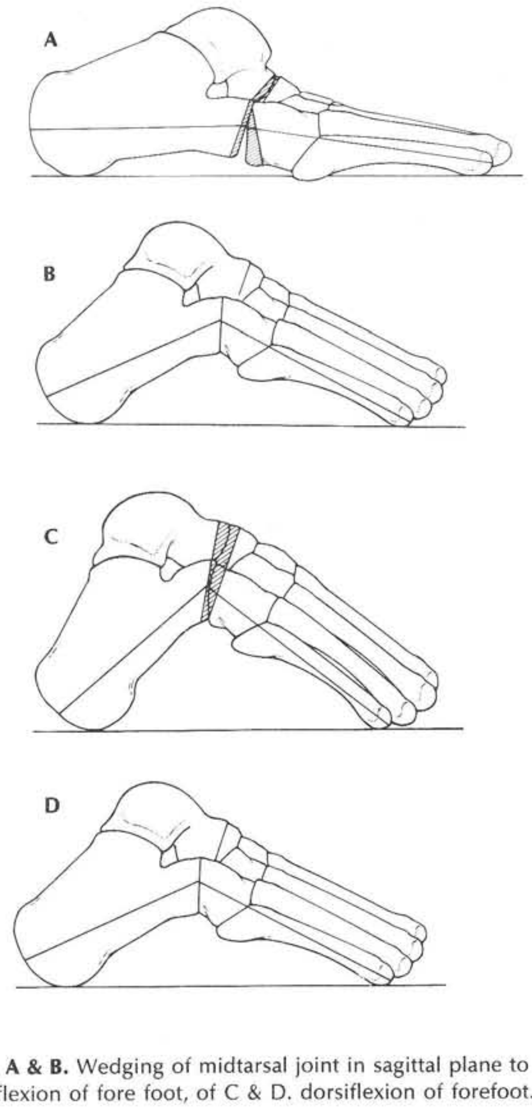


Fig. 33. A & B. Wedging of midtarsal joint in sagittal plane to afford plantarflexion of fore foot, of C & D. dorsiflexion of forefoot.

ated. The midtarsal joint can then be derotated, wedged as needed, and shaved or planed with the oscillating blade until a perfect fit is obtained. The foot is then held in corrected alignment while the talonavicular and calcaneocuboid joints are temporarily pinned.

Avoid Varus Deformity

Because we are so accustomed to treating pronation we tend to want to avoid pronation in most situations. This is NOT the case in triple arthrodesis. When the subtalar and midtarsal joints have been fused the foot has NO mechanism to compensate for varus. Therefore it is imperative to avoid arthrodesing the foot in a varus position. A mild valgus position is acceptable, even desirable, but a varus position of fusion results in a painful foot deformity that cannot be accommodated by shoe or orthosis.

Reciprocal Planing

Reciprocal planing is a technique initially developed and employed in triple arthrodesis. Since its inception it has proven useful in many other areas of osseous work. This technique has been compared to "feathering" but is quite different. The purpose of reciprocal planing is to provide a smooth, flush fit to the osteotomy or resected joint surfaces.

After joint resection or an osteotomy has been performed the surfaces are aligned and inspected. Often times the alignment is adequate however the surfaces are not flush. At this point a large power saw is introduced to the osteotomy site to remove the high spots on the adjacent opposing bone surfaces. The blade is moved in and out quickly several times through the very center of the osteotomy to collapse the high spots until a smooth flush fit is noted.

This technique is used following fixation of the subtalar joint to gain proper alignment of the midtarsal joint.

Because of the complex interrelationships of the foregoing conditions it is our recommendation that all of the resections and temporary fixations be carried out and the foot x-rayed before proceeding to more perma-

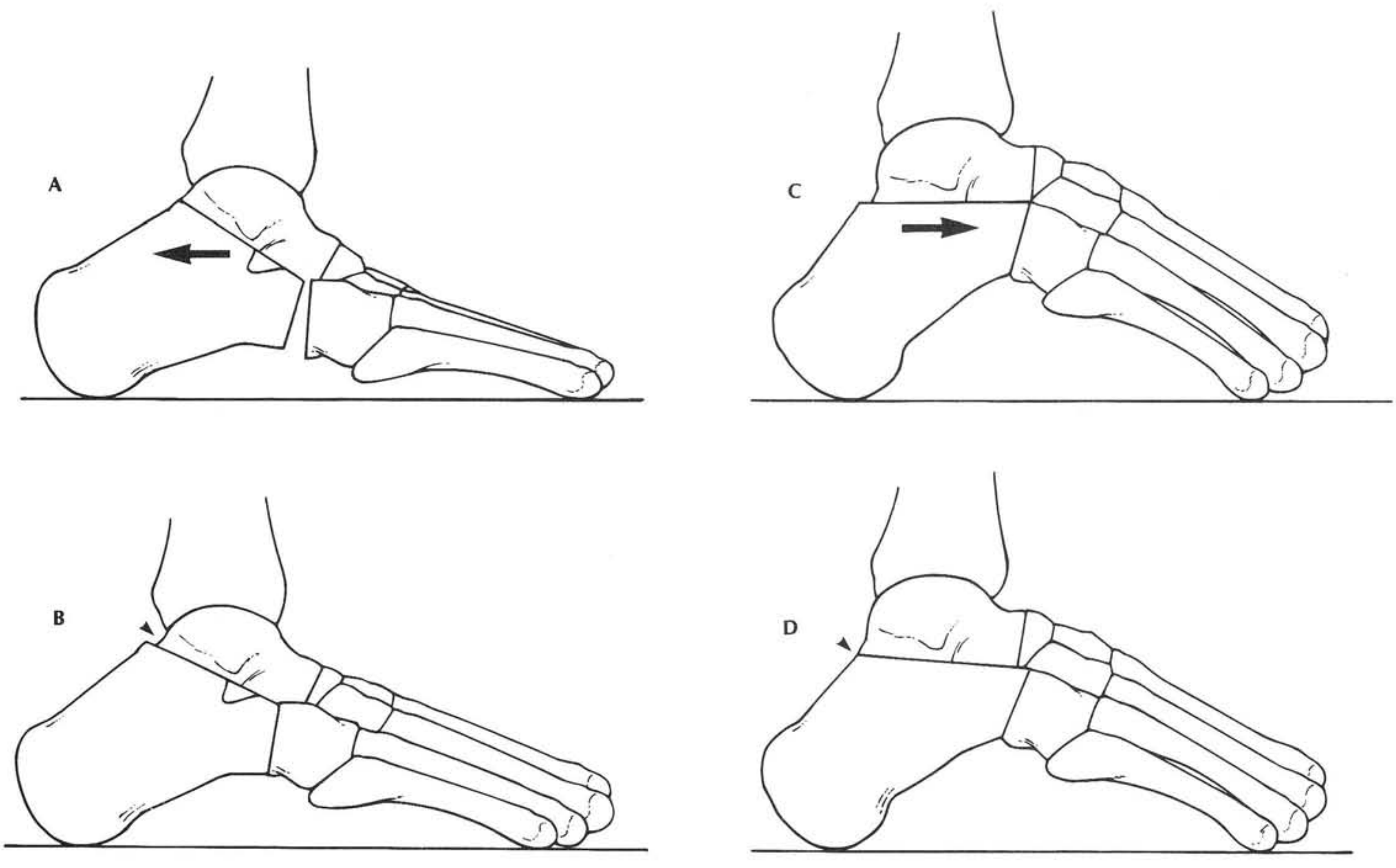
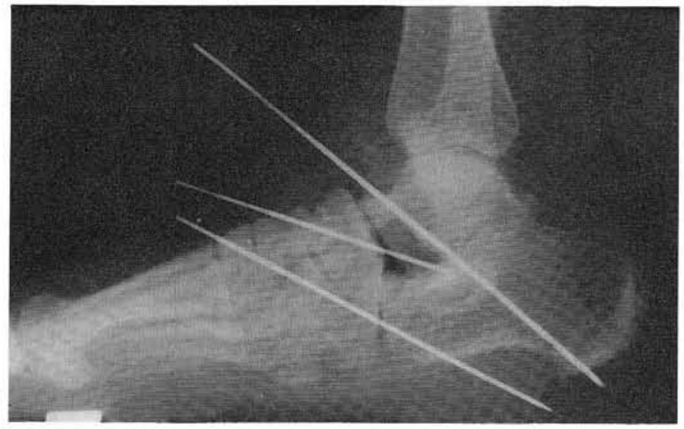


Fig. 34. Alteration of position of talus and calcaneus. A & B. Sliding calcaneus posteriorly on talus effects plantarflexion of forefoot on rearfoot (increased arch height). Sliding calcaneus anteriorly on talus effects dorsiflexion of forefoot on rearfoot (decrease arch height).

A

B



C

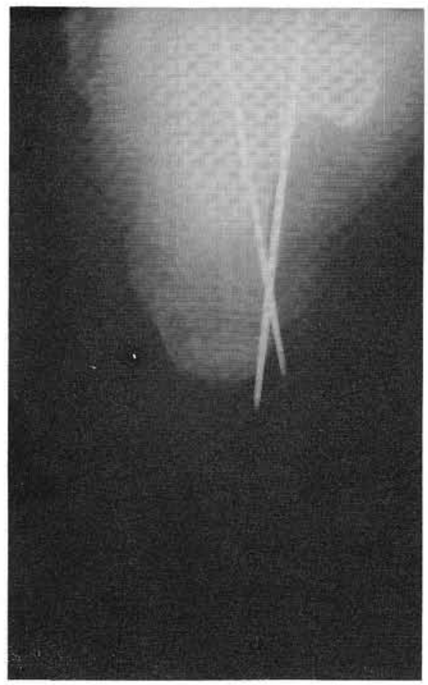


Fig. 35. Intraoperative radiographs illustrating temporary fixation. (AP, LAT, AXIAL).

nent fixation. If the x-rays substantiate satisfactory alignment then the permanent fixation can be installed. If on the other hand the alignment is less than satisfactory appropriate pins can be withdrawn and fitting or wedging accomplished before repinning and re-xray. With appropriate correction and good fitting of the realigned joints the permanent fixation is facilitated.

Rigid Internal Fixation in Triple Arthrodesis

The addition of rigid compression fixation to tarsal arthrodesis has led the way to more consistent joint fusion and to a decrease in nonunion, an all too common complication in the course of triple arthrodesis.

The cornerstone of rigid internal fixation in triple arthrodesis is the 6.5 millimeter cancellous bone screw. Other forms of fixation are often used in conjunction with the large cancellous screw; however, the primary stability of the rearfoot fusion is dependent upon the use of the large compression screw.

The technique begins with accurate joint resection and alignment of the rearfoot.

Subtalar Joint Reduction

The first joint to be fixated is the subtalar joint. The surgeon or assistant manually reduces the calcaneus beneath the talus in the proper position. Care must be taken to avoid varus positioning of the calcaneus.

With the subtalar joint reduced the surgeon or assistant then drives a Steinmann pin from the dorsal aspect of the neck of the talus across the subtalar joint and into the body of the calcaneus.

The pin can be visualized through the lateral incision and its correct relationship in the subtalar joint must be visualized.

Proper positioning of the pin is essential to rigid fixation. Radiographs are taken at this point in the lateral and axial projections (Fig. 35). The lateral projection confirms the proper point of entry in the neck of the talus and the proper angle crossing the subtalar joint. An estimate at the length of screw for fixation and its position within the body of the calcaneus can also be appreciated from the lateral projection.

The axial projection is also quite essential in this preliminary pin insertion. It is often possible to drive the pin medial to the main body of the calcaneus. The axial projection will identify the K-wire localized within the body of the calcaneus. If an inaccuracy exists the pin can be withdrawn, reinserted, and reconfirmed.

The surgeon must consider the placement of the fixation screw prior to the temporary fixation. Placement of the Steinmann pin or K-wire becomes an important step in the fixation process.

Midtarsal Reduction

The next step in fixation is the midtarsal joint. If proper bone resection has occurred there will be flush apposition of the talonavicular surfaces and the calcaneal cuboid surfaces. Steinman pins are then introduced from the distal medial surface of the navicular, crossing the talonavicular joint into the neck of the talus. A similar technique is used to bring a pin from the distal surface of the cuboid, crossing the calcaneocuboid joint into the calcaneus.

Radiographs are taken to confirm the proper alignment of the midtarsal joint; however, the actual placement of the pins is not as critical a point of this temporary fixation process. The pin placement must leave room for appropriate placement of the permanent fixation (Fig. 35).

Again, the surgeon needs to visualize the placement of his fixation devices and avoid unnecessary repetition of steps, i.e. repositioning of temporary fixation prior to permanent fixation placement.

As mentioned earlier, the 6.5 mm cancellous screw is the cornerstone of the internal fixation process. The technical steps for placement of the 6.5 mm cancellous screw will be reviewed also.

Subtalar Joint Fixation

Fixation of the subtalar joint is facilitated by proper placement and alignment of the initial Steinman pin. The screw position should parallel the placement of this wire. In some instances the initial K-wire may be the actual position of the screw as presented in previous seminars but this technique has been modified. The AO three hole drill guide may be used to guide the placement of the 3.2 mm drill bit so a true parallel line and position is established.

Technical Steps for Fixation of the Subtalar Joint With the 6.5 mm Cancellous Bone Screw (Fig. 36)

1. *3.2 millimeter drill* is passed directly into the hole created by the K-wire. The drill crosses the subtalar joint and penetrates into the body of the calcaneus for the appropriate depth of the compression screw.

2. *Depth gauge* is used to measure the actual length of compression screw needed. (*Counter sinking* is omitted to avoid over-reaming of the dorsal neck of the talus. Penetration of the head of the screw with the great force of compression that is used is possible with the large compression screw. The original placement of the primary fixation pin is critical to avoid impingement of the head of the screw with the ankle joint range of motion.)

3. *6.5 millimeter tap* is then used to cut the threads for the screw across the neck of the talus and into the body of the calcaneus. The tap is graduated to ensure tapping to the proper depth.

4. *Selection of cancellous bone screw*. The 6.5 millimeter screw comes with a long and short thread pattern. The long 32 millimeter thread pattern is usually selected for greater purchase in the body of the calcaneus. (A washer is occasionally selected for use with the compression screw especially if the bone substance of the neck of the talus is somewhat soft.)

5. *Insertion of cancellous bone screw*. The 6.5 cancellous screw is then inserted across the neck of the talus, through the subtalar joint, and into the body of the calcaneus. Extreme compression is created and should bone grafting be necessary it should be inserted into the subtalar joint prior to final tightening of the large compression screw.

Talonavicular Joint Fixation

Fixation of the talonavicular joint is usually the most difficult. In order for a large compression screw to be used in this joint an extreme distal approach must be used. Surgical dissection must be extended past the level of the cuneiform and counter-sinking is done in part by an advancing groove within the body of the cuneiform. This allows the head of the screw to glide past the cuneiform and compress against the distal surface of the navicular.

The identical steps for insertion of a compression screw are utilized; however, the point of approach should be at the distal inferior surface of the navicular

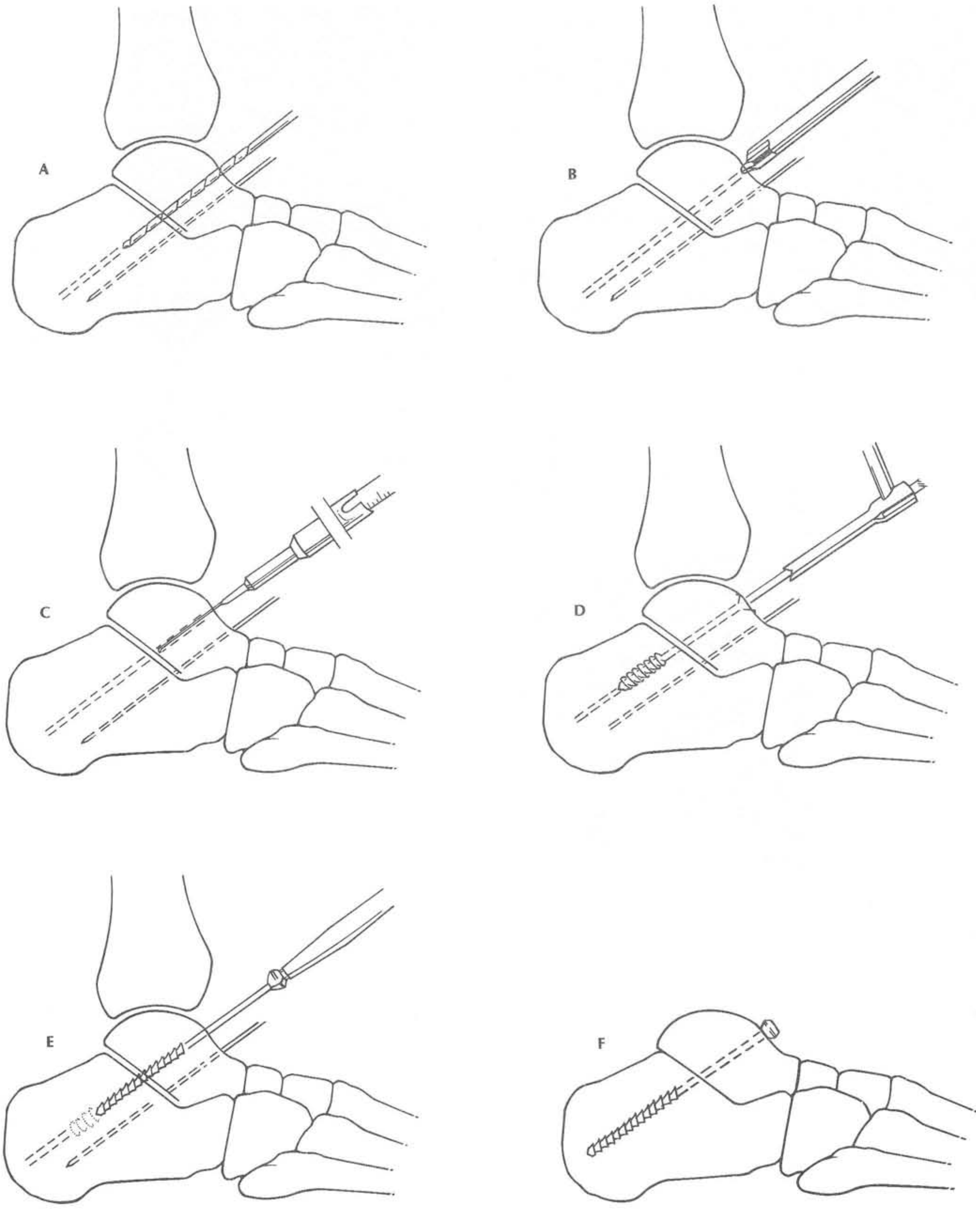


Fig. 36. Illustration of fixation with 6.5 mm cancellous screw, subtalar joint. A. Drill hole parallel to temporary fixation. B. Countersink (May be eliminated ocasionally). C. Depth gauge. D. TAP. E. Screw placement.

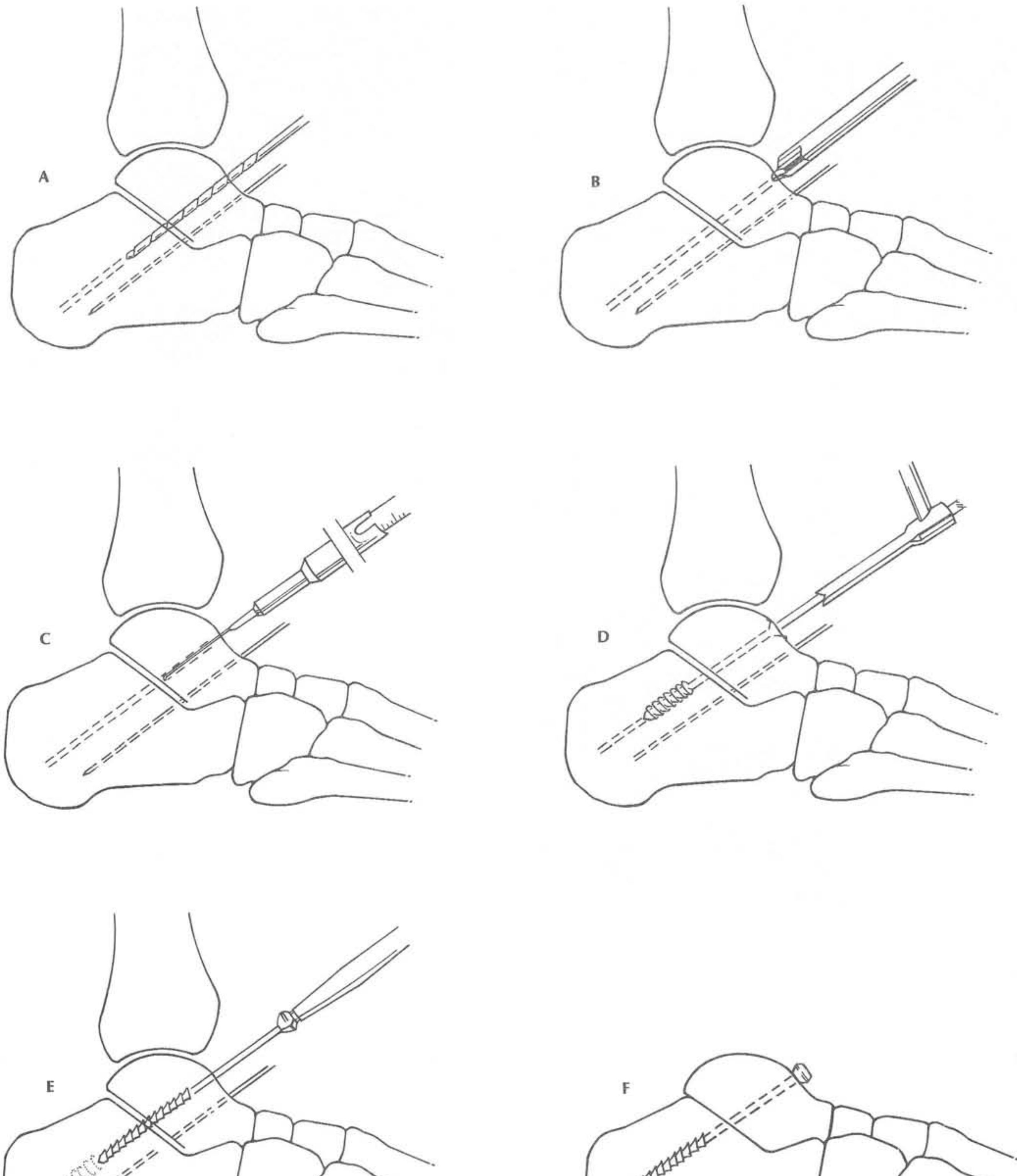
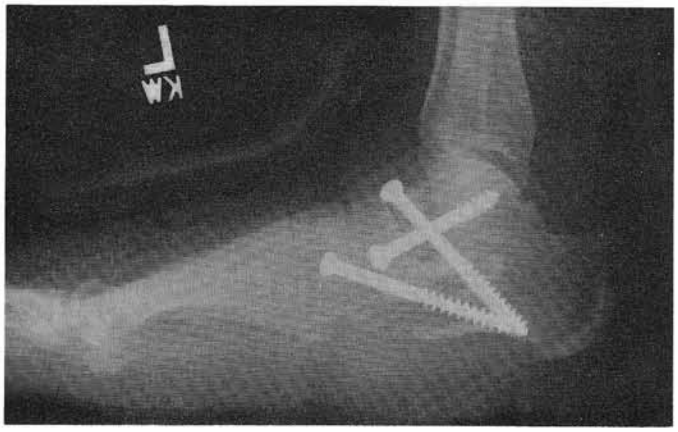
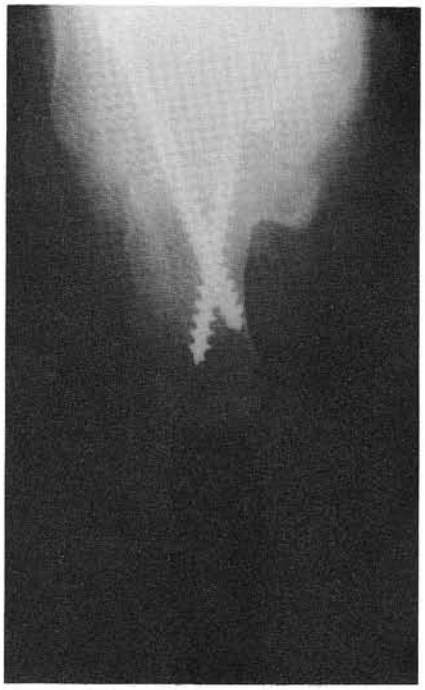


Fig. 36. Illustration of fixation with 6.5 mm cancellous screw, subtalar joint. A. Drill hole parallel to temporary fixation. B. Countersink (May be eliminated ocasionally). C. Depth gauge. D. TAP. E. Screw placement.

A



C



to allow proper angulation across the talonavicular joint and into the neck of the talus.

This is usually the most difficult screw for fixation. However, if a large 6.5 compression screw can be successfully applied across the talonavicular joint, extremely rigid compression fixation of this joint is possible.

Calcaneocuboid Fixation

A similar technique is then utilized to fixate the calcaneocuboid joint. A distal approach on the cuboid is necessary. Penetration of the screw is usually at the junction of the base of the fifth metatarsal and the cuboid joint. If use of the large compression screw is feasible, fixation of the calcaneocuboid joint will be extremely rigid (Fig. 37).

B

Fig. 37. Radiographic confirmation of internal fixation.

An alternative method of fixation of the midtarsal joint is using Blount staples. There may be times when the technical execution of the 6.5 mm screw is not accomplished or is not stable. In cases where the cancellous bone is not adequate to support a screw staples provide rigid fixation. One author (EDMc) prefers staples for the midtarsal joint but uses the 6.5mm screw for fixation of the subtalar joint. If staples are used, they should be oriented 90 degrees to one another and two staples should be employed in each joint, talonavicular and calcaneocuboid (Fig. 38).

Care must be taken to ensure that the staples do not impinge on other joints upon motion. Their placement and positioning should not be random.

Previous methods of fixation have included K-wire, Steinmann pins, circlage wire. These techniques are reserved purely as alternatives where more rigid fixation is not possible.

Once appropriate and stable fixation has been achieved, the layers are closed in a traditional fashion. Closed suction drainage is usually incorporated in the medial and lateral wounds.

The use of rigid compression fixation has greatly enhanced the success rate of fusion in triple arthrodesis. Rehabilitation can be initiated at a much earlier date because of the rigidity of the fixation.

Postoperative Management and Accelerated Aftercare

The authors and attending podiatry staff at Doctors Hospital manage the triple arthrodesis in a similar manner. Variation would arise in special circumstances such as insensitive patient, the patient with neuromuscular disease or imbalance, the severe arthritic with other osseous deformities.

Briefly, the postoperative management can be viewed as a sequence of phases beginning with the day of surgery and extending for the period of one or two years. The most common problems and complications will be discussed and their appropriate management.

Phase I: Initial Management. Days 0-5

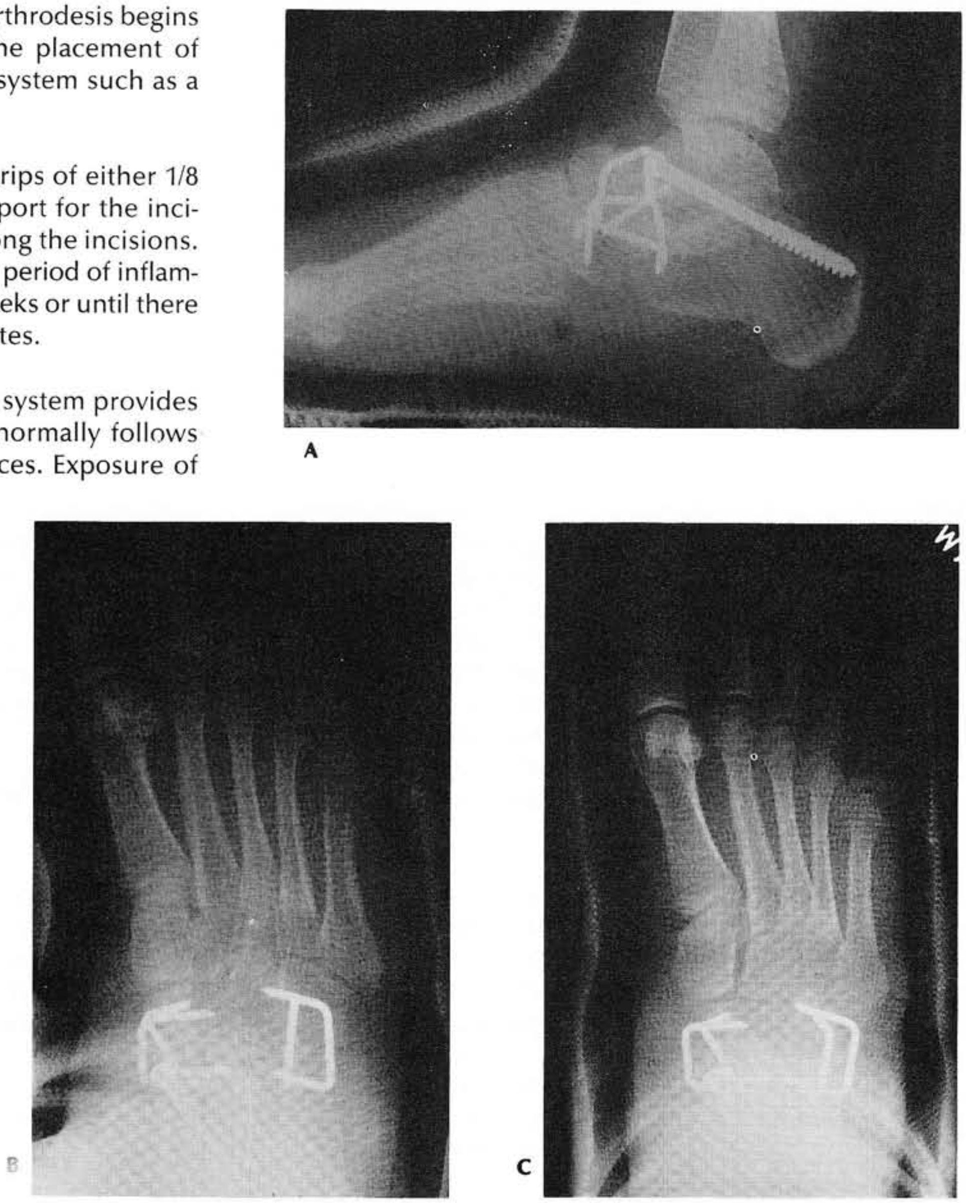
The initial management of the triple arthrodesis begins before closure of the incision with the placement of some type of closed suction drainage system such as a TLS drain.

After wound closure adhesive steristrips of either 1/8 inch or 1/4 inch will provide extra support for the incision lines by decreasing the tension along the incisions. Steristrips will be used during the initial period of inflammation and edema for a period of six weeks or until there is sufficient strength at the incision sites.

The use of a closed suction drainage system provides for the evacuation of hematoma that normally follows from resection of multiple bone surfaces. Exposure of the well vascularized cancellous bone is responsible for the large amount of hemorrhagic drainage that is present postoperatively. Prior to the advent of efficient and simple closed drainage systems large cumbersome drainage systems or gravity drainage were employed that often resulted in many bedside problems for patient and staff.

Placing a TLS drain medially and laterally will provide for evacuation of hemorrhagic and serous fluids during the immediate period to considerably reduce the edema. It is not uncommon for a triple arthrodesis to drain 200 to 300 cc or more over the first three postoperative days with the lateral drain providing two-thirds to three-fourths of the drainage.

Fig. 38. Alternative fixation of midtarsal joint with Blount staples.



A

B

C

Placement of the drain should be to facilitate the greatest drainage. Placing the drain in the subcutaneous level will rely on the compression dressing to provide compression to push the hemorrhage from the osseous layer.

During phase I the patient will undergo a cast change on or about the third postoperative day. This is extremely important for two reasons: 1) evaluation of the wound for progression of healing and possible wound infection, and 2) preliminary evaluation of the extent of edema. If the foot proves to be too edematous for casting at three days another compression dressing is employed for another one to three days. Occasionally the initial cast will provide adequate compression at the surgical site forcing edema proximally and distally. In cases where digital or forefoot work was done in conjunction with the triple arthrodesis this could prove to be detrimental. Once casting has been performed phase II begins.

Phase II: Consolidation. Day 5-four weeks, Nonweightbearing

The second phase in the management of the triple arthrodesis can be considered as a period of wound healing and waiting for the inflammatory phase to resolve. Depending on a number of factors casting can be of several forms; above knee, below knee, bivalved, synthetic or plaster. These factors include the type of fixation used, its stability and appropriateness, and the dependability of the patient.

There exists several philosophies for the management of this phase and the management is often as important as the surgical procedure. Inappropriate management may actually endanger the performed surgical procedure and pose even greater problems for the patient. If any problems exist with fixation, i.e. bone quality, poor fixation, non compliant patient, then above the knee casting is an appropriate choice. The above knee cast provides increased stability from the disruptive forces of torque that can take place at the midtarsal joint region. The above knee cast absorbs this disruptive force at the level of the thigh.

The bivalved cast will be utilized for patients demonstrating high physician trust. The cast may be bivalved the day it is applied or at three weeks postoperatively. Initially this is done to facilitate wound care with dressing changes taking place at ten to fourteen days post casting and then at two week intervals until the sixth week. Occasionally the patient may progress well enough so that after the fourth week dress ings are not needed. In these cases some type of elastic support for compression such as ace warps are used to enclose the foot from metatarsophalangel joints to above the ankle.

Phase III: Preliminary Physical Therapy. Weeks 4-8, Nonweightbearing

After one month radiographs are obtained to assess the progress of osseous healing. This will be repeated at two months. During this phase the patient becomes actually involved with the rehabilitation. The previously bivalved cast is removed for a total of one to two hours per day. Active and passive range of motion exercises of the toe, foot, and ankle are performed, initially while soaking (provided skin healing is complete) in a tub or whirlpool against no resistance. The goal of this phase is reduction of edema through range of motion exercises and continual compression. The above knee cast is cut down to a below knee cast.

Phase IV: Progressive Physical Therapy. Weeks 8-10-12.

This period is significant for more aggressive physical therapy. Radiographs are obtained at the eighth week (two months) to assess healing. Orthotic molds or impressions are also formed at this time. The goal of the device is to control midtarsal joint motion. This is best accomplished using a neutral shell with a 3/16 inch to 5/16 inch heel lift on the rearfoot portion. The goal is still reduction of edema. The patient may begin partial weightbearing with crutches or walker at ten weeks in some cases, beginning with weightbearing of 10% of body weight with gradual increase. The goal is for weightbearing at 12 weeks without assistance. A commonly encountered problem will be ankle pain, muscle weakness, especially the posterior group of muscles, with resultant calcaneal gait. The patient performs isometric exercises while lying or sitting down at night by enhancing range of motion against resistance for ankle motion. As weightbearing is begun new aches and pains will be experienced. These may be secondary to periods of decreased use while other discomforts were probably present before surgery but were unrecognized.

Phase V: Graduation (to full weightbearing) Months 3-6

At three months the uncomplicated ideal triple arthrodesis with good internal rigid fixation is ready for full weightbearing, preferably without assistance from crutches. Weightbearing is usually in some type of padded high top basketball shoe or padded work boot. The foot and ankle are continually supported and compressed with a closed heel device like a malleotrain, tubergrip stocking, or similar sorbothane/spenco type device designed to give compression to the ankle capsule area and rearfoot. Any support with an open heel is avoided as the open heel area becomes a site of edema and irritation. This period is continued until six months at which time the patient and physician must begin considering a back to work plan depending on the patient's type of work and the demands that might be placed upon him/her.

Below Knee Casting Management

A number of the triple arthrodesis patients are placed in below knee casts. These individuals selected for this type of casting generally have solid, stable, rigid internal fixation. They will progress through phase I in a similar manner but will begin phase II in a solid below knee cast and go directly to phase III.

Phase III: Preliminary Physical Therapy. Weeks 4-8, Below Knee Cast

Treatment is similar as before. The cast is bivalved, range of motion exercises are performed while resting, and ace wraps are applied to the limb. At this point it is not recommended that the malleotrain be used because the ankle and subtalar joint areas will still be mildly edematous and quite sensitive to the extreme pressure of a snugly fitting compression device. Again radiographs are obtained at four weeks and eight weeks.

Phase IV: Progressive Physical Therapy. Initial Weightbearing, Weeks 8-12

The situation of ideal fixation with normal progress of soft tissue and osseous healing should be the clinical picture. There should be a return of normal foot contours (medial and lateral lines), normal or near normal skin lines, and no decreased edema. This is the patient that may begin partial progressive weightbearing. Weightbearing is initiated at ten to twelve weeks with beginning contact at 10% of body weight progressing to 25%, to 75%, to 100% assisted weightbearing then finally 100% unassisted ambulation.

This phase may begin with a weightbearing walking cast of contact weight-bearing device similar to a Bledsole walking cast. The Bledsole cast tends to be quite cumbersome to sleep in so the bivalved cast is kept for sleeping purposes. The goal at twelve weeks is full weightbearing unassisted wearing a Bledsole cast or often a hightop padded basketball shoe.

Phase V. Graduation Months 3-6.

The weight-bearing device will be maintained until the patient can comfortably maintain the same activity level in a hightop shoe or sneaker. Accommodation of edema with elastic support, such as the malleotrain, is usually tolerated at this point. The goal is to return to work at six months.

Emphasize to the patient that footwear is important. If a low cut oxford type shoe is worn before 12 to 16 weeks, the patient may develop moderate to severe edema at the shoe counter. This can be minimized with use of the malleotrain ankle brace.

If the physician is not confident in the form of fixation used, fears that the patient is in poor compliance, or is concerned about the physician who will be doing the after-care, twelve weeks in an above knee cast is an acceptable method of management. The postoperative physical therapy will need to be more aggressive as stiffness will be more of a problem.

Problems

The number one problem encountered or expected is edema. The second is usually osteoporosis with associated pain and prolonged soreness though it is lessened with early active range of motion.

Wound Complications

Eschar which may separate wound margins is usually the result of an intraepidermal hemorrhage. The result will be a small slough followed by granulation tissue. This can be stimulated with gentian violet (2%). The full thickness eschar may become a source of irritation with pressure about the surrounding tissues. The problem can best be treated with thinning of the eschar with a drill and debriding the tissue as necessary.

Arthritis patients with multiple joint complaints will have a stable foot but the conditions of their other joints will not be valued by the triple arthrodesis. Other encountered problems include difficulty with the walker or crutches, possibility of wound dehisence, perineal tendonitis, entrapment neuropathy.

FLOW CHART

Phase	Above knee cast (bivalve)	Below knee cast
I Immediate Post Op Days 0-5	Closed suction drain Compression cast Rest, ice, elevation Pain management Wound management Cast change Postoperative radiographs No weightbearing	
II Consolidation Day 5 to 4 weeks	Dressing changes week 2, 4 No weightbearing Dressing maintained 4 to 6 weeks Radiographs at 4 weeks Wound support after dressing removed * Avoid long periods of dependency	Dressing change week 4 Radiographs at 4 weeks
III Preliminary Physical Therapy Week 4-8	AK cast changed to BK cast Dressings removed Elastic support Hydrotherapy, moist heat Range of motion no resistance No cast for short periods Avoid edema	BK cast bivalved Dressings removed Elastic support Hydrotherapy Range of motion No cast for short periods Avoid edema
	Nonweightbearing Radiographs week 8	
IV Progressive Physical Therapy Week 8- 10-12	Radiographs at week 8 and 12	Same
	Cast for orthotics (heel lift)	Same
	Continued elastic support (closed heel)	Same
	Malleotrain (after 12 weeks)	Same
	Range of motion against resistance	Same
	Muscle strengthening	Same
V Graduation Full weight bearing Return to work 12 weeks to 6 months	Unassisted full weight bearing	Same
	High top basketball shoe or work boot	Same
	Continued elastic support	Same
	Increased physical therapy	Same
	Return to work — job dependent	Same

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