CALCANEAL FRACTURES: WHAT COULD BE . . .

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Introduction

The classic joint depression fracture of the os calcis is a devastating injury (Fig. 1). The injury has been relatively popular in orthopedic literature and has been classically described by such prominent authors as Essex-Lopresti, Bordeaux and Palmer. These authors have offered extensive insight into the mechanism of injury and consequences of these severe intra-articular impaction fractures of the calcaneus. While these discussions are interesting, they are not the main emphasis of this paper. A general consensus with regard to the mechanism of injury will be presented and the focus of this article will be directed toward a specific course of treatment, that of open reduction and internal fixation.

Biomechanical Principles Of Compression Fractures

Fractures of the os calcis sustained during a fall from a height (or direct impact load) are usually primary intra-articular fractures which cause disruption of the subtalar, and at times, the calcaneocuboid joints.

The fact that calcaneal fractures present a somewhat similar fracture pattern on x-ray suggest that the mechanism involved is fairly consistent. A basic discussion of orthopedic biomechanics will offer some insight into calcaneal fractures.

A fracture is the result of loading forces on the skeleton which exceed its elastic modulus. The primary force or "load" involved in a calcaneal fracture is compression. Secondary forces of shear and tension are then created to manifest the complex fracture pattern of the joint depression fracture of the os calcis. A homogenous cylinder can be used as a simplified model to demonstrate disruptive forces which occur when a uni-axial load is applied to a solid (Fig. 2).

As we can see in this model, the simple action of applying compression to an object creates all three of the disruptive forces which are manifested in compression fractures of the os calcis. Unfortunately, the calcaneus is not a homogenous cylinder and the fracture pattern produced will be complicated by uneven distribution of forces because of variations in the topography and loading points. Despite the multiplicity of variables which are present in

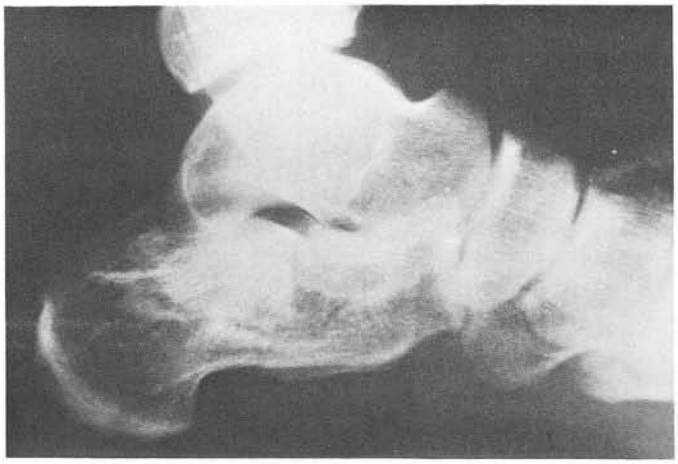


Fig. 1. Severe depression of posterior facet of calcaneus is depicted. Complete disruption of subtalar joint and intra-articular fracture of calcaneocuboid joint was seen intra-operatively.

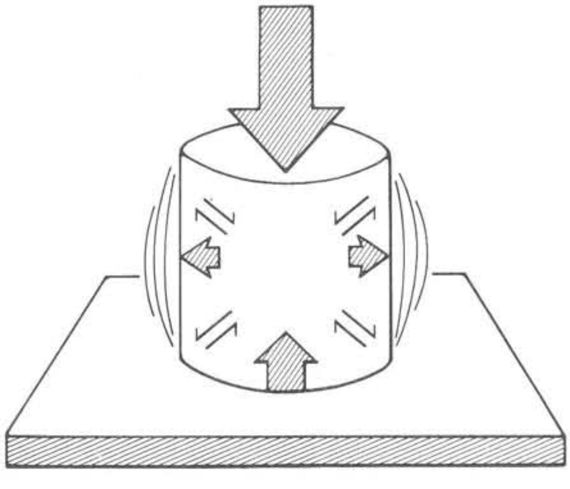


Fig. 2. Model depicts forces which result as compression (C) is applied to homogenous cylinder. Note that compression from above and below causes expansion of solid and tension forces (T). Finally shear strain (S) is effected at interface between compression and tensile components.

each clinical presentation, the basic components of the joint depression calcaneal fracture remain quite similar.

Mechanics of Injury

Tongue Fracture vs. Joint Depression

Essex-Lopresti describes two types of compression fractures of the os calcis which involve the posterior facet of the subtalar joint. He based his classification of a tongue-type fracture or joint depression fracture on the posterior exit of the primary fracture line which divides the posterior facet (Fig. 3).

The tongue-type fracture occurs as a sagittal or longitudinal fracture line separates a major lateral portion of the posterior facet from the medial aspect of the calcaneus. As the fracture line progresses posteriorly, it takes on a more plantar-lateral orientation or more horizontal plane and includes the entire superior portion of the calcaneal tuber and lateral portion of the posterior facet as a solid and intact segment of the fracture. In many cases, this fracture pattern takes on the appearance of an avulsion fracture of the superior portion of the posterior segment of the calcaneus and does not appear to involve the subtalar joint (Fig. 4). This however, according to Essex-Lopresti, Palmer and Bordeaux, is not the case as the tongue-type fracture definitely is a compression and shear fracture which does involve the subtalar joint in its superior extension.

The classic joint depression type fracture occurs when the lateral portion of the posterior facet, as an isolated segment, is depressed into the body of the calcaneus. A fracture line at the posterior rim of facet margin allows the lateral portion of the facet to separate from the proximal tuber and drive deep into the body of the calcaneus without proximal extension or the appearance of a tongue-type configuration.

The production of a tongue or a joint depression fracture is felt to be dependent on the sagittal plane position of the foot on impact. Thoren clearly demonstrated, in cadaveric studies, the significance of foot position on the mechanism of injury and subsequent fracture pattern. He found that the tongue-type fracture was consistently reproduced when the foot was impacted while in a plantar-grade or plantar-flexed attitude (Fig. 5). The joint depression type fracture occurred when the impaction force struck the foot in a dorsiflexed position driving the isolated segment of the posterior facet into the tuber of the os calcis (Fig. 6).

Joint Depression Fractures

Essex-Lopresti's description of the joint depression fracture postulated a sequence of events in the mechanism pattern. He felt that the initial fracture line was the result of the lateral process of the talus being driven into the calcaneus (Fig. 7). He described this initial phase of the injury as a frontal plane fracture which begins superiorly at the crucial angle and extends to the plantar cortex dividing the calcaneus into anterior and posterior segments. The level of the frontal plane fracture is most commonly seen at the anterior edge of the posterior facet.

However, this frontal plane fracture configuration or crucial angle fracture is not always seen as was pointed out by Palmer and later by Bordeaux. Palmer felt that the initial fracture line in the joint depression type injury of the os calcis is a vertical shear fracture and is the primary fracture of this devastating injury. This sagittal plane fracture divides the calcaneus into a medial and antero-superior fragment, containing the sustentaculum tali and frequently a medial portion of the posterior facet, and a lateral-posterior fragment consisting of the lateral portion of the posterior facet and the calcaneal tuber (Fig. 8). This primary sagittal plane fracture which shears off the sustentaculum tali is consistently seen in all joint depression fractures of the os calcis. Both Palmer and Bordeaux felt that the cru-

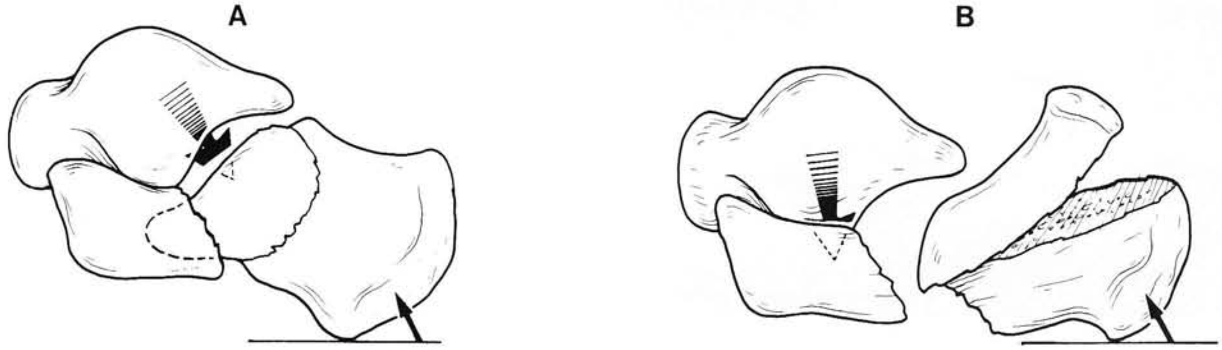


Fig. 3. Compression fractures of calcaneus classically are described as **(A)** joint depression, or **(B)** tongue type based on superior exit point of posterior facet fracture.

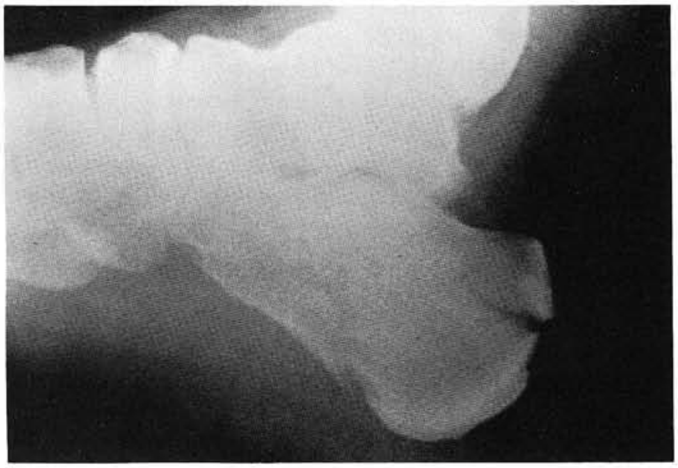


Fig. 4. Failure to recognize this fracture as intra-articular involving posterior facet of os calcis may lead to inappropriate treatment of injury.

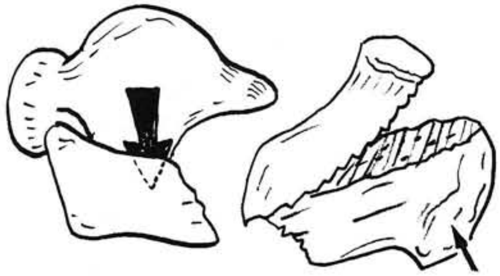


Fig. 5. Tongue type intra-articular calcaneal fracture is depicted. Plantargrade or plantarflexed foot position usually results in this configuration.

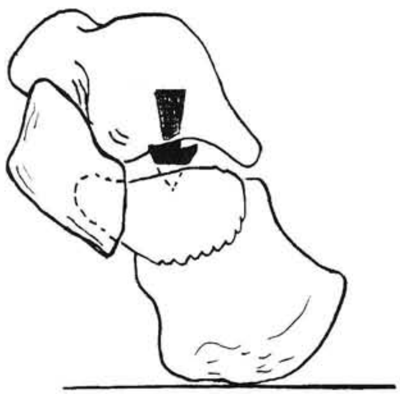


Fig. 6. Joint depression type intra-articular fracture is depicted. Dorsiflexed foot position at impact results in this fracture configuration.

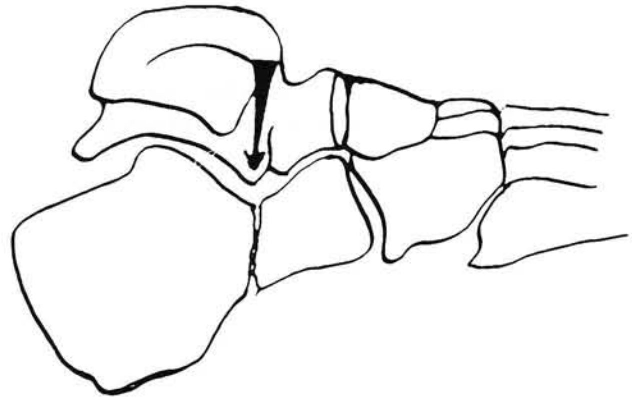


Fig. 7. Initial or "primary" fracture line as described by Essex-Lopresti was felt to be result of lateral talar process acting as wedge during compression injury.

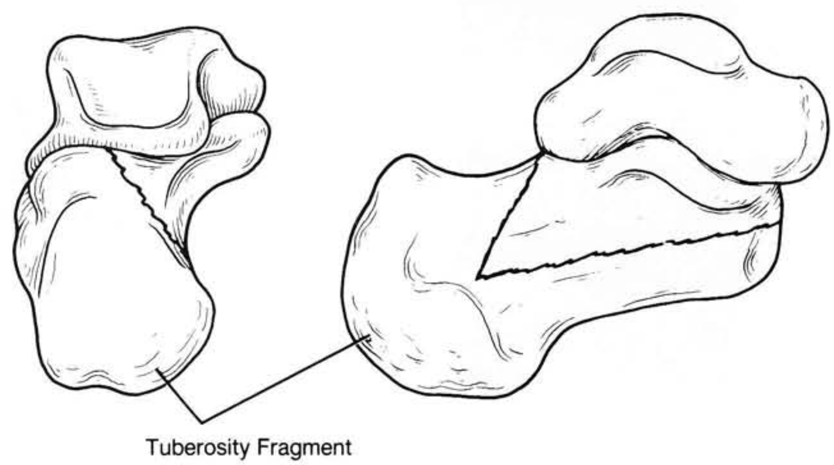


Fig. 8. Sagittal plane "shear fracture" divides calcaneus into anteromedial and posterolateral fragments as shown.

cial angle fracture described by Essex-Lopresti was a secondary fracture, which explained its absence in a significant percentage of the cases examined.

The last consistent portion of the intra-articular calcaneal fracture is the lateral wall "blow-out". The lateral portion of the posterior facet of the subtalar joint becomes an isolated impaction fragment with progression of the joint depression injury (Fig. 9). The fragment has initially been created as the medial portion is sheared away with the primary sagittal fracture line. The lateral portion of the posterior facet then further impacts into the body of the calcaneus with a combination of secondary fracture lines. The anterior defect can occur with the occurrence of the crucial angle fracture as the anterior edge of the posterior facet is depressed into the body of the calcaneus and separated from the neck portion of the calcaneus. Posteriorly, a secondary fracture line occurs around the rim of the facet and can allow the lateral facet fragment to separate from the calcaneal tuber. And finally, the isolated and free impaction fragment of the lateral portion of the posterior facet is created as a secondary lateral fracture occurs at the base of this major facet. This allows the complete separation and impaction of the isolated lateral portion of the posterior facet of the calcaneus to be depressed inside of the lateral wall of the calcaneus and deep into the body itself.

As the lateral portion of the posterior facet of the subtalar joint is driven into the body of the calcaneus, the body is expanded and osseous failure occurs as the outer wall of the calcaneus is exploded laterally. This medial to lateral expansion of the calcaneus results in another sagittal plane fracture line as the wedge action of the lateral segment of the posterior facet shears away the lateral wall of the calcaneus.

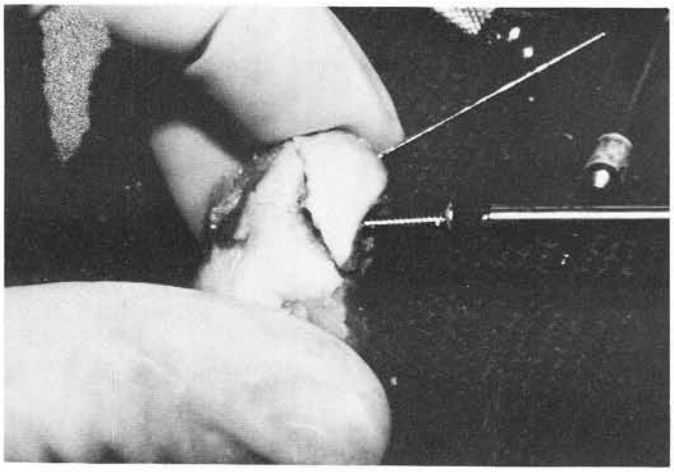


Fig. 9. Lateral portion of posterior facet often completely detaches during joint depression type os calcis injury. Repair of fragmented portion of lateral aspect of posterior facet is shown. This entire fragment was then reimplanted and fixated within calcaneus restoring subtalar joint surface.

The sagittal plane fracture which creates the lateral wall blow-out can present as one of two basic configurations. The cortical type occurs when the fracture line extends distally and exits out the lateral wall of the calcaneus just proximal to the calcaneocuboid joint. The intra-articular configuration is created when the fracture line extends more longitudinally out into the calcaneocuboid joint creating another intra-articular fracture.

It can again be postulated that foot position can dictate the pattern of the lateral wall blow-out fracture. In a pronated foot, the apex of the lateral process of the talus and focus of the impacting force is directed inside of the lateral wall of the body of the calcaneus. This results in a wedge-like action that splits the neck of the calcaneus and extends distally to terminate as an intra-articular fracture of the calcaneocuboid joint (Fig. 10).

In a slightly supinated foot, the lateral process of the talus and direction of impaction force is directed external to the lateral wall of the calcaneus and the fracture line propagates out through the substance of the lateral cortex of the body of the calcaneus. In this type of lateral wall fracture, the distal exit of the lateral wall injury is proximal to the calcaneocuboid joint and may communicate directly with the frontal plane fracture line of the crucial angle fracture. It is this combination of fracture lines that makes the crucial angle fracture radiographically demonstrable (Fig. 11).

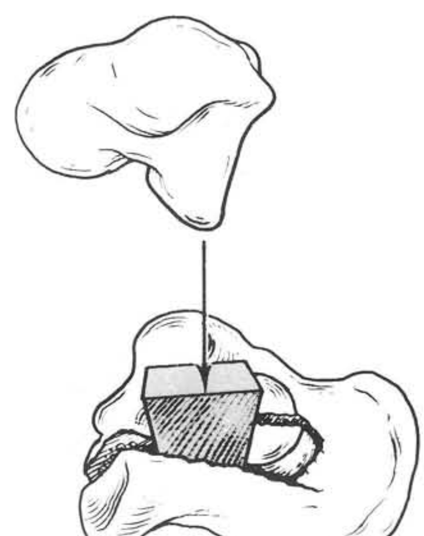


Fig. 10. Lateral process of talus acts as wedge as it descends within substance of calcaneus during compression type injury. An intra-articular fracture usually results within calcaneocuboid joint.

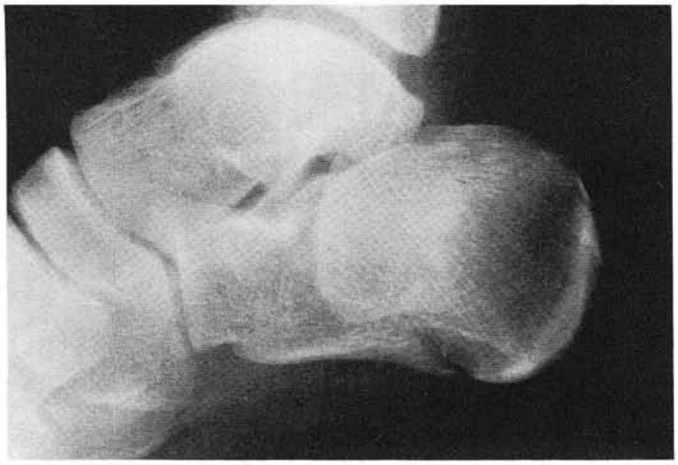
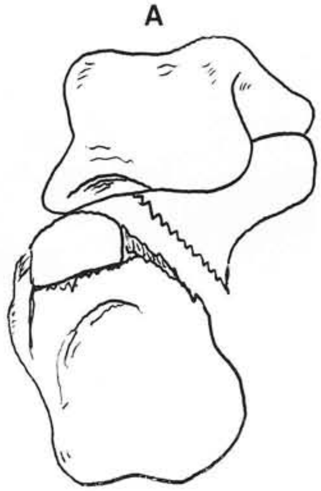


Fig. 11. "Crucial angle" fracture becomes visible when lateral wall blow-out exits proximal to calcaneocuboid joint and communicates with frontal plane fracture or primary fracture line.

A



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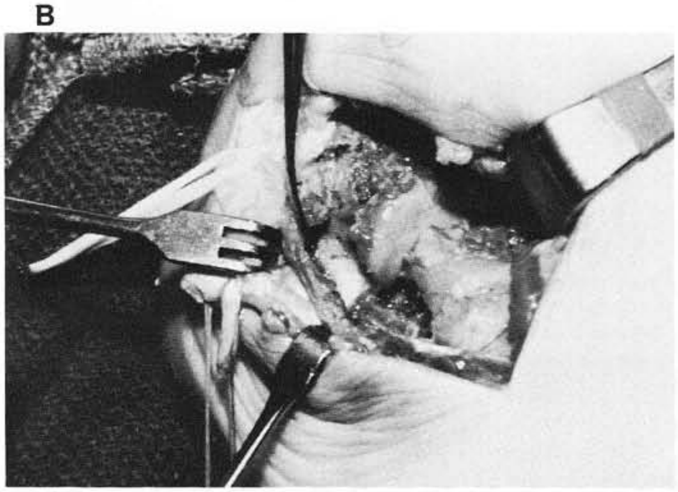


Fig. 13. A. Depicts fracture lines separating posterior facet from medial, posterior, and lateral aspects of calcaneus. **B.** Anterior and lateral separation of posterior calcaneal facet is seen in this severe joint depression fracture.

Fig. 12. Vertical fracture line seen in this axial radiograph divides calcaneus into anteromedial (sustentaculum) fragment and posterolateral (tuberosity) fragment.

Composite Mechanism and Pattern of the Joint Depression Type Fractures of the Os Calcis

Computerized tomography and intra-operative experience have greatly enhanced and completed our knowledge of the components of the joint depression type fracture of the os calcis. While there is often significant and interesting variation of the actual fracture lines, the basic components of this severe injury fall into a predictable and logical pattern. The consistent fracture patterns and resultant fracture fragments of the joint depression type of calcaneal fracture, in our experience, can be listed as follows:

1. Medial Fragment (Fig. 12) including the sustentaculum tali, resulting from a sagittal plane vertical fracture line.
2. Fracture and Depression of the Posterior Facet lateral portion of the posterior facet which has been separated:

   from the medial sustentaculum fragment by the primary sagittal plane fracture,

   from the proximal calcaneal tuber by depression and fracture at the posterior rim of the posterior facet (Fig. 13A),

   from the anterior neck by the crucial angle fracture, and

   inside the lateral cortex to begin the process of the lateral wall blow-out fracture (Fig. 13B).

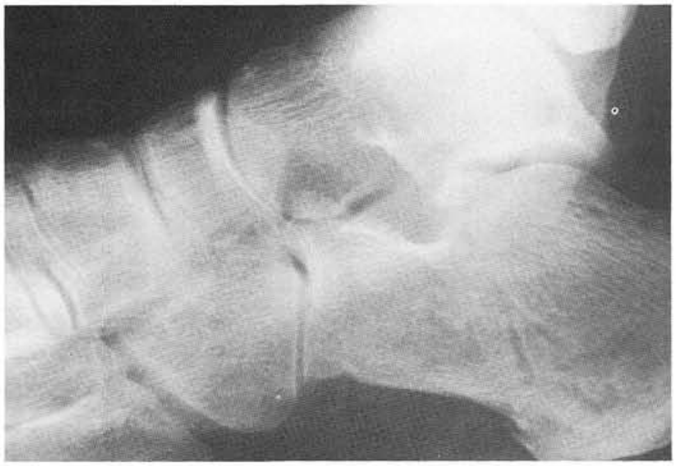


Fig. 14. Frontal plane fracture line is seen in this lateral radiograph of calcaneus. Fracture extends from crucial angle to plantar cortex.

3. Frontal Plane Fracture Line (Crucial Angle Fracture) (Fig. 14)
4. Lateral Wall Blow-Out Fracture (Fig. 15)

   Cortical Type

   (exiting distally through the lateral cortex of the calcaneus, short of the calcaneocuboid joint (Fig. 15A)

   or

   Intra-Articular Type

   (extending into the calcaneocuboid joint) (Fig. 15B).

Treatment of the Joint Depression Type Fracture of the Os Calcis

Historical Review

Treatment of the joint depression type fracture of the os calcis historically has ranged from benign neglect to bizarre reconstruction.

At one extreme, E.T. James and associates (1983) described a series of 16 patients all of whom had undergone amputation as final treatment for their os calcis fractures. In each case, the acute fracture had been treated conservatively without resolution of chronic and disabling symptoms.

Pozo and associates (1984) described a series of 21 patients who were treated conservatively for severely comminuted calcaneal fractures. The treatment regiment consisted of early range of motion of the ankle, subtalar, and midtarsal joints. Maximal recovery from the injury was described at two to three years. The vast majority of these patients experienced significant disability as a result of their injury, while the authors described the rating as "good" in 76% of the cases.

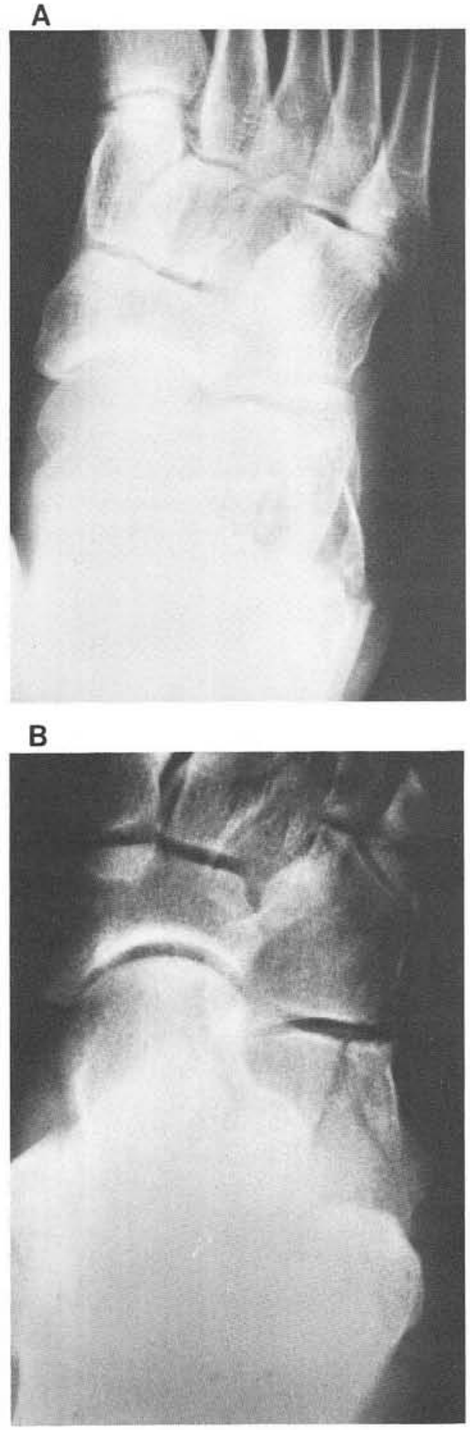


Fig. 15. Lateral wall "blow-out" fracture takes on two configurations. **A.** Cortical type results when fracture exits short of calcaneocuboid joint. **B.** Intra-articular type lateral wall fracture is seen in this dorsoplantar radiograph of calcaneus.

A technique of closed reduction was described in 1982 by Omoto and associates. The technique relied on a ligamentous traction and was recommended as the primary treatment for joint depression fractures.

A semi-invasive technique involving manipulation of fracture fragments with percutaneously inserted pins was presented by Nakaima and associates in 1983. They reported complete anatomic reduction in 58 out of 72 fractures.

Jarvholm and associates (1984) felt that primary surgical reduction of the fractured calcaneus was rarely indicated. He based his statement on finding no significant difference in his series of patients treated operatively or conservatively. However, review of the surgical technique of these authors revealed less than anatomic reduction and stable fixation of the fractures.

As early as 1948, Palmer recommended the use of open reduction and internal fixation, "osteosynthesis". The Palmer method is based upon a three point surgical plan for restoration of the configuration of the calcaneus:

1. reduction of the shearing fracture,
2. reduction of the secondary compression fracture of the articular surface, and
3. filling of the bony defect within the body of the calcaneus.

His early work is the cornerstone of most current surgical approaches to treatment of the joint depression type fracture of the os calcis.

Hammesfahr and Flemming (1981) described a series of patients treated with a variety of different techniques. Their findings included relatively poor results with percutaneous pinning of joint depression fractures. Their best results were obtained with primary open reduction and internal fixation via the Palmer method. They concluded "treatment of intra-articular calcaneal fractures should follow the same guidelines as the treatment of any other intra-articular fracture; that is, reduction of the articular surface and restoration of joint congruity."

Stephenson (1987) further supported the use of open reduction and internal fixation for the primary treatment of intra-articular fractures of the calcaneus. He described the primary approach to reduction of the calcaneal fracture from a lateral incision and combined a medial approach when necessary to ensure anatomic reduction of the medial shear fragment. Compression screw techniques were utilized as the primary fixation of the articular fragments. The primary fixation was supplemented when necessary with a buttressing staple to reinforce the lateral wall injury. Stephenson summarized his findings with the statement, "for optimum results in the treatment of displaced intra-articular fractures, the normal anatomy of the joint must be restored and motion of the joint must be started early."

We similarly have adopted the Swiss approach to the treatment of intra-articular fractures as the mainstay for reconstruction of joint depression fractures of the calcaneus. Judicious patient selection is obviously a primary consideration when pursuing a surgical treatment plan.

The Swiss concept for management of intra-articular fractures is relatively simple and straight-forward. It includes two basic premises:

1. Accurate reconstruction of the joint surface, (specifically the sub-chondral plate of the joint)
2. Early range of motion of the joint (while restricting weightbearing for an appropriate period of time.)

Application of the AO philosophy for management of intra-articular fractures to the specific injury of joint depression fracture of the os calcis can be expanded and specialized to include:

1. re-establish joint surface congruity of the calcaneal facets,
2. reconstruction and support of the understructure of the joint, (repair of secondary fractures and grafting of any significant bone defect),
3. realignment of the calcaneal tuber,
4. early range of motion and restriction of weightbearing (healing and repair of the cartilagenous surface of the joint).

With these ideals in mind and the appropriate technical skills at hand it is possible to pursue a realistic goal; successful repair of the joint depression fracture of the os calcis.

Open Reduction and Internal Fixation of the Joint Depression Fracture of the Os Calcis

Surgical Timing

While the acute fracture of the calcaneus may not be considered to be a surgical emergency, a rapid surgical intervention can be quite beneficial to the patient and the course of treatment. The os calcis is a highly vascularized bone with its extensive trabecular network and bony sinusoids. A severe joint depression fracture of the os calcis typically causes considerable internal bleeding with extensive edema and ecchymosis and a massive internal hematoma.

It is common to find extensive soft tissue damage associated with the os calcis injury. Devitalization of the skin can readily occur with the expansion of the dissecting hematoma. The extreme internal pressure of the hematoma can produce additional devitalization of the skin and also trauma blisters.

If the hematoma is allowed to persist for several days, the inflammatory response to this foreign substance can produce an extremely angry and fragile situation.

Early diagnosis and evacuation of hematoma through surgical intervention and postoperative management including closed suction drainage apparatus and compression dressings is the most direct method of avoiding wound complications and additional problems commonly reported in the management of this injury.

If surgical intervention is delayed, successful surgical reduction of the fracture fragments can be accomplished even as long as three to four weeks following the actual injury. The longer open reduction is delayed however, the harder it is to mobilize the individual fragments due to the anticipated bone healing process.

Radiographical Evaluation

While it is possible to miss a diagnosis of calcaneal fracture, radiographic examination of the fracture of the os calcis serves a more significant purpose than simple diagnosis. A variety of radiographic techniques can be used in the analysis of this injury and each can reveal unique aspects of this complex fracture. The common modalities used include:

- Standard roentgenographic views: Lateral, DP, and Oblique, Axial
- Linear tomography: medial to lateral projection
- Computerized tomography (CT scans): frontal plane projection.

Standard Roentgenographic Studies

Static views of the foot can provide very adequate analysis of the classic joint depression fracture of the os calcis. Each of the specific views can provide pertinent information about the nature and severity of the fracture pattern.

Lateral View

The standard lateral radiograph of the foot is routinely used for evaluation of the extent of joint depression in the os calcis fracture. Boehler's angle is classically utilized to give a degree rating to the extent of posterior facet depression. The normal foot demonstrates a Boehler's angle ranging from 20 to 45 degrees (Figs 16 A & B). Values that fall below this arbitrary normal range are commonly observed in the frank joint depression fracture. Below normal values may suggest joint depression when a calcaneal fracture is suspected by clinical history but not graphically demonstrated on the radiograph. It can also be of value in evaluating an old injury where a fracture actually occurred but was undiagnosed and the patient is now seeking care of a chronically painful condition. Contra-lateral views can also be of value when evaluating the obscure or occult injury.

The lateral radiographic view of the foot can also demonstrate secondary fracture lines, such as the crucial angle fracture and disruption of the plantar cortex in the more severe injuries.

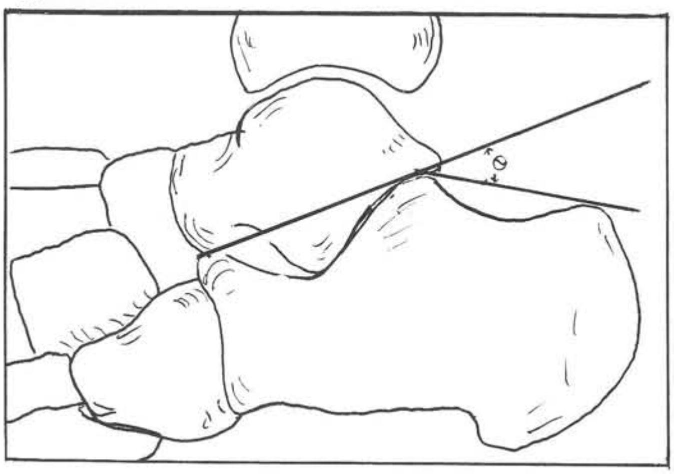
DorsoPlantar and Oblique Views

Both the dorsoplantar and oblique views of the foot primarily provide evaluation of the lateral wall blow-out fracture and the extent of calcaneocuboid joint involvement (Fig. 17). These views can demonstrate the distal exit of the lateral wall fracture and give additional information for formulation of the surgical plan.

Axial Views

The standard axial view of the foot can reveal one of the most dramatic distortions of the joint depression fracture

A



B

Fig. 16. A. Boehler's angle is measured at intersection of two lines. First line is drawn from posterosuperior aspect of calcaneal tuberosity to posterosuperior point of posterior calcaneal facet. Second line is drawn from anterosuperior aspect of anterior calcaneal process to same posterior facet point. Normal angle measures from 20 to 45 degrees. **B.** Severe joint depression results in narrowing of Boehler's angle. Contralateral films should be used in questionable cases.

Fig. 17. Dorsoplantar views are useful in evaluating calcaneocuboid joint involvement. Fracture into calcaneocuboid joint is readily identified.

Fig. 18. Standard calcaneal axial view reveals extent of subtalar joint disruption. Varus angulation of calcaneal tuber can also be evaluated.

of the calcaneus (Fig. 18). The axial view readily demonstrates the calcaneal tuber and the sustentaculum tali. The primary sagittal fracture line is usually clearly demonstrated and the extent of disruption of the sustentaculum tali is easily appreciated. Frontal plane angulation of the calcaneal tuber is typically visualized with an acute varus angulation, impaction of the medial-superior fragments and comminution of the medial cortex.

It is also common to identify the isolated lateral fragment of the posterior facet that has been depressed into the body of the os calcis. Determination of the extent of comminution of the posterior facet is difficult to ascertain in this view because of the degree of overlap and superimposition of the multiple fracture fragments.

In most cases, a complete study of standard radiographic views can provide a detailed picture of the joint depression fracture for the experienced trauma surgeon. Additional techniques such as linear tomography and computerized tomography may be necessary in unique situations when a complete appreciation of the fracture is not evident from the traditional studies.

Linear Tomography

Tomograms of the foot are really unnecessary in the analysis of the typical joint depression fracture of the calcaneus. These studies demonstrate a sagittal plane view of the os calcis and can only enhance appreciation of the extent of depression of the posterior facet of the joint (Fig. 19).

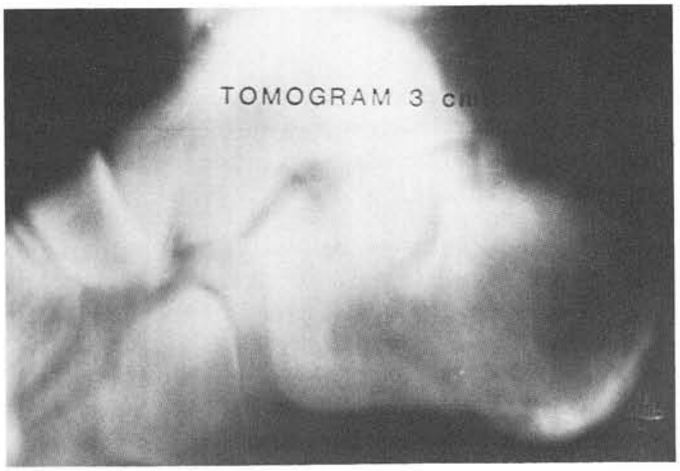


Fig. 19. Enhancement of visualization of joint depression fracture is afforded by linear tomography. Poor quality and resolution limit usefulness of this technique.

Computerized Tomography

CT imaging of the calcaneus for evaluation of the joint depression fracture clearly adds another dimension for appreciation and understanding of this injury. The frontal plane image obtained with the CT scan graphically demonstrates the sagittal plane fracture lines and relative displacement of the critical fracture fragments. This knowl-

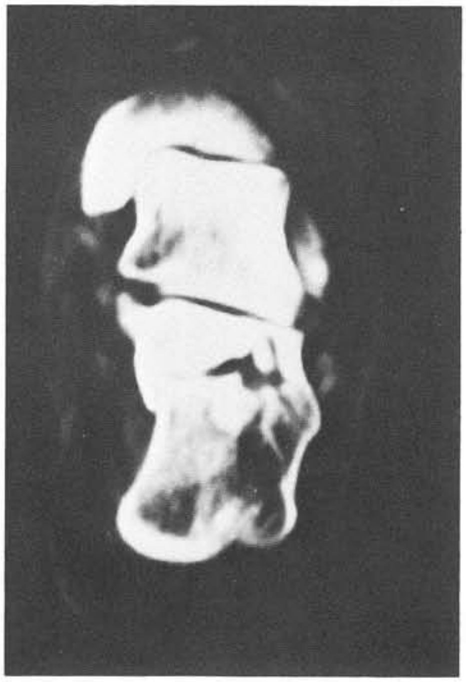


Fig. 20. Computerized tomography represents state-of-art imaging of this joint depression type fracture of calcaneus. Note severe involvement of posterior calcaneal facet and loss of internal osseous understructure in this calcaneus following joint depression injury.

edge can be extrapolated from standard radiographic views by the experienced surgeon, but the CT image leaves little room for imagination when evaluating the frontal plane aspects of this injury (Fig. 20).

The CT study can be very helpful in assessing the degree of fragmentation of the posterior facet of the subtalar joint and the degree of comminution of the remaining fracture fragments. This information can be of vital importance when considering surgical intervention in the severely comminuted and possibly irreparable fracture. Primary open reduction and internal fixation may not be a feasible plan when severe comminution of the articular fragments precludes accurate reconstruction of the joint surfaces.

Operative Technique

Incision Planning

Proper placement of the surgical incision is critical in the successful repair of the joint depression fracture of the calcaneus. Unrestricted exposure of the underlying osseous fragments or target structures is predicated on accurate placement of the skin incision. Because of the severe depression of the posterior facet of the calcaneus, the normal positional relationships of the lateral aspect of the foot and ankle are significantly altered. Great care must be taken to clearly identify the critical landmarks for plotting of the surgical incision (Fig. 21).

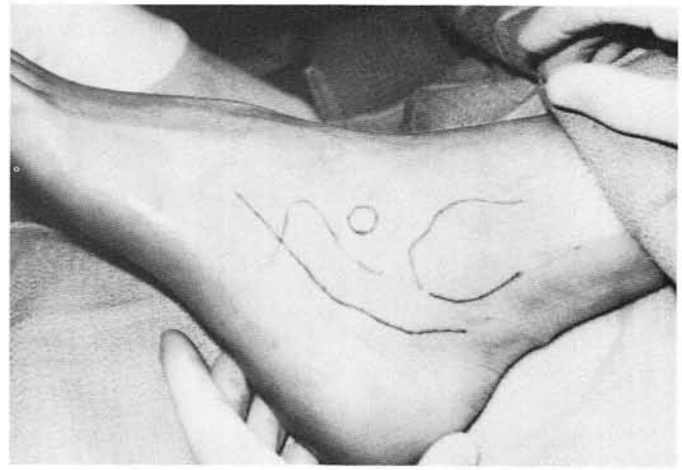


Fig. 21. Incision used in exposing calcaneal fracture is placed laterally. Landmarks for its course include dorsolateral margin of calcaneocuboid joint, tip of fibular malleolus, and superior-lateral margin of calcaneal tuber.

The key landmarks for placement of the incision include:

the dorsal-lateral margin of the calcaneocuboid joint,
the tip of the fibular malleolus, and
the superior-lateral margin of the calcaneal tuber.

The incision should cross each of these specified land marks to provide direct access to the critical components of the fracture complex, even in the presence of severe positional distortion.

As the incision courses proximally, it is directed linearly toward the superior-lateral margin of the calcaneus rather than curving around the tip of the fibular malleolus as commonly performed in other similar surgical approaches to the subtalar joint. This variation allows for direct evaluation of the posterior exit of the tuber fracture and accurate restoration of the posterior margin of the posterior facet to the calcaneal tuber. Care must be taken to avoid laceration of, or traction injury to the sural nerve and lesser saphenous vein which will be directly exposed (Fig. 22).

Soft Tissue Dissection

Dissection through the soft tissues over the lateral side of the foot for exposure of the subtalar joint and fracture fragments, while similar to that of an elective approach, is complicated significantly by distortion of key landmark relationships created by the joint depression fracture. The lateral process of the talus, which is a key targetting landmark in the clean approach to the subtalar joint is usually so severely depressed into the body of the calcaneus that it is not even palpable and therefore cannot be used as a guide into the sinus tarsi or the posterior facet of the subtalar joint. The soft tissues must be used as the initial guide to the deeper levels of the fracture.

Meticulous dissection is needed to identify the displaced osseous components of the fracture and still preserve the integrity of the soft tissues and vital blood supply.

Once the skin incision has been made, the standard techniques of anatomic dissection are used to separate the superficial fascial layer from the deep fascia over the lateral aspect of the foot and ankle. The deep fascia is most readily identified over the extensor digitorum brevis muscle belly and over the tip of the fibular malleolus. These two initial areas are exposed to facilitate separation of the superficial layers from the deeper layers over the area of the sinus tarsi and the posterior lateral aspect of the calcaneus.

The technique of separation is critical behind the fibular malleolus. Here, the dissection plane along the deep fascia must cleanly lift the superficial tissues away from the peroneal retinaculum and along the dorsal lateral margin of the calcaneus without actual incision through superficial tissues. The sural nerve and lesser saphenous vein course posteriorly around the fibular malleolus and can be preserved and protected by elevating this intact tissue layer and retracting it from the field of operation.

The next step in the sequence involves incision of the deep fascia along the inferior border of the extensor digitorum brevis muscle. The fascia is solely incised and the muscle belly is separated from the superior margin of the peroneal tendons (Fig. 23) to give direct access to the periosteum and capsular tissues over the lateral wall of the calcaneus and the region of the calcaneocuboid joint. The superior margin of the lateral wall blow-out fracture is usually encountered with this manipulation.

At this point, the lateral wall fracture is explored and the extent of joint depression is evaluated to determine the need for possible transection of the peroneal tendons. When there is significant depression of the major portion of the posterior facet into the body of the calcaneus, open reduction is greatly facilitated by Z-plasty or transection of the peroneal tendons (Fig. 24) to give free and unrestricted access to the lateral aspect of the calcaneus and subtalar joint region. If the degree of joint depression is less severe, open reduction may be accomplished without the need for transection of the peroneal tendons. While transection of the peroneal tendons can greatly facilitate the procedure, a significant degree of limitation of subtalar joint motion is commonly experienced due to fibrosis and loss of gliding function of these tendons through the surgical area. This is one area where the classic axiom "one wound, one scar" seems to hold true. The primary motion lost is in the direction of inversion and may be an acceptable consequence for successful anatomic restoration of the subtalar joint itself.

The extent of joint depression is specifically evaluated by exposing the area of the crucial angle fracture. Periosteum and muscle tissue is cleanly lifted from the dorsal

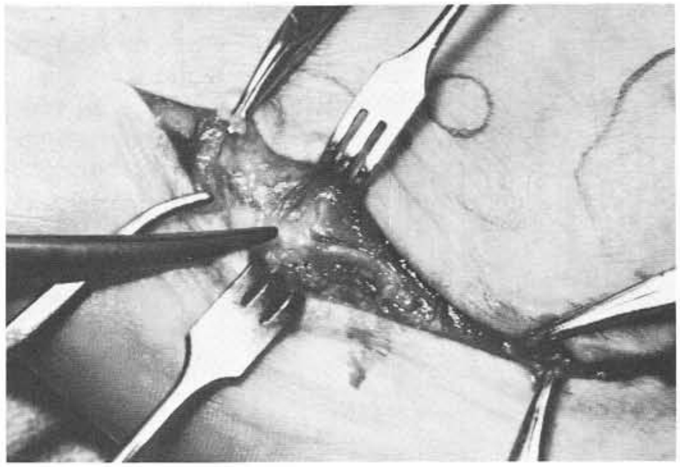


Fig. 22. Sural nerve is directly exposed during dissection for calcaneal joint depression fracture repair. Careful dissection and retraction of nerve will help prevent injury and entrapment.

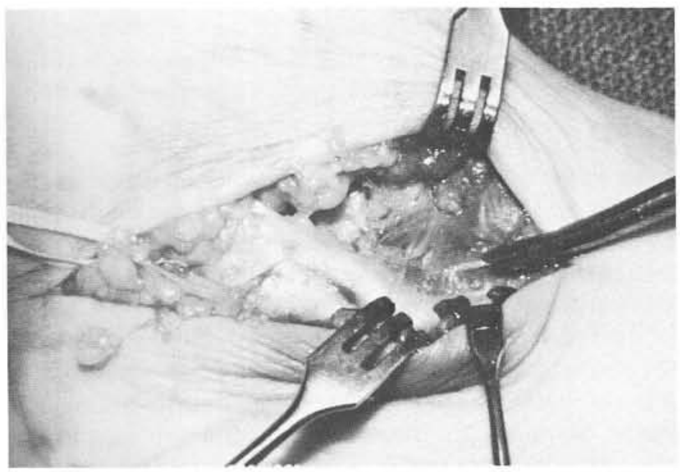


Fig. 23. Deep fascia is shown as it is incised superior to peroneal tendons.

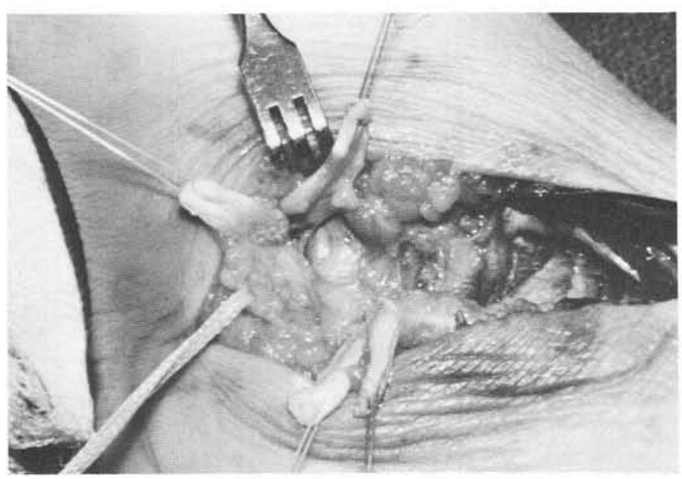


Fig. 24. Exposure of lateral wall of calcaneus may require "Z-plasty" transection of peroneal tendons. Colored suture material will aid in identification of opposing tendon ends during wound closure.

surface of the neck of the calcaneus. This dissection plane is followed proximally into the area of the crucial angle fracture and the once easily identified anterior margin of the posterior facet of the subtalar joint. Typically, as the crucial angle fracture is appreciated, an unfamiliar mass of bone blocks further proximal progression into the anticipated region of the sinus tarsi. This obstruction is actually the superior and anterior aspect of the lateral process of the talus. This critical distortion must ge appreciated before proper orientation of the relationships of the key fragments of the fracture can be identified.

The lateral process of the talus has been driven deep into the body of the calcaneus and the level of the posterior facet may not even be visible as the lateral facet fragment may have been recessed within the confines of the lateral wall fragment of the body of the calcaneus.

At this point, the soft tissues must be meticulously dissected from the key components of the joint depression fracture. The two critical areas to cleanly expose include the region of the sinus tarsi and the lateral aspect of the subtalar joint and calcaneus itself.

Exposure of the sinus tarsi began with elevation of the soft tissues from the dorsal surface of the neck of the calcaneus (Fig. 25). The capsular tissues from the anterior surface of the lateral process are also cleanly reflected as dissection is carried medially across the calcaneus at the level of the crucial angle fracture. Evacuation of the tissues of the sinus tarsi is usually necessary with resection of the fibro-fatty plug and the inter-tarsal ligament for full visualization of the neck of the calcaneus, the entrance to the sinus tarsi, and the level of the middle facet of the subtalar joint. These bony surfaces must be cleanly exposed for complete identification of the fracture lines that have disrupted the integrity of the calcaneal platform of the subtalar joint (Fig. 26).

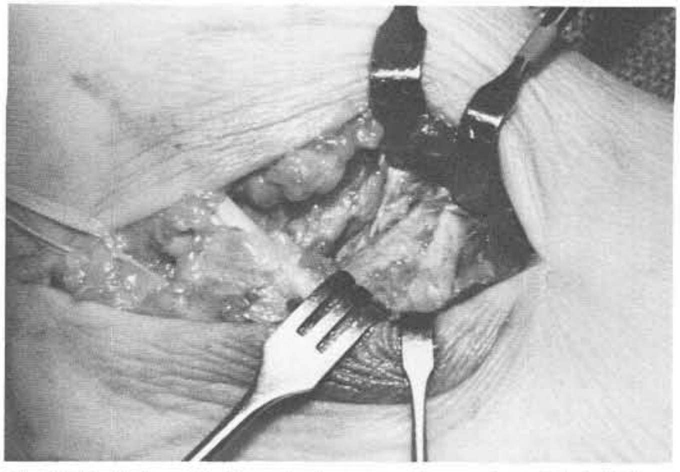


Fig. 25. Soft tissue is dissected across calcaneal neck to initiate exposure of sinus tarsi.

Once a determination is made with respect to transection of the peroneal tendons, the lateral wall fracture must be identified and its margins determined. With the peroneal tendons reflected, the calcaneofibular ligament is primarily transected and the superior edge of the lateral fracture is exposed. Minimal periosteal reflection is carried along the superior edge of the lateral wall plate to define its margins and identify its distal and proximal exit points. It is important to attempt to leave periosteum and ligamentous attachments to the major portion of the lateral wall fragments to preserve blood supply and maintain alignment if significant comminution has occurred.

Manipulation and Temporary Fixation

The key to reduction of the joint depression fracture of the calcaneus is elevation of the lateral segment of the posterior facet of the subtalar joint. The lateral wall of the calcaneus if folded laterally and the full extent of depression of the lateral segment of the calcaneal portion of the posterior facet is appreciated. A Sayer elevator is useful in the reduction sequence. The elevator is inserted beneath the main fracture fragment and used to apply an upward pressure on the lateral segment of the calcaneal facet. The fragment is usually totally separated anteriorly from the neck of the calcaneus at the level of the crucial angle fracture but may be hinged at its proximal aspect along the fracture line which separates it from the calcaneal tuber. The lateral portion of the facet must be elevated and retracted laterally to more fully explore and evaluate the internal fracture lines of the calcaneus, specifically the primary sagittal fracture line which has separated the sustentaculum tali from the lateral portion of the calcaneus. Additional secondary fracture lines may be present which even divide the medial aspect of the posterior facet from the sustentaculum tali as well. This multiple comminution pattern can significantly complicate the reduction and fixation process and can also represent more extensive damage to the primary posterior facet of the subtalar joint.

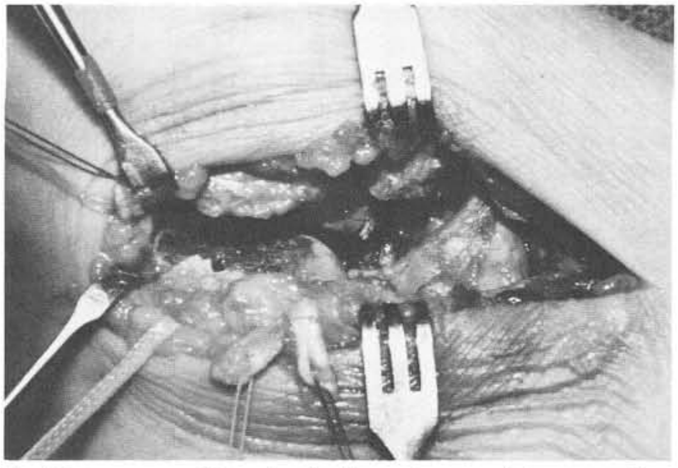


Fig. 26. Exposure of sinus tarsi will require complete evacuation of fibrous and fatty tissue located in area. Middle facet and calcaneal neck is easily seen once this dissection is performed.

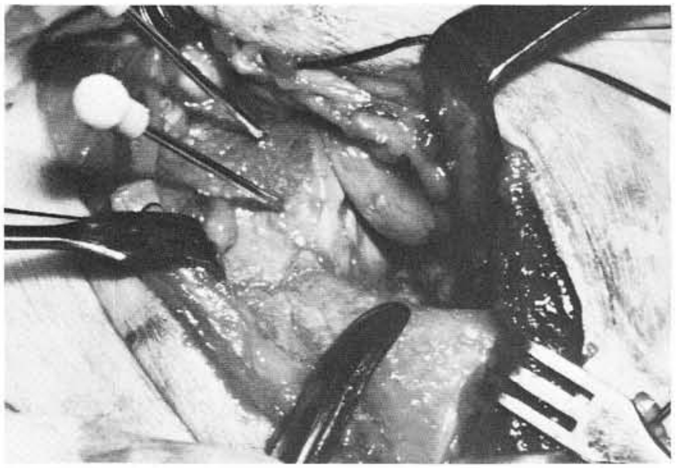


Fig. 27. Two 0.062 Kirschner wires (K-wires) are seen providing temporary fixation of posterior facet fragment to medial aspect of calcaneus.

With the fracture fully opened, copious lavage and removal of clot material and small fracture fragments must be performed to fully expose all surfaces of the fracture fragments and allow for clean anatomic reduction of the main components of the fracture.

The primary guideline in the reduction sequence is the restoration of the subchondral bone plate pattern of the posterior facet of the subtalar joint. The middle facet is intact and pinnacled as the medial apex of the reconstruction scheme. The primary structural fragment of the middle facet is the sustentaculum tali and the subtalar joint is actually rebuilt by re-aligning the sequential fracture fragments to the medial sustentacular fragment of the calcaneus.

The subchondral bone pattern of the medial fragment of the calcaneus is clearly visualized and the main lateral fragment is reduced by re-aligning the articular relationship of the posterior facet to the main medial fragment. In accomplishing this end goal, the anterior margin of the posterior facet will be elevated to produce reduction of the crucial angle fracture. Similarly, the posterior fracture line across the calcaneal tuber should be restored to its anatomic contour to confirm complete anatomic restoration of the calcaneal platform of the subtalar joint.

The primary lateral fragment of the posterior facet now becomes the pinnacle for reduction of the calcaneal fracture. Its anatomic relationship to the medial fracture fragments must be temporarily maintained for completion of the reduction and fixation process. Two 0.062 Kirschner wires (K-wires) are driven from lateral to medial to provide temporary fixation and a guide for permanent fixation (Fig. 27).

The fracture line that is being temporarily fixated is actually a sagittal fracture line running down the middle of the posterior facet. The direction of the Kirschner wires is essentially lateral to medial but at least one of these wires should be aimed at the focal prominence of the sustentaculum tali to establish complete medial to lateral transfixion of the calcaneus. Permanent fixation directed along this path from the main lateral fragment of the posterior facet to the main medial fragment of the sustentaculum tali will be accomplished with a small cancellous bone screw. This fixation device will actually act as an internal Boehler's clamp and also securely maintain restoration of the calcaneal contour of the facets of the subtalar joint.

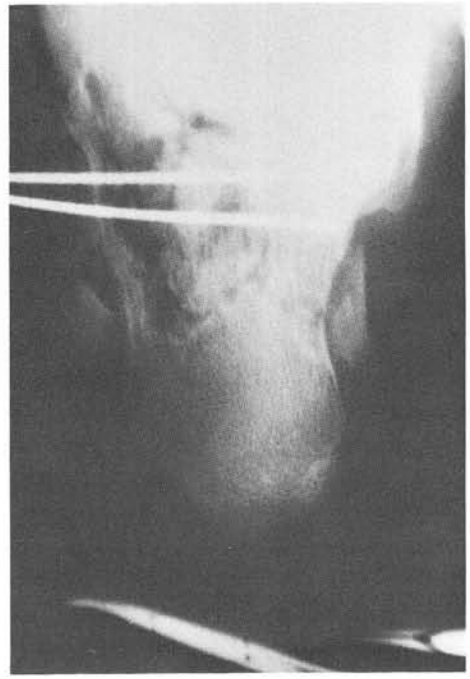


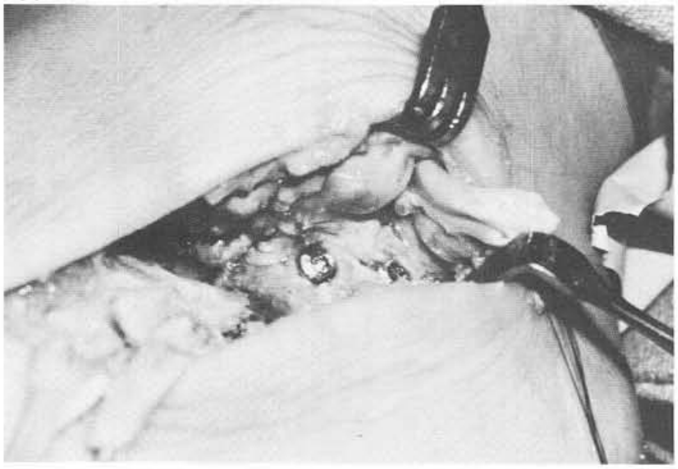
Fig. 28. Intra-operative radiographs verify restoration of normal facet patterns. 0.062 K-wires also acts to provide a guide for placement of permanent fixation.

Intra-operative radiographs should be taken once temporary fixation has been achieved (Fig. 28). A lateral projection will demonstrate the restoration of the normal facet pattern of the subtalar joint with elevation of the previously depressed posterior facet and a normal angular relationship between the middle and posterior facets. The axial view will reveal the remaining incongruity of the calcaneal tuber to the superior segment of the calcaneus which includes the anatomically restored articular facets of the subtalar joint. The calcaneal tuber is usually in a varus angulation and still apparently impacted.

Final Fixation

Once satisfactory restoration of the subtalar joint is determined, small cancellous bone screws are introduced for permanent fixation. Typically, one of the K-wires is removed and its guide hole is used for the thread hole of the compression bone screw. A standard technique is fol-

A



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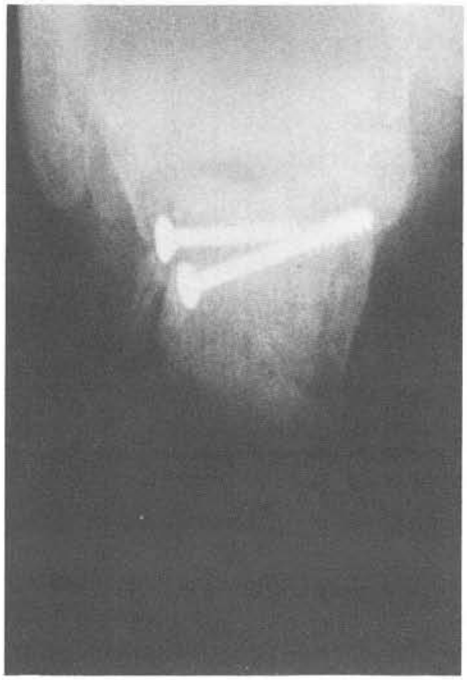

Fig. 29. Two compression screws are used to fixate main lateral fragment of posterior facet. **A.** Intra-operative appearance of compression screws is seen. **B.** Axial radiograph of same fracture seen in 29A.

lowed for insertion of the compression screws. If the alignment or position of the temporary K-wire was unsatisfactory, a new thread hole may be used for insertion of the fixation screws. The main lateral fragment of the posterior facet is usually fixated to the main medial fragments of the calcaneus with two compression screws and the remainder of the fixation process is continued (Fig. 29).

Reduction of the Calcaneal Tuber and Lateral Wall Fracture

The calcaneal tuber is actually reduced by classic closed reduction technique. The tuber is manipulated into a varus position and then distal tension is applied. The heel is then forcibly everted to realign the medial wall fragments and restore the anatomic position of the main body of the calcaneus beneath the subtalar facets. Successful reduction can be confirmed with a second intra-operative axial view of the calcaneus (Fig. 30).

At this point, reduction of the lateral wall blow-out fracture is all that remains. The internal substance of the calcaneus should be inspected before reduction of the lateral wall fragments. Cancellous bone chips can be inserted if significant loss of bone has occurred.

The two basic patterns of lateral blow-out fracture can be encountered. If the intra-articular pattern has occurred, restoration of the calcaneocuboid articulation becomes as important as the primary reduction of the subtalar joint facets. Lateral to medial compression screws are usually employed to fixate the intra-articular fracture which extends through the neck of the calcaneus and into the calcaneocuboid joint (Fig. 31).

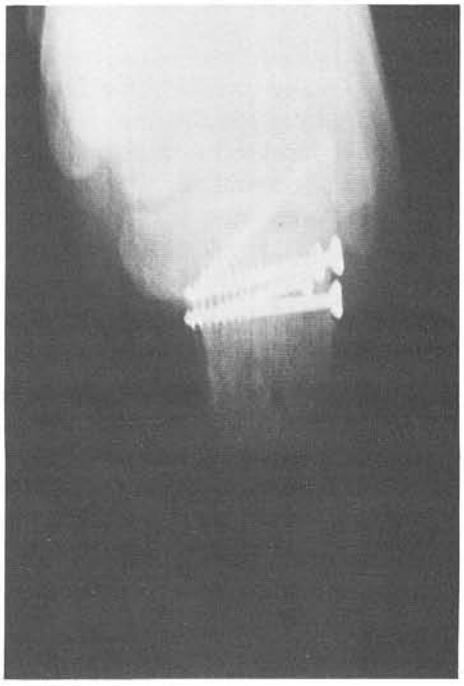

Fig. 30. Intra-operative x-rays are used to confirm proper screw placement and adequate fracture reduction.

Fig. 31. Compression screws were also used to fixate large intra-articular fracture of calcaneocuboid joint in this tongue-type calcaneal fracture.

Fig. 32. Jones compression dressing is shown. This type dressing allows for control of post-traumatic edema. Closed suction drainage is also employed.

The cortical type of lateral blow-out fracture can require a variety of different types of fixation. Comminution and fragile cortical bone may make solid and rigid fixation impossible. Lateral to medial fixation, however, is attempted with at lest one compression screw directed into the main substance of the sustentaculum tali. A laterally applied plate, staples, or even variations of tension band wire may be used to maintain reduction of the lateral wall fragments.

The key reduction, however, remains the restoration of the articular facets of the subtalar joint and re-alignment of the calcaneal tuber. A smooth and relatively normal range of motion can be attained once the alignment of the subtalar joint has been accomplished. Successful salvage of this joint is then dictated by appropriate postoperative management and maintenance of the initial fracture reduction.

Wound Closure and Management

Repair of soft tissues follows standard technique. Each tissue layer is closed separately and transected ligament and tendon are repaired primarily. A closed suction apparatus is routinely employed for evacuation of postoperative hemorrhage. A surgical dressing is applied and the extremity is incorporated in a Jones compression dressing and splint (Fig. 32).

Postoperative management is strictly non-weightbearing. The extremity is immobilized for several weeks and early range of motion is initiated as soon as possible. Partial weightbearing may be initiated within two to three months. The most significant complication we have encountered to date involves wound dehiscence and full thickness skin slough along the incision line (Fig. 33). Its incidence is related to the severity of the injury, amount of edema and hematoma before and after the surgery, tissue handling, and other peri-surgical factors.

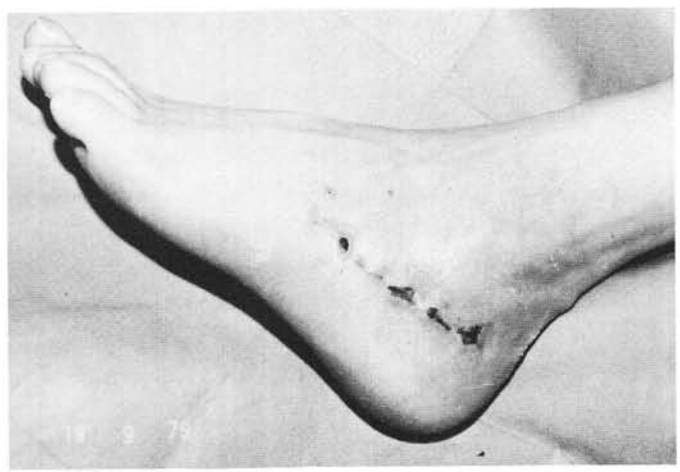

Fig. 33. Minor full thickness skin slough resulted postoperatively following open reduction and internal fixation of this patient's calcaneal fracture. Patient eventually healed quite satisfactorily.

A detailed summary of our surgical experience will be presented at the March, 1988 Doctors Hospital Surgical Seminar in Atlanta. To date, 21 fractures have been surgically treated and followed over a period of approximately ten years. Our experience has been favorable with no need to date for arthrodesis of a successfully reconstructed joint (Fig. 34). While symptoms of post-traumatic arthritis does occur in most patients, these symptoms have not proven to be disabling and are readily controlled with oral medications. Restoration of joint motion has been quite impressive and several patients have returned to work in a fully weightbearing capacity within as few as three months after the initial injury and surgical reductions.

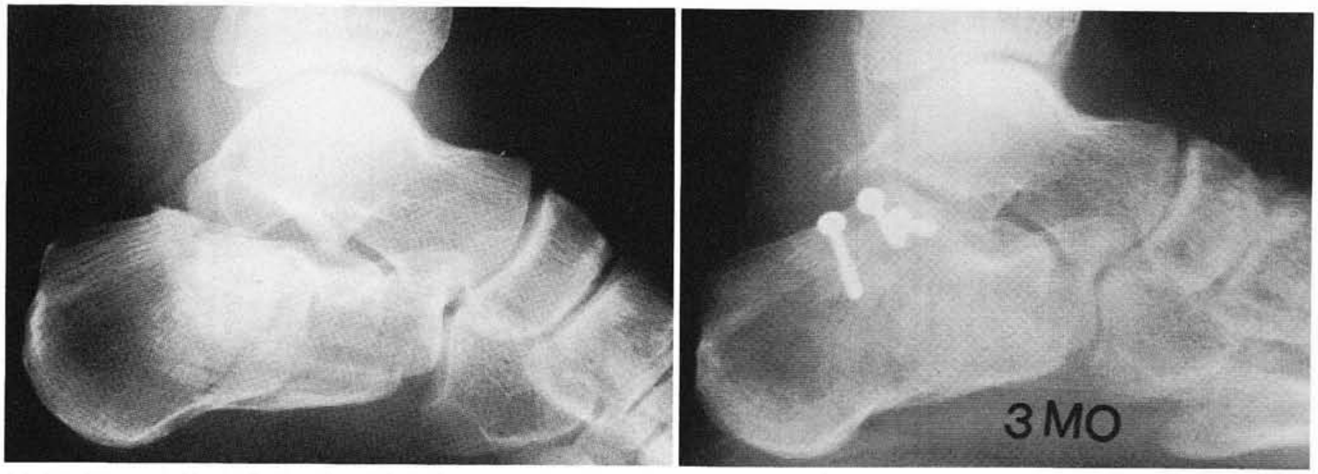

Fig. 34. Successful reduction of calcaneal fracture requires skillful operative technique and proper postoperative management.

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