Review

The Use of Arthroscopy in Acute Foot and Ankle Trauma

A Review

David A. Wood, DPM, Jeffrey C. Christensen, DPM, and John M. Schuberth, DPM

Abstract: *The use of arthroscopy in the management of acute traumatic conditions of the foot and ankle has increased in recent years, primarily because of an appreciation of fracture morphology and the utility of reducing the surgical footprint. This article presents an overview of the use of this modality in foot and ankle trauma and presents an anatomical survey of the various fractures where arthroscopic assistance can be of benefit. In addition, a discussion of the seminal articles on this subject is included.*

Level of Evidence: *Therapeutic Level IV: Review*

Keywords: arthroscopy; foot; ankle trauma

Introduction

Since ankle arthroscopy was first described in 1972 by Watanabe[1] as a diagnostic tool, the utility of this modality has increased substantially. It has been used to treat various pathologies, including osteochondral lesions, arthrofibrosis, and ankle impingement.[2,3] Arthroscopy has also been used in the treatment of subtalar joint pathology.[4-8] Although the role of arthroscopy is expanding, its use in the setting of acute trauma, with the exception of the knee, is mostly undefined.[9,10] There are numerous reports of arthroscopic-assisted treatment of acute foot and ankle trauma,[11-24] but there is no universal agreement with regard to specific indications in this arena.

The use of percutaneous techniques and limited exposure during repair of acute trauma is appealing because of the potential reduction in surgical exposure and morbidity. The benefits of a less-invasive approach include earlier mobilization and rehabilitation, fewer wound complications, and reduction in postoperative morbidity.[25] The application of arthroscopy for operative reduction is referred to as arthroscopic reduction and internal fixation (ARIF). The ability to clearly evaluate the extent of chondral injury and achieve anatomical reduction without formal arthrotomy has intuitive benefits, yet the impact on definitive functional outcomes has not been formally established.[17] The purpose of this article is to survey the literature regarding the adjunct use of arthroscopy in the treatment of traumatic foot and ankle injuries and related posttraumatic conditions.

> "The benefits of a less-invasive approach include earlier mobilization and rehabilitation, fewer wound complications, and reduction in postoperative morbidity."

General Technique

The ankle and subtalar joint can be accessed with standard arthroscopic techniques that are well described in the literature.[2,3,26-28] In most cases, a standard 2-portal (anteromedial and anterolateral) approach can be used in ankle trauma.[20] However, initial portal placement can be difficult because of soft-tissue swelling and may also compromise the ability to identify the intermediate dorsal

DOI: 10.1177/1938640014546863. From Swedish Medical Center, Seattle, Washington (DAW); Department of Orthopedics, Swedish Medical Center, Seattle, Washington (JCC); and Kaiser Foundation Hospital, San Francisco, California (JMS). Address correspondence to: John M. Schuberth, DPM, Department of Orthopedic Surgery, Kaiser Foundation Hospital, 450 6th Avenue, San Francisco, CA 94118; e-mail: jmfoot@aol.com.

cutaneous nerve.[29,30] Earlier personal experience with ankle arthroscopy showed a tendency to make the portals too proximal, which can result in suboptimal visualization of the joint surface and reduce the capacity for intraoperative manipulation of the anatomy. Distraction is rarely required in the anterior approach and infrequently in the posterior approach; if necessary, manual distraction can provide adequate visualization.[28] An accessory ankle portal, particularly with the posterior approach, may be useful for better global visualization and improved fluid flow.[31] Hintermann et al[32] have also described the use of a single anterocentral portal for global visualization of the distal tibial plafond; however, the deep peroneal nerve and dorsalis pedis artery are more at risk with this approach. Gravity flow instead of a pump will minimize extravasation of fluid into already swollen soft tissues. Epinephrine, 1 mg/L, in the inflow solution is also helpful in minimizing bleeding and may preclude the use of a tourniquet.[28,33] Often, there is synovial tissue from old injury or preexisting arthritic changes that needs to be resected to visualize the intra-articular fracture lines. Once adequate visualization of the intra-articular injury has been obtained, the fracture sites are freed of interposed hematoma prior to any attempt at reduction. A 4-mm, 70° scope is preferable for optimal visualization of the joint surfaces and fracture lines.

Acute Ankle Fractures

The use of ankle arthroscopy for treatment of acute malleolar fractures has been described for a wide variety of situations. However, the precise indications have yet to be defined, primarily because of the lack of correlation with better clinical outcome[17]; the use of arthroscopy can help identify concomitant pathology or treat intra-articular damage that would otherwise be undetected, which in turn should lessen long-term morbidity such as posttraumatic arthritis.[2,5,32] In addition to damage to the chondral surfaces, the integrity of the ligaments and the quality of syndesmotic reduction can also be assessed.[34,35]

Specific Pathological Entities

Acute Osteochondral Lesions. Occult chondral injury at the time of ankle injury may be responsible for residual symptoms after ankle trauma.[20,36,37] Even lateral ligament injuries from ankle sprains have a high rate of associated chondral lesions, ranging from 89% in acute to 95% in chronic injuries.[38] The overall incidence of chondral lesions associated with acute ankle fractures varies with the severity of injury but has been reported to be as high as 79%.[32] In a series of 288 ankle fractures treated with arthroscopic assistance, Hintermann et al[32] noted an increase in osteochondral lesion incidence and severity in Weber-B and Weber-C fracture patterns. Active treatment of these lesions occurred in 20% of patients and consisted of frayed cartilage removal and, rarely, pinning of a loose osteochondral fragment.

There are numerous other reports regarding the arthroscopic identification of osteochondral damage that occur consequent to an ankle fracture.[16,37-41] These reports advocated active treatment of these lesions, ranging from excision to microfracture.

The effect of treating these chondral lesions at the time of ankle fracture fixation on the functional outcome is still unknown. There is only supposition that standard treatment of these lesions is actually effective in reducing symptoms. Furthermore, there is little evidence that links the latent discovery of osteochondral damage to previous ankle fracture, especially given the high incidence of lesions in acute ankle sprains. Our personal experience in the management of more than 3000 acute ankle fractures confirms an extremely low incidence of latent presentation of osteochondral lesions (Figure 1).

Deltoid Ligament Injury. It is well known that the diagnosis of a deltoid ligament tear can be elusive, particularly with an isolated lateral malleolar fracture and a widened medial clear space.[34] There is ample evidence to suggest that loss of deltoid integrity increases instability of the ankle fracture, which influences the mode of treatment. Although operative repair of the deep deltoid ligament is seldom practiced, the threshold for operative repair of the fibula fracture is lower to prevent lateral migration of the talus caused by a lack of an intact medial tether.[42,43] Yet the rationale for arthroscopy only to establish the level integrity of the deltoid ligament is obscure because it is illogical to place patients under anesthesia just to establish the condition of the ligament, particularly if the mode of treatment is not dependent on the outcome of such an observation.

However, the integrity of the deltoid ligament at the time of surgery may influence postoperative activity. Some would suggest that an incompetent deltoid represents a more unstable fracture and, as such, requires more cautious postoperative activity. Schuberth et al[34] performed arthroscopy in a large series of unimalleolar ankle fractures and concluded that 4 mm of a widened medial clear space on the injury radiographs represents failure of the deltoid ligament. Although the integrity of the deltoid ligament did not influence treatment in that series, other surgeons may be less tolerant of immediate weight bearing after operative reduction[44] (Figure 2).

Figure 1.

Intraoperative Photograph of Rotational Ankle Fracture: The Lateral Aspect of the Talar Dome Has a Large Cartilaginous Defect as a Result of the Injury.

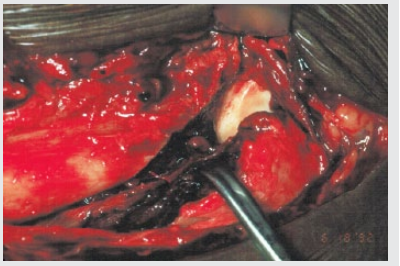
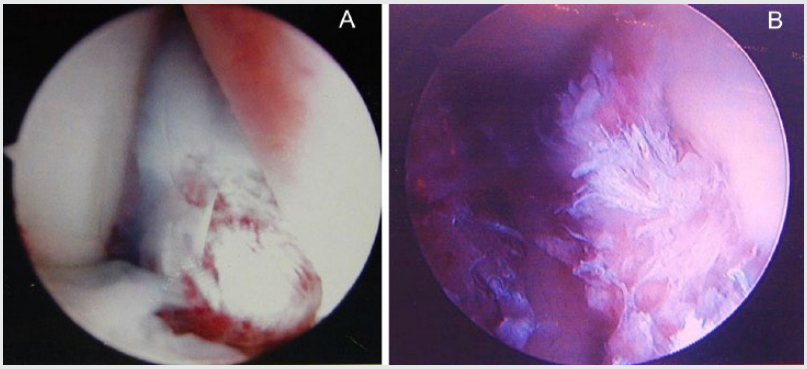


Figure 2.

A. Intraoperative Arthroscopic Appearance of a Completely Intact Deltoid Ligament in a Left Ankle. The Talus Is to the Right and Medial Malleolus to the Left. B. Intraoperative Arthroscopic View of Ruptured Deep Deltoid Ligament in a Left Ankle. The Ligament Is Still Attached to the Talus.



Reduction of the Syndesmosis. The Lauge-Hansen classification of injury patterns in ankle fractures can be predictive of syndesmotic injury, but there is evidence that it is not entirely accurate with respect to damage to the syndesmosis, especially in nonrotational ankle fractures.[45] Furthermore, clinical evaluation of syndesmotic instability can be challenging when there is no obvious radiographic syndesmosis injury. Four planes of instability have been described for syndesmotic injuries,[46] and there is increasing evidence that there is a high percentage of malreduction in the routine operative management of a disrupted syndesmosis with ankle fractures.[47-49]

Even with intraoperative image intensification, determination of the precise multiplanar position of the fibula is often spurious. Although intraoperative CT scans may aid in anatomical restoration of the tibiofibular relationship, it is not widely available in the United States and still corresponds to a high rate of malreduction.[50] Although the exact mechanism of malreduction is unknown, it is believed to be based on the lack of direct visualization of the incisura, unappreciated rotational deformity of the fibula, or inaccurate placement of trans-syndesmotic fixation. Accordingly, intra-articular arthroscopic inspection of the tibiofibular relationship may increase the accuracy of syndesmotic reduction.[46,51] The discovery of more subtle syndesmotic disruptions may also increase with arthroscopic inspection.[46] Regardless, one needs to be familiar with the arthroscopic appearance of the normal syndesmosis to appreciate any planar malalignment.

There is little debate as to the need for operative stabilization of overt syndesmotic injury, but the need for trans-syndesmotic fixation for those injuries that are only evident arthroscopically is less clear. One may argue that postoperative management may be affected based on the results of arthroscopic inspection of the syndesmosis (Figure 3).

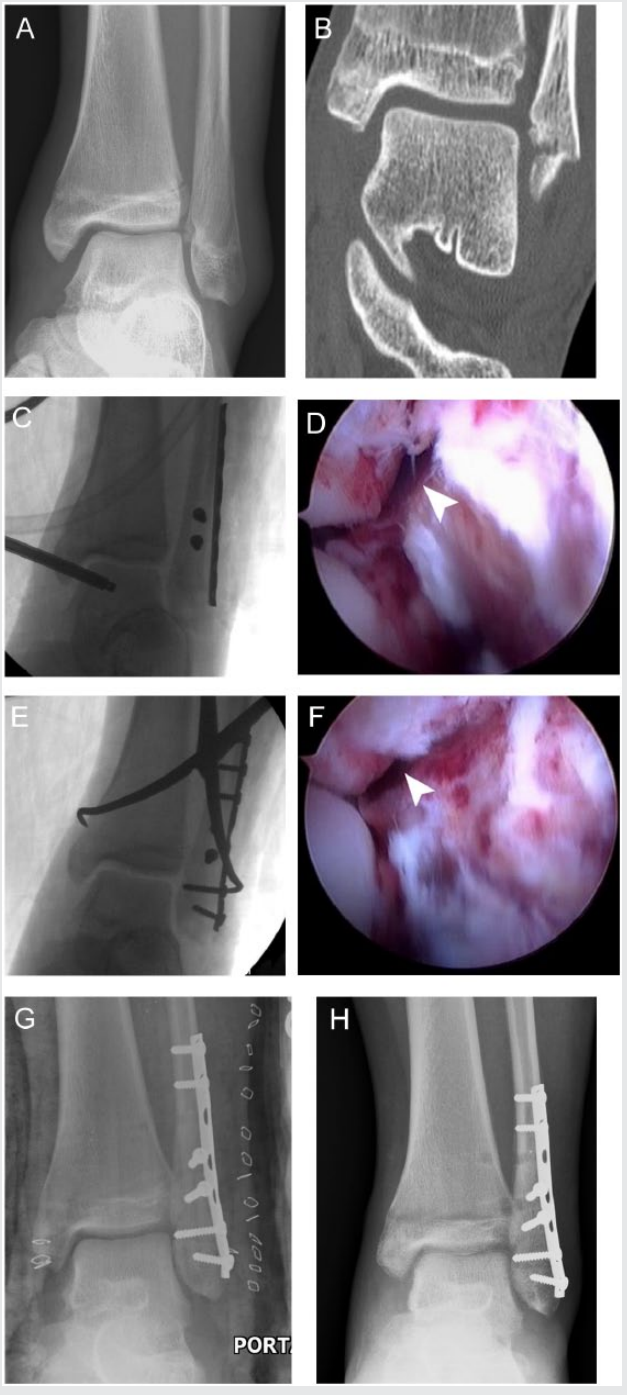
Latent Syndesmotic Instability. In spite of modern techniques and fixation, latent instability of the syndesmosis is not uncommon. It has been shown that even with seemingly anatomical reduction, there can be widening of the syndesmosis after retrieval of the hardware.[52] Furthermore, insufficient reduction can be discovered distant from the operative session. Although it is commonly accepted that an overt syndesmosis disruption will lead to premature ankle arthrosis, there are no guidelines to establish a threshold in those patients with less-than-perfect operative reductions. Unfortunately, there is little evidence to provide guidance to surgeons with regard to which patients require a second procedure to improve the tibiofibular relationship. In part, this results from a lack of disabling symptoms in many of these patients. Furthermore, it is very difficult to differentiate residual symptoms caused by latent syndesmotic insufficiency from those caused by the original injury because patients with acute syndesmotic disruption generally have less-favorable prognoses and presumably more residual symptoms.[53] Accordingly, the effect of delayed operative reduction of the sprung syndesmosis on the ultimate prognosis and the immediate symptoms remains obscure.

There are several techniques available for latent reduction of the diastasis. Most of these involve extensive exposures, and some require the sacrifice of otherwise normal anatomical structures.[3,54,55] These procedures may be effective but can be avoided because of the capacity to reduce and stabilize the syndesmosis arthroscopically.[35] This technique involves debridement of the syndesmosis of all interposed scar tissue, as well as the medial clear space, prior to attempted mobilization of the fibula into the incisura. In particular, when debriding the syndesmosis, the scope is placed in the medial portal and the shaver or equivalent instrument is placed laterally for more direct access to the tibiofibular space. Preparation of the deltoid ligament medial clear space is done with placement of the scope in the lateral portal.

Preparation of the syndesmosis involves resection of enough tissue to allow for direct apposition of the fibula with the tibial incisura. After one is satisfied with the preparation of syndesmosis, it is reduced by placing a clamp on the tibia and fibula to oppose the respective surfaces. The clamp should be oriented in the same direction as the tibiofibular axis to avoid anterior or posterior migration. Opposition can be checked with the arthroscope prior

Figure 3.

A. Spiral Left-Fibular Fracture in a 15-Year-Old Boy. Note the Diastasis of the Fibula and Lateral Shift of the Talus. B. CT scan. C. Intraoperative Fluoroscopy Image With Interfragmentary Screws in Fibula. The 70° Scope Has Been Inserted Into the Medial Portal. D. Arthroscopic View of Diastasis (arrow). E. Fluoroscopic View With Reduction Forceps in Place and Restoration of the Tibiofibular Apposition. F. Arthoscopic View of Reduction of Syndesmosis (arrow). G. Final Reduction With Absorbable Syndesmotic Fixation. H. 1-Year Postoperative Weight-Bearing Radiograph With Normal Radiographic Alignment.



to insertion of the hardware. Stabilization of the tibiofibular joint involves standard screw fixation placed under fluoroscopic control. The final stability and orientation of the construct can be directly visualized in addition to standard imaging. Excessive debridement may expose the cancellous bone on either side of the syndesmosis and may result in fusion.[35] However, it has been our experience that this restriction of motion is minimal, and patients function well with a solid tibiofibular space (Figure 4).

Ankle Instability

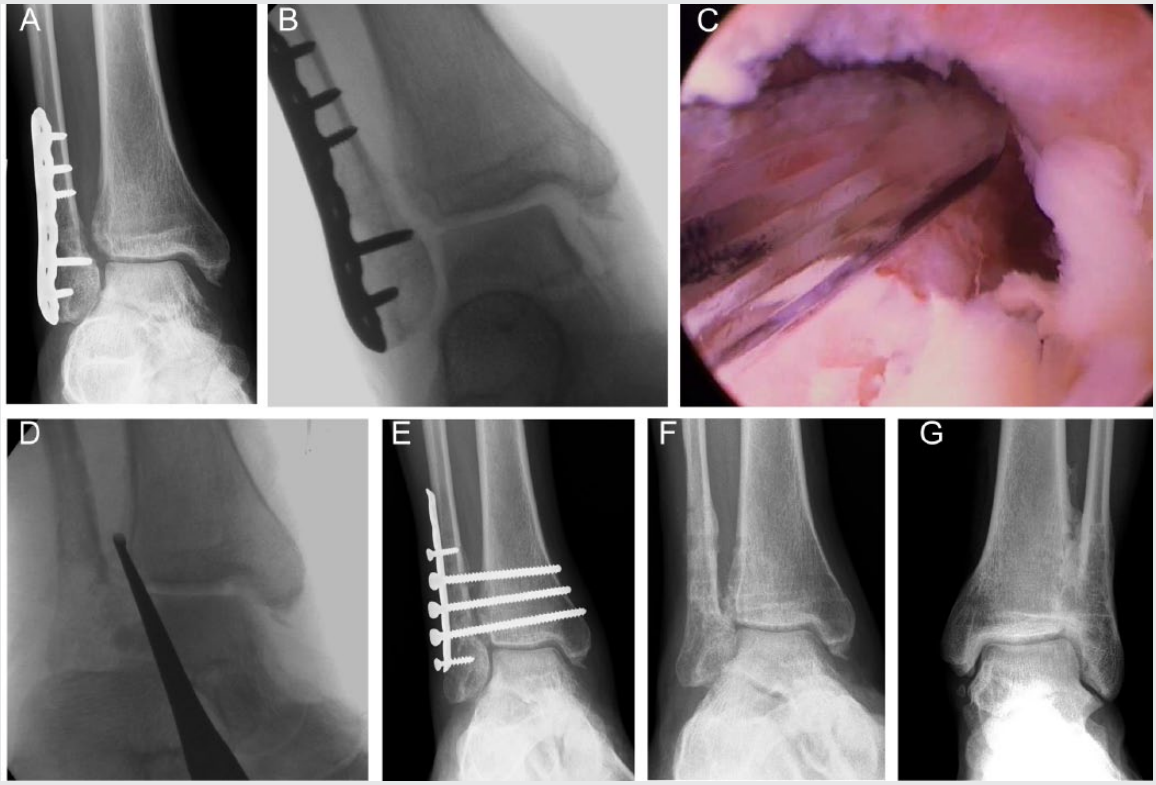
Arthroscopic treatment of ankle instability has been described.[56-60] Past experience with the arthroscopic technique proved unsatisfactory, and performing an open modified Broström ankle stabilization is expedient and reliable. Further research on the "all-arthroscopic" treatment of lateral ankle instability is required to arrive at any conclusions or make recommendations for such treatment.[61] The use of arthroscopy in evaluating the cartilage in ankle instability has been described but with concomitant open treatment with a modified Broström.[62] Given the ease, expediency, and limited morbidity of this open technique, we believe that it is more advantageous than arthroscopic stabilization.

Pilon Fractures

Most fractures of the tibial plafond require formal open reduction and internal fixation. It is well established that the prognosis after the operative treatment of pilon fractures is primarily dependent on the quality of articular congruity.[63-67] However, arthroscopy can assist in establishing articular congruity in those pilon fractures amenable to minimally invasive approaches.[11,12,22,68] It is most applicable when the fracture patterns are simple and involve a low-energy mechanism. The specific indications are those fractures in which articular

Figure 4.

A. 7-Month Postoperative Radiograph After Open Reduction in Another Institution. B. Intraoperative External Stress Fluoroscopic Image Demonstrating Increased Medial Clear Space and Diastasis. C. Arthroscopic View of Shaver in the Syndesmosis for Preparation of the Tibiofibular Space. The Tibia Is to the Right of the Shaver. D. Curette Placed Through Lateral Portal for Excavation of Syndesmotic Debris. E. Definitive Fixation. F. 2-Year Postoperative Film Showing Reduction of Medial Clear Space and Apposition of Tibia and Fibula. G. Fusion of Syndesmosis After Arthroscopic Repair of Latent Syndesmosis Insufficiency in a Different Patient.



congruity can be established without a formal arthrotomy. Some have advocated arthroscopic assistance even with formal arthrotomy to visualize the posterior aspect of the plafond, but most commonly, posterior visualization is achieved with distraction of the joint during reconstruction.[21] Those fractures with central depression are probably best served with an open approach, but simple central depressions can be manipulated with instruments placed through the primary fracture plane (Figure 5).

Pediatric Ankle Fractures

Percutaneous fixation in pediatric ankle fractures is becoming common practice,[69-71] and the use of ARIF is increasing.[72] The high incidence of intra-articular invasion of the fracture planes lends to the increased utility of this modality. Between the ages of 8 and 15 years, there is asymmetric closure of the physis of the distal tibia, which results in distinct fracture patterns from rotational injury. These fractures are termed *transitional* because the injury occurs during skeletal maturation. Physeal closure of the distal tibia starts centrally, progresses medially, and then laterally. The last portion of the physis to close is the anterolateral corner.[73] Although the incidence of growth arrest is quite low in this age group, these fractures require precise reduction of the load-bearing distal tibial surface to reduce the incidence of posttraumatic arthritis. It is has been established that more than 2 mm of intra-articular incongruity should be treated with operative reduction.[73] Accordingly, ARIF can be quite useful in reducing the surgical exposure and still allow precise reduction.[5]

Intra-articular fractures that occur before the commencement of physeal closure also can be treated with ARIF, if there are relatively simple fracture patterns. It is recognized that the physis must be anatomically restored to prevent premature growth arrest. Although direct visualization of the growth plate is not feasible arthroscopically, perfect restoration of the articular surface indirectly restores the apposition of the growth plate. Yet one is cautioned to accept nothing less than perfect intra-articular reduction (Figure 6).

Figure 5.

A. Anteroposterior Radiograph of Right Ankle in 35-Year-Old Man After a Vertical Fall. B. Intraoperative Fluoroscopic View With the Scope Placed Through the Medial Portal. C. Visualization of the Primary Fracture Line. The Mobile Lateral Fragment Is to the Left of the Image. D. Intraoperative Photo With Reduction Forceps and Arthroscope. E. Intraoperative Fluoroscopic View Showing Reduction of Articular Surface. F. Arthroscopic View Showing Anatomical Reduction. G. Definitive Fixation Placed in a Percutaneous Manner. H. 3-Year Postoperative Radiograph.

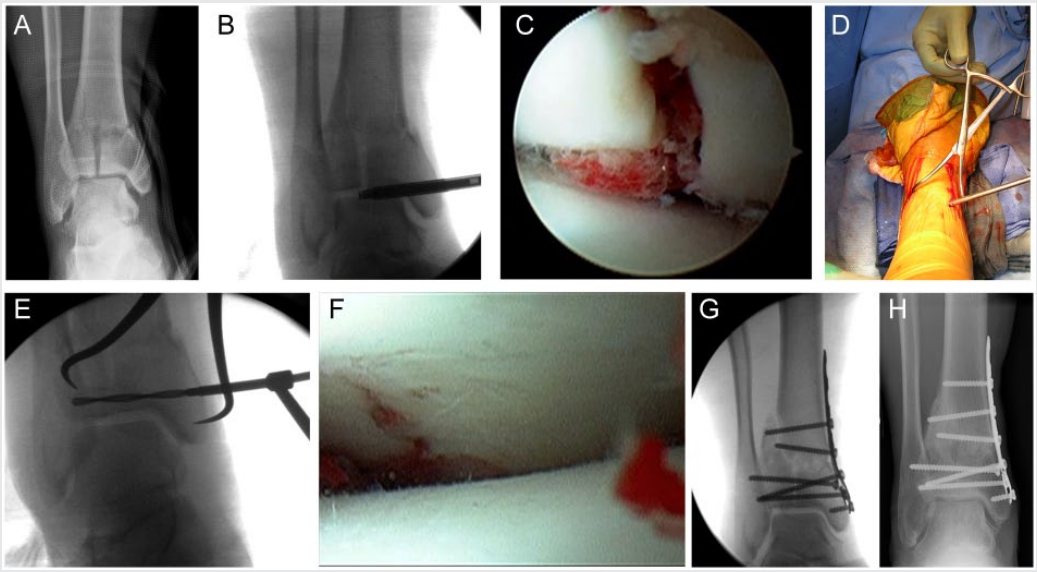
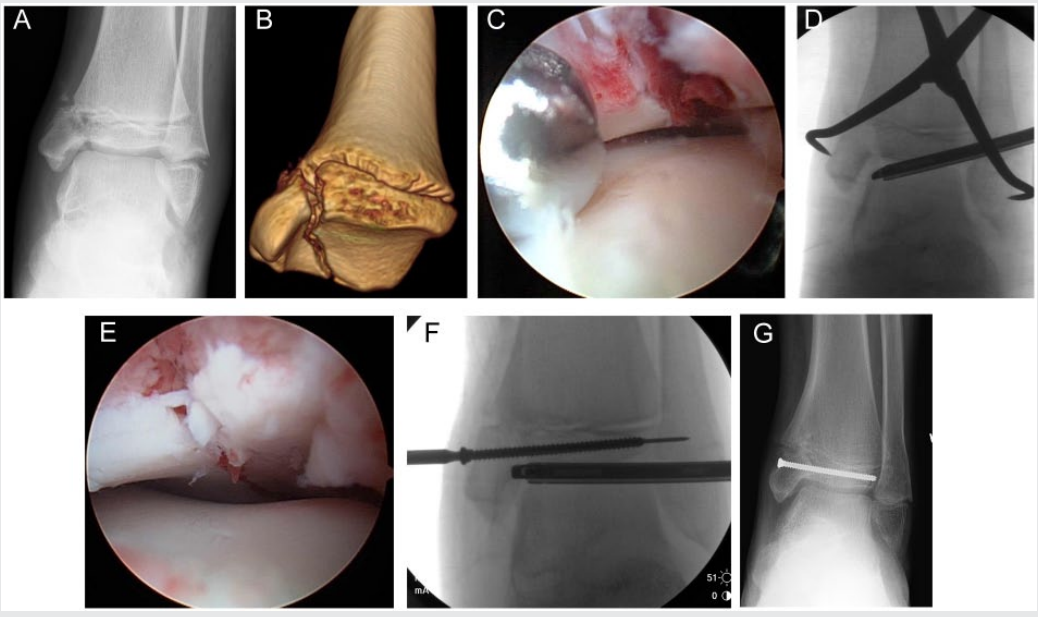


Figure 6.

A. Anteroposterior Radiograph of Salter IV Distal Left Tibia Fracture in 9-Year-Old Boy. B. 3D CT Scan Demonstrating the Configuration of the Fracture. C. Arthroscopic View of Fracture Plane and Shaver. D. Intraoperative Reduction. E. Anatomical Reduction. F. Fluoroscopic Image of Cannulated Screw Placed Across Fracture. G. 18-Month Postoperative Radiograph. Note That the Physis Has Started to Close.

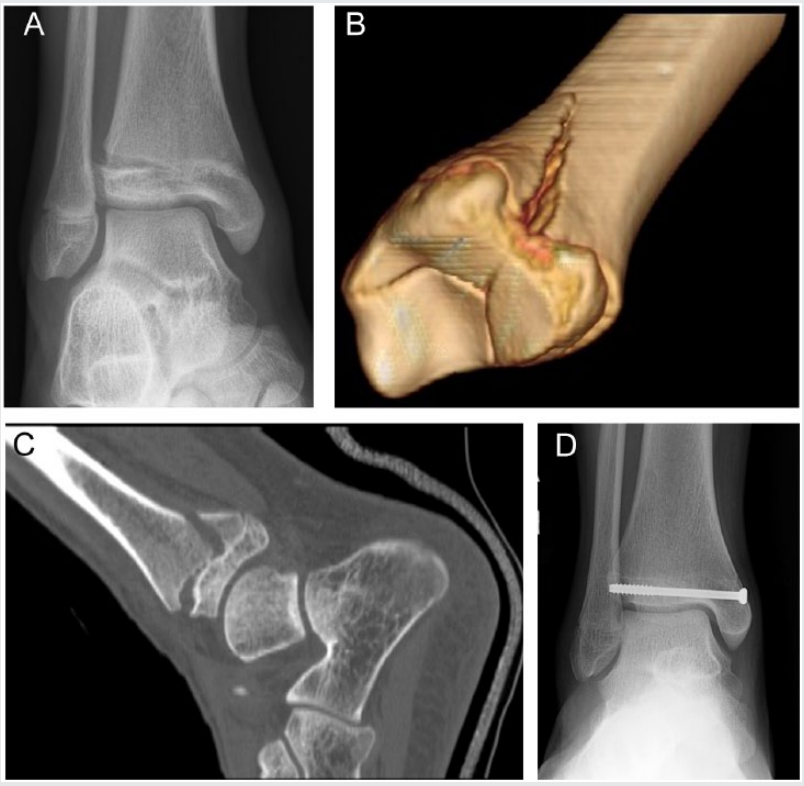


Triplane Ankle Fractures. Triplane ankle fractures are Salter-Harris type IV fractures that have components in all 3 cardinal body planes. They account for 5% to 7% of all pediatric ankle fractures.[74] These fractures typically have the appearance of type II patterns on lateral-view and type III on anteroposterior-view ankle radiographs and are easily underappreciated on plain film. Because of poor radiographic visualization of the entire physis and variability of appearance of the distal tibial physis, these injuries must be evaluated more thoroughly with a CT scan. If closed reduction under anesthesia is unsuccessful in reducing the intra-articular gap to less than 2 mm, then operative intervention is warranted.[73] The exact approach to open operative intervention depends on the characteristics of the fracture, but precise articular congruity must be achieved.[19] Standard anteromedial and anterolateral portals are created, and reduction clamps are used percutaneously to reduce the fracture after evacuation of the fracture hematoma. It is important to understand the rotational mechanism of the injury for proper orientation of the reduction clamps. The force applied by closure of the forceps should be perpendicular to the fracture plane. One or more lag screws with a washer are placed across the main fracture fragments under arthroscopic and fluoroscopic visualization, ensuring that the physis is not violated.[13,14,19,75] Although the risk of growth arrest is minimal, traversing the growth plate with fixation other than smooth Kirschner wires is still to be avoided (Figure 7).

Juvenile Tillaux Fractures. Tillaux fractures are Salter-Harris type-III fractures of the anterolateral portion of the distal tibia and account for 3% to 5% of all pediatric ankle fractures.[74] They occur from epiphyseal avulsion by the anteroinferior tibiofibular ligament during a rotational injury. This fracture is typically seen in the adolescent whose physis is nearly closed and at the end of the transitional period of growth. Because growth arrest is of no concern, the goal of treatment is to prevent arthritis in adulthood. Those fractures that exceed the 2-mm threshold of displacement are quite amenable to ARIF. Smaller fractures may not be large enough for screw fixation but may be pinned in a similar fashion.[75]

Figure 7.

A. Mortise Radiograph of Right Triplane Fracture in a 12-Year-Old Girl. B. 3D CT Scan Confirming the Triplane Configuration. C. Sagittal CT Image Showing Posterior Displacement of Major Fragment. D. 2.5-Year Postoperative Radiograph.



Foot Fractures

Although it is possible to evaluate many of the small joints of the foot, such as the calcaneocuboid and first metatarsophalangeal joint, the practicality of this has not been established.[76] Primarily this is because of a paucity of fractures in these joints and the unresolved question of whether the amount of operative trauma is actually reduced with arthroscopy. Furthermore, the capacity to manipulate any articular fracture fragments is limited because of the small confines of the joint. However, there has been interest in the use of arthroscopy for operative reduction of acute calcaneal fractures.[5,77-79]

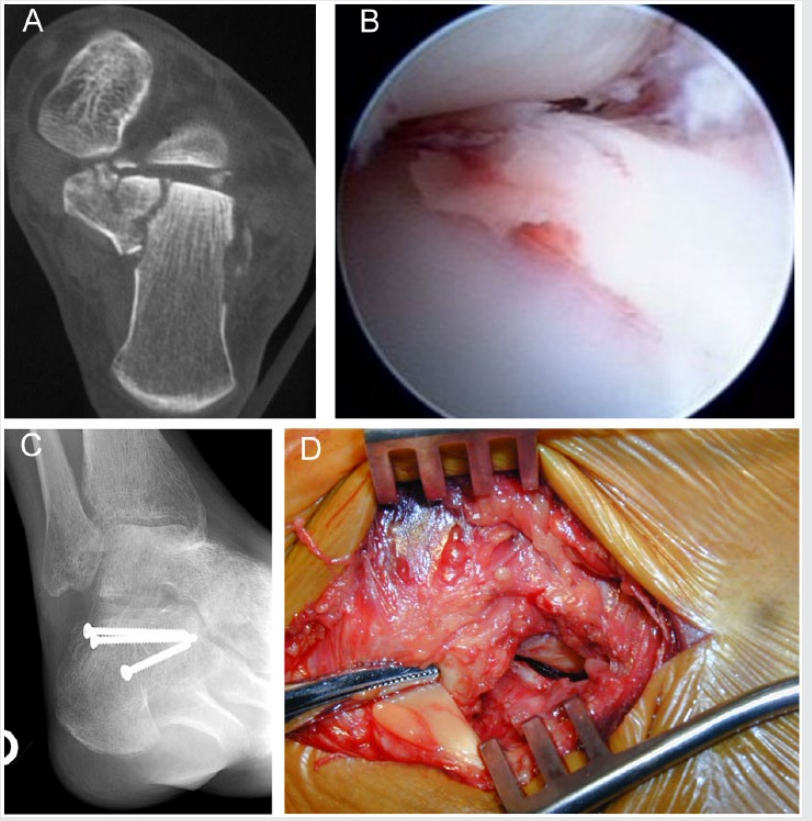
Calcaneal Fractures

Restoration of articular congruity and osseous morphology remain the seminal goal in the treatment of intra-articular calcaneal fractures. There has been a decrease in the use of the lateral extensile approach because of increased understanding of the pathoanatomy of these fractures and the risk of soft-tissue complications.[80,81] Wound complication

rates are upward of 11% to 25%.[80-82] A limited sinus tarsi exposure with and without arthroscopic assistance has been utilized for reduction of the articular surface.[4,5,77-79,83] The capacity to restore calcaneal morphology with a more limited approach has increased because of the individual surgeon's familiarity with the fracture and fluoroscopic image intensification. Nonetheless, visualization of the articular surface is afforded with the minimally invasive approach. Accordingly, the use of arthroscopy has diminished considerably because of the realization that the sinus tarsi approach provides superb visualization without significant complications of wound healing, even in patients with compromised soft-tissue envelopes. Furthermore, in our hands, the limited exposure, open reduction is expedient and avoids the cumbersome combination of arthroscopic and fluoroscopic machinery in place during the procedure. It is much easier to manipulate the fracture fragments with a limited open approach, particularly the depressed lateral portion of the posterior facet. Yet the utility of arthroscopy has not completely disappeared because many of the simpler fracture patterns can be anatomically reduced in a completely arthroscopic approach. It is also useful as an adjunct to see the medial side of the posterior facet and middle facet when the fracture planes have invaded the more medial articular surfaces[77,78,84,85] (Figure 8).

Figure 8.

A. Axial CT Image of Comminuted Right Calcaneus Fracture. Note That the Comminution Is Primarily Through the Sustentaculum Tali. B. Arthroscopic View of the Sustentaculum and Medial Portion of the Posterior Facet. C. Definitive Fixation 1 Year After Injury. D. Intraoperative Photo of Limited Open Approach in Right Calcaneal Fracture.



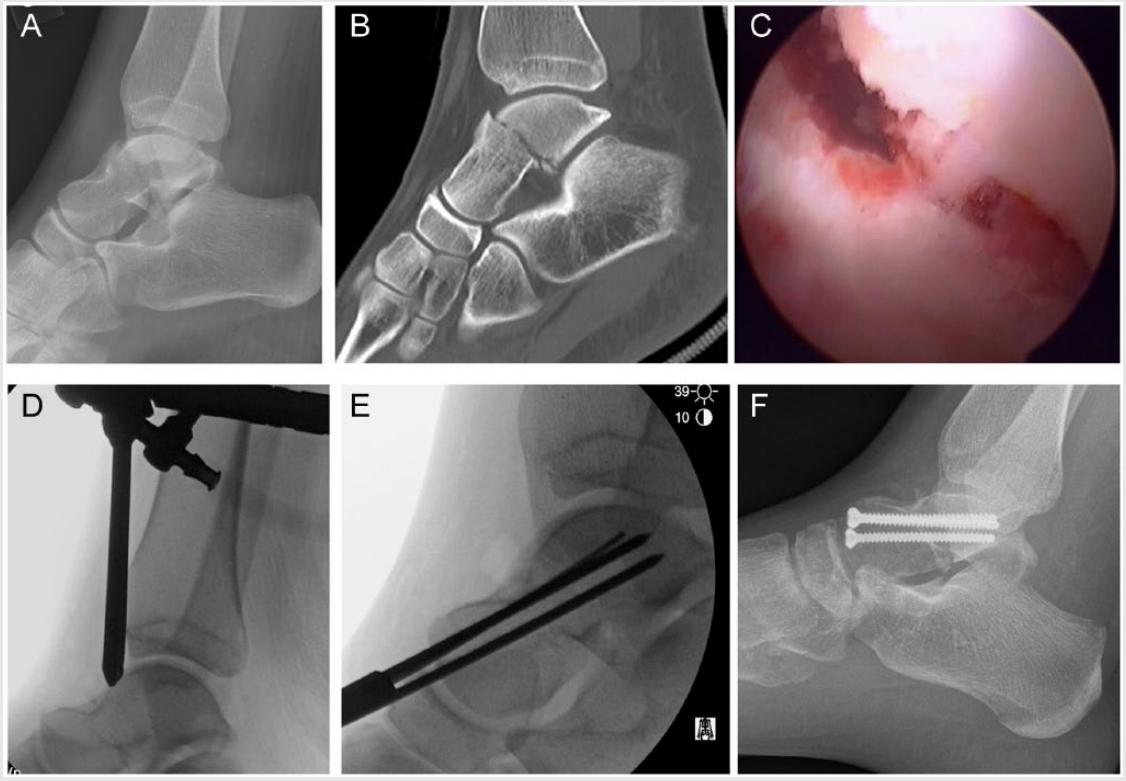
Talar Fractures

There has been much written about the operative reduction of talar fractures particularly in light of potential genesis of avascular necrosis.[86-90] Furthermore, it is commonly accepted that precise anatomical reduction is important in minimizing posttraumatic arthritis, particularly of the ankle. Although many believe that the prognosis for the development of avascular necrosis is predicated on the level of injury,[86-90] little attention has been paid to the possibility of iatrogenic compromise of the precarious blood supply during open reduction. ARIF can be quite helpful in reducing some of the simpler fracture patterns without compromising the concept of anatomical reduction. This potentially avoids extensive dissection around the neck the talus, where the bulk of the blood supply enters the talus. Fracture patterns amenable to ARIF are typically 2-part body and proximal neck fractures.[18,36] One of the more common complications is varus malrotation on the medial side of the neck from either suboptimal technique or highly comminuted medial talar neck patterns. Yet the key to ARIF is the capacity to see across the entire expanse of the talar dome to ensure that there is no rotational offset medially. Accordingly, with anatomical reduction of the talar dome, the potential for post-traumatic arthritis (PTA) is greatly reduced, and indirect reduction of the subtalar joint is accomplished.

The import of excavation of the comminuted articular fragments, particularly of the lateral side, is well appreciated but can be achieved arthroscopically as well. The scope can be placed into the lateral subtalar joint, or the loose fragments can be retrieved by going through the primary fracture site from the standard ankle portals. In some instances, an accessory subtalar portal will be necessary to this end. It must be understood that the subtalar joint is frequently very stiff, even with anatomical reduction of the talus and is probably

Figure 9.

Lateral Injury Film of Left Talus Fracture After Closed Reduction of the Subtalar Dislocation. Note That the Primary Fracture Line Is Intra-articular for Both the Ankle and Subtalar Joint. B. CT scan. C. Arthroscopic View of Primary Fracture Line. D. Intraoperative Fluoroscopic Image Demonstrating Position of Scope and Reduction of Fracture. E. Temporary Fixation. F. 6-Month Postoperative Radiograph Demonstrating Reduction.



consequent to articular damage at the time of injury (Figure 9).

Risks and Pitfalls of ARIF

There are a number of risks and disadvantages with the use of ARIF. Most of the specific complications are endemic to any arthroscopy procedure.[91,92] Others are simply potentiated by the concomitant use in acute trauma.

Compartment Syndrome

There have been isolated case reports of postarthroscopy compartment syndrome because of fluid extravasation into the leg.[92,93] Using a pump can increase the intra-articular pressure and drive fluid into the anterior compartment such that gravity flow is recommended. In addition, excess fluid extravasation may exacerbate soft-tissue swelling and blisters.

Nerve Injury

Injury to the intermediate dorsal cutaneous nerve as it traverses over the ankle joint is not uncommon. The proximity of this nerve to the anterolateral portal and the difficult identification because of swelling increases its vulnerability. Identifying this nerve prior to creation of the anterolateral portal can help avoid damage to this nerve.[29,30] Identification of the nerve can be facilitated by plantarflexing the fourth toe and inverting the foot. Furthermore, creation of the anteromedial portal first can facilitate the proper position of the anterolateral portal via transillumination.

Increased Operating Time

The time for completion of the operative procedure will most likely increase with the use of arthroscopy, even with experienced arthroscopists. In this era of increased cost consciousness, the increased time, additional equipment, and setup should prompt the surgeon to be judicious when selecting the ARIF approach.

Conclusion

Arthroscopic assistance during acute trauma can be invaluable for the precise articular reduction required in most fractures. The specific indications are

mostly surgeon specific, and as such, judgment should be exercised. Although it is difficult to demonstrate unequivocal utility in this setting, common sense should prevail. Increased experience in these techniques will likely refine this issue. FAS

References

1. Watanabe M. *Selfoc Arthroscope (Watanabe no 24 Arthroscopes)*. Tokyo, Japan: Teishin Hospital; 1972.
2. Ferkel RD, Orwin JF. Ankle arthroscopy: a new tool for treating acute and chronic ankle fractures (abtract). *Arthroscopy*. 1993;9:352-353.
3. Van Dijk CN, Verhagen RA, Tole JL. Arthroscopy for problems after ankle fracture. *J Bone Joint Surg Br*. 1997;79: 280-284.
4. Ahn JH, Lee SK, Kim KJ, Kim YI, Choy WS. Subtalar arthroscopic procedures for the treatment of subtalar pathologic conditions: 115 consecutive cases. *Orthopedics*. 2009;32:891.
5. Schuberth JM, Cobb MD, Talarico RH. Minimally invasive arthroscopic-assisted reduction with percutaneous fixation in the management of intra-articular calcaneal fractures: a review of 24 cases. *J Foot Ankle Surg*. 2009;48:315-322.
6. Hsu AR, Grgoss CE, Lee S, Carreira DS. Extended Indications for foot and ankle arthroscopy. *J Am Acad Orthop Surg*. 2014;22:10-19.
7. Rubin LG. Subtalar joint arthroscopy. *Clin Podiatr Med Surg*. 2011;28:539-550.
8. Smyth NA, Zwiers R, Wiegerinck JI, et al. Posterior hindfoot arthroscopy: a review. *Am J Sports Med*. 2013;42:225-234.
9. Barber FA, Prudich JF. Acute traumatic knee hemarthrosis. *Arthroscopy*. 1993;9:174-176.
10. Glinz W, Segantini P, Kaegi P. Arthroscopy in acute trauma of the knee joint. *Endoscopy*. 1980;12:269-274.
11. Hammond AW, Crist BD. Arthroscopic management of C3 tibial plafond fractures: a technical guide. *J Foot Ankle Surg*. 2012;51:382-386.
12. Kim HS, Jahng JS, Kim SS, Chun CH, Han HJ. Treatment of tibial pilon fractures using ring fixators and arthroscopy. *Clin Orthop Relat Res*. 1997;334:244-250.
13. Mcgillion S, Jackson M, Lahoti O. Arthroscopically assisted percutaneous fixation of triplane fracture of the distal tibia. *J Pediatr Orthop B*. 2007;16:313-316.
14. Miller MD. Arthroscopically assisted reduction and fixation of an adult Tillaux fracture of the ankle. *Arthroscopy*. 1997;13:117-119.
15. Nehme A, Tannous Z, Wehbe J, Moucharafieh R, Maalouf G. Arthroscopically assisted reconstruction and percutaneous screw fixation of a pilon tibial malunion. *J Foot Ankle Surg*. 2007;46:502-507.
16. Ono A, Nishikawa S, Nagao A, et al. Arthroscopically assisted treatment of ankle fractures: arthroscopic findings and surgical outcomes. *Arthroscopy*. 2004;20:627-631.
17. Thordarson DB, Bains R, Shepherd LE. The role of ankle arthroscopy on the surgical management of ankle fractures. *Foot Ankle Int*. 2001;22:123-125.
18. Wajsfisz A, Makridis KG, Guillou R, et al. Arthroscopic treatment of a talar neck fracture: a case report. *Knee Surg Sports Traumatol Arthrosc*. 2012;20:1850-1853.
19. Whipple TL, Martin DR, Mcintyre LF, Meyers JF. Arthroscopic treatment of triplane fractures of the ankle. *Arthroscopy*. 1993;9:456-463.
20. Gumann G, Hamilton GA. Arthroscopically assisted treatment of ankle injuries. *Clin Podiatr Med Surg*. 2009;28:523-538.
21. Kralinger F, Lutz M, Wambacher M, Smekal V, Golser K. Arthroscopically assisted reconstruction and percutaneous screw fixation of a pilon tibial fracture. *Arthroscopy*. 2003;19:E45.
22. Poyanli O, Esenkaya I, Ozkut AT, et al. Minimally invasive reduction technique in split depression type tibial pilon fractures. *J Foot Ankle Surg*. 2012;51: 254-257.
23. Salvi AE, Metelli GP, Bettinsoli R, Hacking SA. Arthroscopic-assisted fibular synthesis and syndesmotic stabilization of a complex unstable ankle injury. *Arch Orthop Trauma Surg*. 2009;129:393-396.
24. Imade S, Takao M, Nishi H, Uchio Y. Unusual malleolar fracture of the ankle with talocalcaneal coalition treated by arthroscopy-assisted reduction and percutaneous fixation. *Arch Orthop Trauma Surg*. 2007;127:277-280.
25. Pires RE, Mauffrey C, De Andrade MA, et al. Minimally invasive percutaneous plate osteosynthesis for ankle fractures: a prospective observational cohort study [published online August 20, 2013]. *Eur J Orthop Surg Traumatol*. doi:10.1007/s00590-013-1295-x.
26. Amendola A, Petrik J, Webster-Bogaert S. Ankle arthroscopy: outcome in 79 consecutive patients. *Arthroscopy*. 1996;12:565-573.
27. Frey C, Gasser S, Feder K. Arthroscopy of the subtalar joint. *Foot Ankle Int*. 1994;15:424-428.
28. Jennings MM, Bark SE. Practical aspects of foot and ankle arthroscopy. *Clin Podiatr Med Surg*. 2011;8:441-452.
29. Öğüt T, Akgün I, Kesmezacar H, et al. Navigation for ankle arthroscopy: anatomical study of the anterolateral portal with reference to the superficial peroneal nerve. *Surg Radiol Anat*. 2004;26:268-274.
30. Woo S, Wong T, Chan W, et al. Anatomic variations of neurovascular structures of the ankle in relation to arthroscopic portals: a cadaveric study of Chinese subjects. *J Orthop Surg*. 2010;18:71-75.
31. Donnenwerth MP, Roukis TS. The incidence of complications after posterior hindfoot endoscopy. *Arthroscopy*. 2013;9:2049-2054.
32. Hintermann B, Regazzoni P, Lampert C, Stutz G, Gachter A. Arthroscopic findings in acute fractures of the ankle. *J Bone Joint Surg Br*. 2000;82:345-351.
33. Olszewski AD, Jones R, Farrell R, Kaylor K. The effects of dilute epinephrine saline irrigation on the need for tourniquet use in routine arthroscopic knee surgery. *Am J Sports Med*. 1999;27:354-356.
34. Schuberth JM, Collman DR, Rush SM, Ford LA. Deltoid ligament integrity in lateral malleolar fractures: a comparative analysis of arthroscopic and radiographic assessments. *J Foot Ankle Surg*. 2004;43: 20-29.
35. Schuberth JM, Jennings MM, Lau AC. Arthroscopy-assisted repair of latent syndesmotic instability of the ankle. *Arthroscopy*. 2008;24:868-874.
36. Bonasia DE, Rossi R, Saltzman CL, Amendola A. The role of arthroscopy in the management of fractures about the ankle. *J Am Acad Orthop Surg*. 2011;19:226-235.
37. Loren GJ, Ferkel RD. Arthroscopic assessment of occult intra-articular injury in acute ankle fractures. *Arthroscopy*. 2002;18:412-421.
38. Taga I, Shino K, Inoue M, Nakata K, Maeda A. Articular cartilage lesions in ankles with lateral ligament injury. *Am J Sports Med*. 1993;21:120-127.
39. Aktas S, Kocaoglu B, Gereli A, Nalbantodlu U, Guven O. Incidence of chondral lesions of talar dome in ankle fracture types. *Foot Ankle Int*. 2008;29:287-292.
40. Leontaritis N, Hinojosa L, Panchbhavi VK. Arthroscopically detected intra-articular lesions associated with acute

ankle fractures. *J Bone Joint Surg Am.* 2009;91:333-339.

41. Sorrento DL, Mlodzienski A. Incidence of lateral talar dome lesions in SER IV ankle fractures. *J Foot Ankle Surg.* 2000;39:354-358.
42. Lloyd J, Elsayad S, Hariharan K, Tanaka H. Revisiting the concept of talar shift in ankle fractures. *Foot Ankle Int.* 2006;27:793-796.
43. Ramsey PL, Hamilton W. Changes in tibiotalar area of contact caused by lateral talar shift. *J Bone Joint Surg Am.* 1976;58:356-357.
44. Starkweather MP, Collman DR, Schuberth JM. Early protected weightbearing after open reduction internal fixation of ankle fractures. *J Foot Ankle Surg.* 2012;51:575-578.
45. Gardner MJ, Demetrakopoulos D, Briggs SM, Helfet DL, Lorich DG. The ability of the Lauge-Hansen classification to predict ligament injury and mechanism in ankle fractures: an MRI study. *J Orthop Trauma.* 2006;20:267-272.
46. Lui TH, Ip K, Chow HT. Comparison of radiologic and arthroscopic diagnoses of distal tibiofibular syndesmosis disruption in acute ankle fracture. *Arthroscopy.* 2005;21:1370-1374.
47. Miller AN, Barei DP, Iaquinto JM, Ledoux WR, Beingessner DM. Iatrogenic syndesmosis malreduction via clamp and screw placement. *J Orthop Trauma.* 2013;27:100-106.
48. Xenos JS, Hopkinson WJ, Mulligan ME, Olson EJ, Popovic NA. The tibiofibular syndesmosis: evaluation of the ligamentous structures, methods of fixation, and radiographic assessment. *J Bone Joint Surg Am.* 1995;77:847-856.
49. Gardner MJ, Demetrakopoulos D, Briggs SM, Helfet DL, Lorich DG. Malreduction of the tibiofibular syndesmosis in ankle fractures. *Foot Ankle Int.* 2006;27:788-792.
50. Davidovitch RI, Well Y, Karla R, et al. Intraoperative syndesmotic reduction: three-dimensional versus standard fluoroscopic imaging. *J Bone Joint Surg Am.* 2013;95:1838-1843.
51. Sri-Ram K, Robinson AH. Arthroscopic assessment of the syndesmosis following ankle fracture. *Injury.* 2005;36:675-678.
52. Jordan TH, Talarico RH, Schuberth JM. The radiographic fate of the syndesmosis after trans-syndesmotic screw removal in displaced ankle fractures. *J Foot Ankle Surg.* 2011;50:407-412.
53. Horisberger M, Valderrabano V, Hintermann B. Post-traumatic ankle osteoarthritis after rnkle-related fractures. *J Orthop Trauma.* 2009;23:60-67.
54. Cottom JM, Hyer CF, Philbin TM, Berlet GC. Transosseous fixation of the distal tibiofibular syndesmosis: comparison of an interosseous suture and endobutton to traditional screw fixation in 50 cases. *Foot Ankle Surg.* 2009;48:620-630.
55. Rigby RB, Cottom JM. Does the Arthrex TightRope® provide maintenance of the distal tibiofibular syndesmosis? A 2-year follow-up of 64 TightRopes® in 37 patients. *J Foot Ankle Surg.* 2013;52:563-567.
56. Cottom JM, Rigby RB. The "all inside" arthroscopic Brostrom procedure: a prospective study of 40 consecutive patients. *Foot Ankle Surg.* 2013;52:568-574.
57. Lui TH. Arthroscopic-assisted lateral ligamentous reconstruction in combined ankle and subtalar instability. *Arthroscopy.* 2007;23:554.e1-e5.
58. Nuno MCR, Moreira RM. Arthroscopic repair of chronic lateral ankle instability. *Foot Ankle Int.* 2009;30:213-217.
59. Vega J, Golano P, Pellegrino A, Rabat E, Pena F. All-inside arthroscopic lateral collateral ligament repair for ankle instability with a knotless suture anchor technique. *Foot Ankle Int.* 2013;34:1701-1709.
60. Hawkins RB. Arthroscopic stapling repair for chronic lateral instability. *Clin Podiatr Med Surg.* 1987;4:875-883.
61. Guillo S, Bauer T, Lee JW, et al. Consensus in chronic ankle instability: aetiology, assessment, surgical indications and place for arthroscopy. *Orthop Traumatol Surg Res.* 2013;99S:S411-S419.
62. Ferkel RD, Chams RN. Chronic lateral instability: arthroscopic findings and long-term results. *Foot Ankle Int.* 2007;8:24-31.
63. Chen SH, Wu PH, Lee YS. Long-term results of pilon fractures. *Arch Orthop Trauma Surg.* 2007;127:55-60.
64. Conroy J, Agarwal M, Giannoudis PV, Matthews SJE. Early internal fixation and soft tissue cover of severe open tibial pilon fractures. *Int Orthop.* 2003;27:343-347.
65. Decoster TA, Willis MC, Marsh JL, et al. Rank order analysis of tibial plafond fractures: does injury or reduction predict outcome? *Foot Ankle Int.* 1999;20:44-49.
66. Kalenderer O, Gunes O, Ozcalabi IT, Ozluk S. Clinical results of tibial pilon fractures treated by open reduction and internal fixation. *Acta Orthop Traumatol Turc.* 2003;37:133-137.
67. Pollak AN, Mccarthy ML, Bess RS. Outcomes after treatment of high-energy tibial plafond fractures. *J Bone Joint Surg Am.* 2003;85:1893-1900.
68. Salton HL, Rush S, Schuberth JM. Tibial plafond fractures: limited incision reduction with percutaneous fixation. *J Foot Ankle Surg.* 2007;46:261-269.
69. Crawford AH. Triplane and Tillaux fractures: is a 2mm residual gap acceptable? *J Pediatr Orthop.* 2012;32:S69-S73.
70. Podeszwa DA, Mubarak SJ. Physeal fractures of the distal tibia and fibula. *J Pediatr Orthop.* 2012;32:S62-S68.
71. Wuerz TH, Gurd DP. Pediatric physeal ankle fracture. *J Am Acad Orthop Surg.* 2013;21:234-244.
72. Panagopoulos A, Van Niekerk L. Arthroscopic assisted reduction and fixation of a juvenile Tillaux fracture. *Knee Surg Sports Traumatol Arthrosc.* 2007;15:415-417.
73. Von Laer L. Classification, diagnosis, and treatment of transitional fractures of the distal part of the tibia. *J Bone Joint Surg Am.* 1985;67:687-698.
74. Leary JT, Handling M, Talerico M, Yong L, Bowe JA. Physeal fractures of the distal tibia: predictive factors of premature physeal closure and growth arrest. *J Pediatr Orthop.* 2009;29:356-361.
75. Jennings MM, Lagaay P, Schuberth JM. Arthroscopic assisted fixation of juvenile intra-articular epiphyseal ankle fractures. *J Foot Ankle Surg.* 2007;46:376-386.
76. Oloff L, Schulhofer SD, Fanton G, Dillingham M. Arthroscopy of the calcaneocuboid and talonavicular joints. *J Foot Ankle Surg.* 1996;35:101-108; discussion 186-187.
77. Gavlik JM, Rammelt S, Zwipp H. Percutaneous, arthroscopically-assisted osteosynthesis of calcaneus fractures. *Arch Orthop Trauma Surg.* 2002;22:24-28.
78. Gavlik JM, Rammelt S, Zwipp H. The use of subtalar arthroscopy in open reduction and internal fixation of intra-articular calcaneal fractures. *Injury.* 2002;33:63-71.
79. Rammelt S, Amlang M, Barthel S, Gavilk JM, Zwipp H. Percutaneous treatment of less severe intraarticular calcaneal fractures. *Clin Orthop Relat Res.* 2009;468:983-990.
80. Backes M, Schep NW, Luitse JS, Goslings JC, Schepers T. Indications for implant removal following intra-articular calcaneal fractures and subsequent complications. *Foot Ankle Int.* 2013;34:1521-1525.
81. Yu X, Pang QJ, Chen L, Yang CC, Chen XJ. Postoperative complications after closed calcaneus fracture treated by open and internal fixation: a review. *J Int Med Res.* 2014;42:17-25.

82. Harvey EJ, Grujic L, Early JS, Benirschke SK, Sangeorzan BJ. Morbidity associated with ORIF of intra-articular calcaneus fractures using a lateral approach. *Foot Ankle Int*. 2001;22:868.

83. De Vroome SW, Van Der Linden FM. Cohort study on the percutaneous treatment of displaced intra-articular fractures of the calcaneus. *Foot Ankle Int*. 2014;35:156-162.

84. Dewall M, Henderson CE, Phelps T, Dolan L, Marsh JL. Percutaneous reduction and fixation of displaced intra-articular calcaneus fractures. *J Orthop Trauma*. 2010;24:466-476.

85. Rammelt S, Zwipp H, Grass R. Injuries to the distal tibiofibular syndesmosis: an evidence-based approach to acute and chronic lesions. *Foot Ankle Clin N Am*. 2008;13:611-633.

86. Babu N, Schuberth JM. Partial avascular necrosis after talar neck fracture. *Foot Ankle Int*. 2010;31:777-780.

87. Canale ST, Kelly FB. Fractures of the neck of the talus: long-term evaluation of seventy-one cases. *J Bone Joint Surg Am*. 1978;60:143-156.

88. Comfort TH, Behrens F, Gaither D, Denis F, Sigmond M. Longterm results of displaced talar neck fractures. *Clin Orthop Relat Res*. 1985;199:81-87.

89. Morris HD. Aseptic necrosis of the talus following injury. *Orthop Clin North Am*. 1974;5:177-189.

90. Thordarson DB, Triffon MJ, Terk MR. Magnetic resonance imaging to detect avascular necrosis after open reduction and internal fixation of talar neck fractures. *Foot Ankle Int*. 1996;17:742-747.

91. Deng DF, Hamilton GA, Lee M, et al. Complications associated with foot and ankle arthroscopy. *J Foot Ankle Surg*. 2012;51:281-284.

92. Ferkel RD, Small HN, Gittins JE. Complications in foot and ankle arthroscopy. *Clin Orthop Relat Res*. 2001;391:89-104.

93. Imade S, Takao M, Miyamoto W, Nishi H, Uchio Y. Leg anterior compartment syndrome following ankle arthroscopy after Maisonneuve fracture. *Arthroscopy*. 2009;25:215-218.