Irreducible Fractures And Dislocations of the Ankle Associated With Entrapment of the Posterior Tibial Tendon within the Tibiofibular Interosseous Space: A Case Series and Literature Review

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STRUCTURED ABSTRACT (Limit 250 words) Background:	
Note: The following files were submitted by the author for peer review, but cannot be converted to PDF. You must view these files (e.g. movies) online.	
Operative Video of Reduction.mp4	

FAO-20-0079 – Reviewer Note

Irreducible Fracture-Dislocation of the Ankle Associated With Entrapment of the Posterior Tibial Tendon within the Tibiofibular Interosseous Space: A Case Series and Literature Review

Reviewers: The authors have included a video with the submission. Please view the html proof to review.

Paper No. FAO-20-0079 entitled "Irreducible Fracture-Dislocation of the Ankle Associated With Entrapment of the Posterior Tibial Tendon within the Tibiofibular Interosseous Space: A Case Series and Literature Review"

Reviewer #1:

COMMENT	RESPONSE	TEXT CHANGES
I commend you for presenting these cases given that not everything went well during surgery. The trans-syndesmotic PTT has a nice reference list and I appreciate your cautions to the reader. cartoons / drawing would help especially in case 1 case 1 dislocation caused by improper reduction during exfix (CT done later) this is of value, but needs more focus: 1. fx vs disl 2.CT before reduction attempt or after 3. injury or bad reduction resulting in abnormal tendon course which would take a lot of work	The CT was obtained after reduction, prior to definitive internal fixation. The PTT dislocation was caused by initial injury and not by reduction technique.	Figure 1 was modified to also include post-reduction radiographs. Line 58 Added: demonstrating significant improvement of alignment compared to the original injury films. However, the medial malleolus remained displaced and anterior to the tibia. Line 68 Added: secondary to an unrecognized trans-syndesmotic PTT dislocation, having occurred at time of injury prior to initial reduction in the emergency department as well as subsequent external fixation. Line 186 Added: at time of external fixation during the first case Line 187 Added: during subsequent definitive surgical fixation.
Abstract		
13 allowed	N/A	Allowed
Introduction		

20 need reference	Reference added	Line 21 Deleted: neurovascular compromise Added: skin necrosis and infection
35 I think unrecognized is a better term than delayed	Unrecognized	unrecognized
40 not sure post facto CT reading is early...it is certainly not unrecognized	N/A	Line 41 Deleted early
Methods		
case 1 **51 how much time from injury to exfix (not 48hrs as in case 2)**	Based on retrospective note review, we can report time since arrival to our ED to external fixator placement	Line 61 Added: five hours after arrival to the emergency department
53 with all the periosteal stripping it has to be GIII	Noted	Changed to GIII
54 intact. not otherwise intact unless something is out. skeptical that tibial nerve sensation was intact to thee foot	Noted	Line 55 Deleted: Otherwise
60 so the prox aspect of ptt was anterior? this is a sign	Yes this would be a sign. However, at this time the tendon was not yet identified as PTT. Possibly considered as extensor tendon.	Line: 64 Changed:"originating from the extensor surface of the" to "coursing over the anterior"
64 I am surprised there is no valgus impaction fracture	The tibiotalar articulations were inspected and there was not sign of impaction fracture.	Line 74 Added: The tibiotalar joint was inspected and there was no evidence of impaction fracture.
66 how many days?	Noted	Line 72 Added: 8 days later
68-78 I am unable to view the video, and perhaps that would clarify this section. Nonetheless a drawing of the tendon course would be helpful.	The video will significantly aide in clarification. The video was uploaded in accordance to FAO specifications as an mp4 file. A reviewer note added to our submissions reads: "Please view the html proof to review." Perhaps this is	N/A

	helpful information in accessing the video file.	
82 able to perform a single leg toe raise?	Patient was not asked to perform single leg heel raise in clinic. Strength testing was performed with patient seated.	N/A
84 fx healing is certainly not abundant	Noted	Line 91 Changed: “interval” to “early”
case 2 so no CT....	CT has been added. Includes axial series and coronal view.	Line 110 Added: With the diagnosis confirmed surgically, retrospective review of CT imaging of the ankle obtained pre-operatively demonstrates the posterior tibial tendon entrapped within the syndesmosis and entering the tibiotalar joint space.
105 fig 8 is an AP, so it shows overalap and med=sup but not a well maintained mortise med=sup=lat. should be easy to add the mortise view	Figure 8 includes a mortise and lateral view. We recognize it is not a perfect mortise view. However, we were unable to obtain any additional follow-up radiographs of the patient for case 2.	N/A
89 fell while on	Noted	Line 96 Added: while
95 coursing laterally means.....proximal tendon goes laterally?	Clarified	Line 103 Changed: distal medial to proximal lateral over the
a drawing of the tendon course would be helpful.	We were unable to create an original illustration of publication quality. Please reference these articles for illustration examples: Anderson (reference 1), Ermis (reference 5), Heini (reference 6), Pankovich (reference 12), Trividi (reference 19).	N/A
Results		

perhaps reduction maneuver in case one caused the entrapment, since the initial position needed to be repeated.	Surgeon performing external fixation confirmed PTT dislocation present before external fixator placement.	
Discussion		
172 was CT done on case 2?	CT added see above comment	CT added see above comment (Line 110)
182 -190 you found 2 trans-syn ant ptt dislocations. one was fracture and 1 no fracture. both w significant ant lat displacement of talus. I wish you could coalesce these 2 cases but not title them "fractures". you advocate heightened suspicion which is the purpose of this paper, and both cases are interesting, but I would suggest a change in the title to more accurately reflect both cases. Certainly case 2 likely has a prox fib fx (would need to show the reader xray of the knee no r/o fx)	Noted Figures 6 a and b now demonstrate radiographs of ankle dislocation and proximal fibular fracture consistent with Maisonneuve fracture mechanism.	Title Changed to Dislocations **and** Fractures Line 6 Added: and/or
Conclusion		
196 case 2 appears to be low energy	Case 2 was caused by motorcycle accident and is believed to be high energy	N/A
take home pts reduction should be carefully performed and evaluated for proper PTT position after syndes injury with sig initial lat displacement of the talus	These take home points are accurate	Line 216 Added: Reduction should be carefully performed with awareness of proper PTT position.
Artwork		
fig 2 MCS looks normal minimal overlap of tib fib never do see CT w bone windows to assess for valgus impaction fx	Bone window CT figure added (Figure 3). The tibiotalar articulations were inspected and there was no sign of impaction fracture.	Line 74 Added: The tibiotalar joint was inspected and there was no evidence of impaction fracture.
fig 6 not really tri-cortical if it goes through a segmental piece	Noted	Figure 4 description changed to “syndesmotic screws”
fig 8 are there weight bearing images available?	We were unable to obtain any additional follow-up radiographs of the patient for case 2.	N/A

Reviewer #2:

COMMENT	RESPONSE	TEXT CHANGES
Discussion		
Interesting although small case series. Highlights the need to continue to investigate and look for additional problems and causes when the case is more difficult than usual or there is a persistent malreduction identified. Increased morbidity would be expected in missed cases and the authors have highlighted the need for prompt diagnosis.	N/A	N/A
Conclusion		
Perhaps the radiologists would identify this injury more readily on MRI rather than CT scan. Although CT scan is much more commonly obtained prior to surgical intervention.	Noted. References Hodgson and Thoreau added to discuss ultrasound and MRI as imaging options with brief limitations.	Line 191 Added: Ultrasonography and magnetic resonance imaging (MRI) represent additional imaging modalities well described for assessing tendon and ligament pathology. (Hodgson) However, MRI is less accessible and undesirable when an external fixator has been emergently placed. Furthermore, ultrasonography becomes challenging in the acute traumatic setting secondary to edema, air in the soft tissue, and compromised skin condition. (Thoreau)

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Abstract

Closed reduction of acute ankle fractures and/or dislocations are~~is a~~ routine procedures which can be occasionally blocked by bony and soft tissue structures surrounding the tibiotalar joint, preventing anatomic restoration. One rarely described mechanism involves posterior tibial tendon (PTT) entrapment within the ankle syndesmosis or tibiofibular interosseous space. A review of previous case reports has demonstrated significant long-term ankle morbidity associated with failed recognition of this injury pattern at the time of definitive fixation. We present a case series of two patients wherein prompt recognition of a trans-syndesmotic PTT dislocation at the time of definitive fixation~~,~~ allowed~~ing~~ for appropriate anatomic reduction and avoidance of additional surgical procedures. Our case series aims to facilitate early recognition of this rare injury pattern as well as reinforce existing recommendations for early diagnosis and management.

Introduction:

In the setting of ankle fracture-dislocation, achieving timely anatomic ~~closed~~ reduction is crucial in order to alleviate pressure on soft tissues and prevent ~~neurovascular compromise~~skin necrosis and infection.[8] Occasionally, displaced bony and soft tissue structures surrounding the tibiofibular joint may prevent reduction. Such described associated injuries include anterior and

posterior fibular dislocation, deltoid ligament incarceration, as well as extensor digitorum and posterior tibial tendon (PTT) entrapment. [3,4,11,15–18] In the case of PTT dislocation, the tendon more commonly dislocates anteriorly over the medial malleolus through ruptured flexor retinaculum. [10] However, there are descriptions of a dislocation of the PTT around the posterior malleolus with subsequent passage of the tendon posteriorly-to-anteriorly through a concomitantly ruptured and widened tibiofibular syndesmosis. [1,2,5,6,9,11–14,18–20] In some instances, the tendon even extends proximally into the interosseous membrane. In such instances, the PTT may course from lateral to medial along the anterior aspect of the tibia. Such inter-positioning forces anterolateral subluxation of the talus and medial joint space widening, thus blocking closed anatomic reduction.

In ~~a~~ recent case reports, failure to recognize trans-syndesmotic PTT dislocation at the time of definitive internal fixation has involved patients undergoing multiple revision surgeries with subsequent increased morbidity. [9] As a consequence of ~~delayed~~ unrecognized diagnosis, published post-operative sequelae have included significant long-term stiffness, extensive soft tissue compromise requiring coverage, as well as equinovarus and clawtoe deformity secondary to ischemic deep posterior compartment contracture. [1,6,14,18]

In this case series, ~~early~~ recognition of trans-syndesmotic PTT dislocation was achieved at the time of initial open definitive fixation, in one case following external fixator removal and planned ORIF, allowing for appropriate anatomic reduction and avoidance of additional surgical procedures. This case series contributes to a limited body of literature describing and facilitating

earlier prompt recognition of this rare injury pattern as well as reinforces previous recommendations advocating for the benefits of early diagnosis and appropriate treatment.

Case 1

Patient is a 33 year old male who sustained an open left ankle trimalleolar fracture dislocation following a motorcycle accident. The patient was initially seen at an outside hospital where the ankle was splinted in situ and patient was given tetanus and IV cefazolin. He was transferred to our institution where the left lower extremity was found to have a 7 centimeter open wound (Gustillo Anderson Type 32) with extruded distal tibial plafond medially at the ankle joint and significant periosteal stripping (Gustillo Anderson Type 3A). His left lower extremity was otherwise neurovascularly intact. Fluoroscopic imaging demonstrated a trimalleolar ankle fracture (AO 44-C2) with anterolateral tibiotalar dislocation. **(Figure 1)** The ankle was rReduction and splinting of the ankle in the emergency department and non-weight bearing radiographs were obtained demonstrating significant improvement of alignment compared to the original injury films. However, the medial malleolus remained displaced and anterior to the tibia. was unable to be achieved. He was taken to the operating room for urgent irrigation and debridement of the left ankle with application of an external fixator five hours after arrival to the emergency department. Maintenance of the rReduction remained was difficult, and it was noted intraoperatively that there was a tendon interposed between the medial malleolus fracture fragment and the tibial metaphysis originating from the extensor surface of thecoursing over the anterior tibia. At the time of this initial surgical procedure, the unidentified tendon was brought anteromedially through the fractured medial malleolus so that the medial malleolus could be

reduced, and the external fixator was applied. The tibiotalar joint was adequately reduced with improved length and coronal alignment. T~~, although t~~he medial malleolar fracture remained non-~~mal~~reduced secondary to an unrecognized trans-syndesmotic PTT dislocation, having occurred at the time of injury prior to initial reduction in the emergency department. **(Figure 2)** Post-operative computed tomography (CT) was performed for preoperative planning.

The patient returned to the operating room 8 days later for definitive fixation when soft tissue swelling allowed. The medial traumatic arthrotomy was opened and thoroughly irrigated. The tibiotalar joint was inspected and there was no evidence of ~~valgus~~ impaction fracture. **(Figure 3)** Again, the dislocated tendon was noted at the medial malleolar fracture site. Tracing the tendon distally to the navicular bone identified it as likely the posterior tibial tendon, and the groove for the posterior tibial tendon was empty on palpation. However, the tendon was unable to be reduced by simple translation posteriorly to the medial malleolus, and it was noted that the tendon entered the surgical exposure proximally on the anterior tibial surface from lateral to medial. Upon retrospective review of the CT scan obtained pre-operatively, a tendon can be seen emerging through the tibiofibular interosseous space, coursing distally and medially along the anterior tibia. **(Figures 4a-c)** The tendon was successfully reduced by dislocating the talus laterally and bringing the PTT anterolaterally, then finally posteriorly through the disrupted syndesmosis. The tendon was frayed but intact, and damaged tendon was debrided. **(Video Supplementary Material)** Fracture fixation then proceeded in standard fashion.

At 3-month follow-up, the patient demonstrated no issues with pain control and has been weight bearing as tolerated, no longer requiring a CAM boot. Incisions were ~~clean dry and intact~~well

healed with no concerns for infection. Physical examination of the ankle demonstrated 4/5 strength of the PTT, and was ~~otherwise~~ neurovascularly intact. Radiographs obtained in the clinic demonstrated maintained alignment of the ankle mortise, with early~~interval~~ facture healing and no evidence of hardware failure or loosening. **(Figure 5)**

Case 2

Patient is a 68 year old male who fell while on his motorcycle and sustained an ankle dislocation. Closed reduction attempts in the emergency department were unsuccessful. Initial radiographs of the knee and ankle depict anterolateral subluxation of the talus with medial clear space widening, as well as a proximal fibular fracture consistent with a Maisonneuve fracture mechanism. **(Figures 6a-b)** The patient was brought to the operating room for open reduction. However, there was necrotic-appearing skin overlying the medial malleolus as the ankle had been dislocated for approximately 48 hours. A medial approach was performed and a tendinous structure was found coursing distal-medial to proximal-lateral~~laterally~~ over the talar dome. This tendon was irreducible from this approach, therefore a lateral approach to the syndesmosis was performed, and the syndesmosis was found to be completely disrupted with a tendinous structure in the syndesmosis preventing reduction. A third incision was made proximal to the necrotic tissue on the medial side, and the PTT was noted to be absent. The previously seen tendon was identified as the PTT and guided anterior to posterior through the syndesmosis, and the ankle reduced spontaneously upon return of the PTT to its anatomic location. The syndesmosis was then stabilized and deltoid ligament was repaired. With the diagnosis confirmed surgically, retrospective review of CT imaging of the ankle obtained pre-operatively demonstrates the

posterior tibial tendon entrapped within the syndesmosis and entering the tibiotalar joint space. (~~Restrospective review of CT~~Figures 7a-b)

8 months post-operatively, the patient was doing well and demonstrated 5/5 strength of the PTT with full ankle range of motion. The ankle mortise was well maintained with no evidence of hardware loosening or~~f~~ failure **(Figure 8)**.

Discussion

Dislocation of the PTT through the tibiofibular interosseous space is a rare mechanism blocking closed ankle reduction. Such an injury was first described by Böhler et al. in 1936. [2] Several isolated case reports, separated by decades, have documented this same injury pattern at the time of surgery. [5,11–13,20] While each of these reports demonstrated timely open reduction of the ankle joint, PTT interposition in the syndesmotic joint space with associated anterolateral talar dislocation caused initial failed closed reduction.

Trividi et al. [19] recognized persistent PTT dislocation on CT immediately following primary open reduction and internal fixation (ORIF) and underwent timely re-operation and successful anatomic reduction. However, other case reports have unfortunately noted delayed diagnosis of trans-syndesmotic PTT dislocation after ORIF, and reported subsequent poor outcomes and morbidity.

Heini et al. [6] reported an ankle fracture requiring significant force to achieve satisfactory open reduction and fixation. Post-operative loss of syndesmotic fixation and recurrent anterolateral talar subluxation led to an intraoperative discovery of an initially unrecognized PTT coursing through the tibiofibular interosseous space, 8 months following initial injury. After PTT reduction through multiple staged revision procedures, the patient demonstrated improvement, although sustained significant long-term reduction in joint mobility.

Anderson et al. [1] discovered trans-syndesmotic dislocation of the PTT at time of salvage ankle arthrodesis surgery 1 year following initial injury. Noting severe calf atrophy, as well as equinovarus and clawtoe contracture, the author performed a deep posterior compartment exploration and discovered the tendon wrapped laterally around the tibia emerging through dense scar tissue in the syndesmosis. During the interval period, the patient had undergone multiple revisions for loosened hardware, ankle mortise widening, and talar tilting.

Lacasse et al. [9] recognized the PTT coursing through the tibiofibular syndesmosis on MRI 4 months after initial ORIF. Correction required extensive debridement of the syndesmosis, including hardware removal and circumferential release of the ankle joint to allow for reduction of the PTT. Following revision surgery, pain improved but ankle dorsiflexion remained limited at 5 degrees.

In a recent case report by Thoreau et al. [18] , despite extensive soft tissue repair including the deltoid ligament and syndesmosis, failure to initially recognize and reduce a PTT dislocation during primary ORIF led to re-operation one week later including extensive dissection requiring

a cutaneous skin flap. The PTT dislocation was ultimately visualized using CT in the setting of persistent anterolateral talar subluxation.

Most recently, Sato et al. [14] describes a multi-stage case in which recognition and reduction of a PTT trans-syndesmotic dislocation was achieved only after a third attempt at open reduction involving full surgical exposure of the PTT, approximately 3 months after the initial injury. The abnormal tendon course was revealed via CT and MRI in the setting of the patient having difficulty with ankle inversion.

The location of PTT entrapment is influenced by the amount of energy associated with the injury. [1] Upon review of associated high-energy injuries with interosseous PTT location, Thoreau et al. identified common features to PTT dislocation through the ankle syndesmosis including high energy trauma, AO fibula type C ~~AO 44-C2~~ fracture, distal tibiofibular dislocation and lateral talar translation with an increased internal clear space (or malleolar fracture). [18] ~~The first~~Both reported case~~s~~ in our series of PTT dislocations into the syndesmosis features all characteristics formally outlined by Thoreau et al.~~, and the second case also fits the description except for the fracture.~~

Of note in the above presented cases, attempting posterior translation of the PTT (indicated for dislocation directly anterior to the medial malleolus) was met with significant resistance. Furthermore, anatomic reduction of the medial malleolar fragment and tibiotalar joint were similarly difficult. Upon reduction of the PTT, subsequent medial malleolar and tibio-talar reductions required minimal exertion. We emphasize that a failed closed reduction, a persistently

wide distal tibiofibular space, and/or excessive force requirements for satisfactory ankle joint reduction (open or closed) should raise clinical suspicion for possible PTT entrapment.

As demonstrated in previously mentioned case reports, CT imaging has proven diagnostic utility in troubleshooting ~~malreduction~~ fractures and dislocations post-operatively. Although we were fortunate to recognize and reduce both tendon dislocations intra-operatively, subsequent review of the CT imaging revealed the abnormal course of the PTT. Had we noticed the PTT dislocation on imaging ~~prior to returning to the operating room~~at the time of external fixation during the first case, we would have more quickly achieved appropriate reduction, minimizing tourniquet and operating room time during subsequent definitive surgical fixation. With heightened clinical suspicion afforded by characteristics formally outlined by Thoreau et al. [18] , obtaining CT imaging proves useful in identifying PTT displacement and planning for appropriate reduction prior to definitive operative fixation. Ultrasonography and magnetic resonance imaging (MRI) represent additional imaging modalities well described for assessing tendon and ligament pathology. [7] However, MRI is less accessible and undesirable when an external fixator has been emergently placed. Furthermore, ultrasonography becomes challenging in the acute traumatic setting secondary to edema, air in the soft tissues, and compromised skin condition. [18] Such planning will aid in reducing anesthetic and tourniquet time, as well as incisional exposure and excessive soft tissue dissection. As noted previously, delayed recognition of PTT dislocation is associated with significant morbidity and repeat operations.

To our knowledge, we present the most up-to-date review of cases of irreducible ankle fractures due to PTT trans-syndesmotic dislocation reported in the literature. We highlight the morbidity

associated with delayed diagnosis, and emphasize the injury pattern and difficulty in reduction that should alert the orthopaedic surgeon to the possibility of this diagnosis. Given the increase in reports of this relatively rare injury in the past decade, ~~it is possible that~~we suspect that the incidence of this injury pattern is ~~more common than described~~under reported, however recognition in the past has been low. With the increasing use of cross-sectional imaging for complex fractures and irreducible dislocations, and heightened suspicion of this injury pattern, early recognition and the subsequent reduction in patient morbidity are achievable.

Conclusion

Irreducible ankle fractures and ~~-~~dislocations should raise awareness to possible tendon incarceration. Moreover, an irreducible ankle with an AO fibula type C ~~n AO 44-C2~~ fracture pattern and lateral talar dislocation or distal tibiofibular dislocation and lateral talar translation in a high energy injury mechanism warrants heightened suspicion for PTT dislocation through the tibiofibular interosseous space. Reduction should be carefully performed with awareness of proper PTT position. CT imaging can facilitate identification of this injury pattern and aid in pre-operative planning. Early recognition may improve patient outcomes and avoid the need for future exploratory or revision surgery.

Conflict of Interest

No Disclosure

References

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Figure 1: AP and lateral views of left ankle demonstrating dislocation of the ankle mortise with comminuted fracture of the fibula, fracture of the medial malleolus, and anterolateral subluxation of the talus. Closed reduction demonstrates improved length and coronal alignment with persistent anterior displacement of medial malleolus.

164x206mm (144 x 144 DPI)

Figure 2: AP fluoroscopy following external fixation demonstrates improvement in ankle mortise and fibular alignment with persistent medial clear space widening and gapping at medial malleolus fracture site.

164x150mm (144 x 144 DPI)

Figure 3: CT with bone window in coronal and sagittal planes demonstrate fractures of fibula, medial, and posterior malleoli. No evidence of impaction fracture.

295x204mm (144 x 144 DPI)

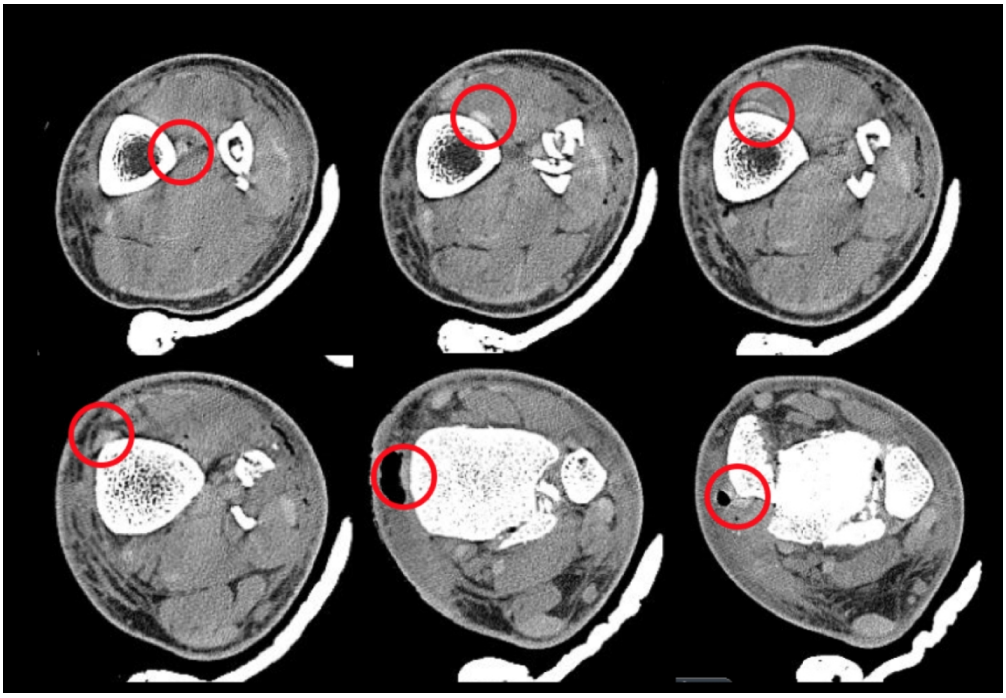

Figure 4a: Axial CT sections (proximal to distal in direction of top-left to bottom-right) demonstrating PTT passing through interosseous space across the anterior surface of the tibia, displacing the medial malleolar fragment anteriorly.

261x179mm (144 x 144 DPI)

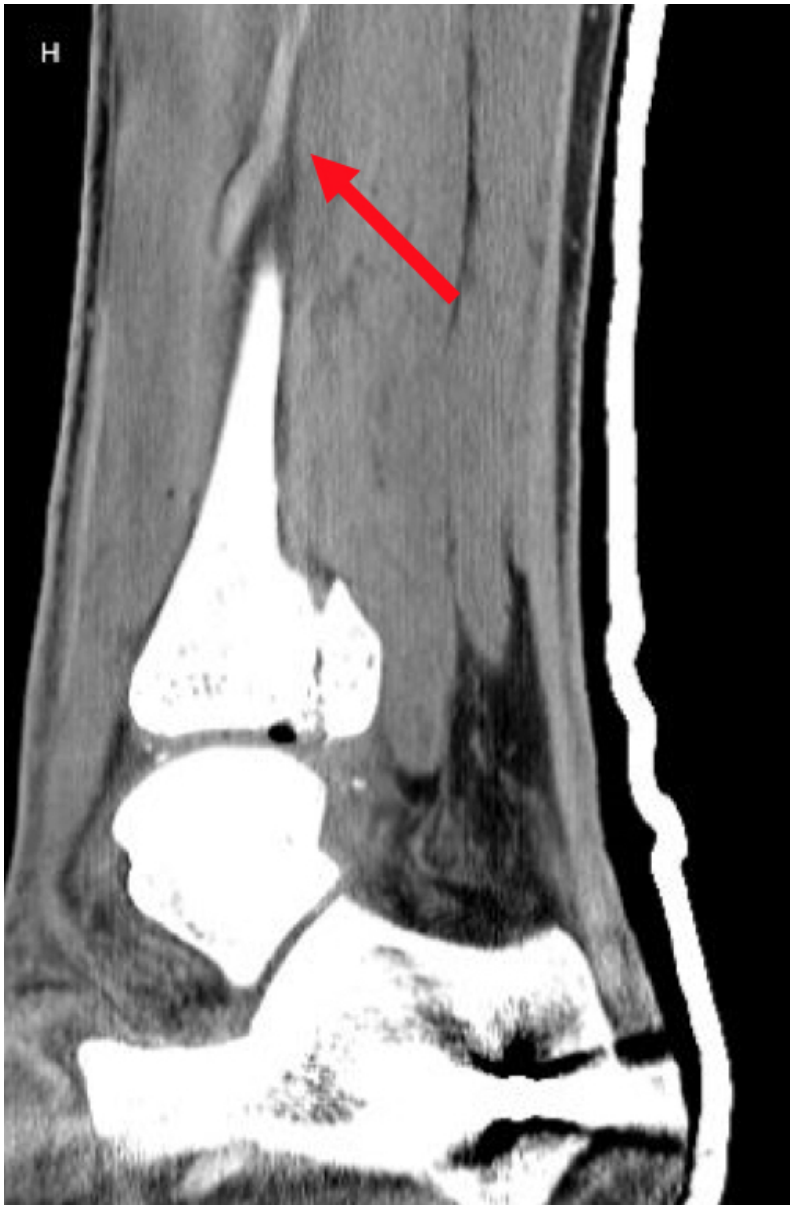

Figure 4b: Sagittal CT section showing PTT penetrating tibiofibular interosseous space.

88x134mm (144 x 144 DPI)

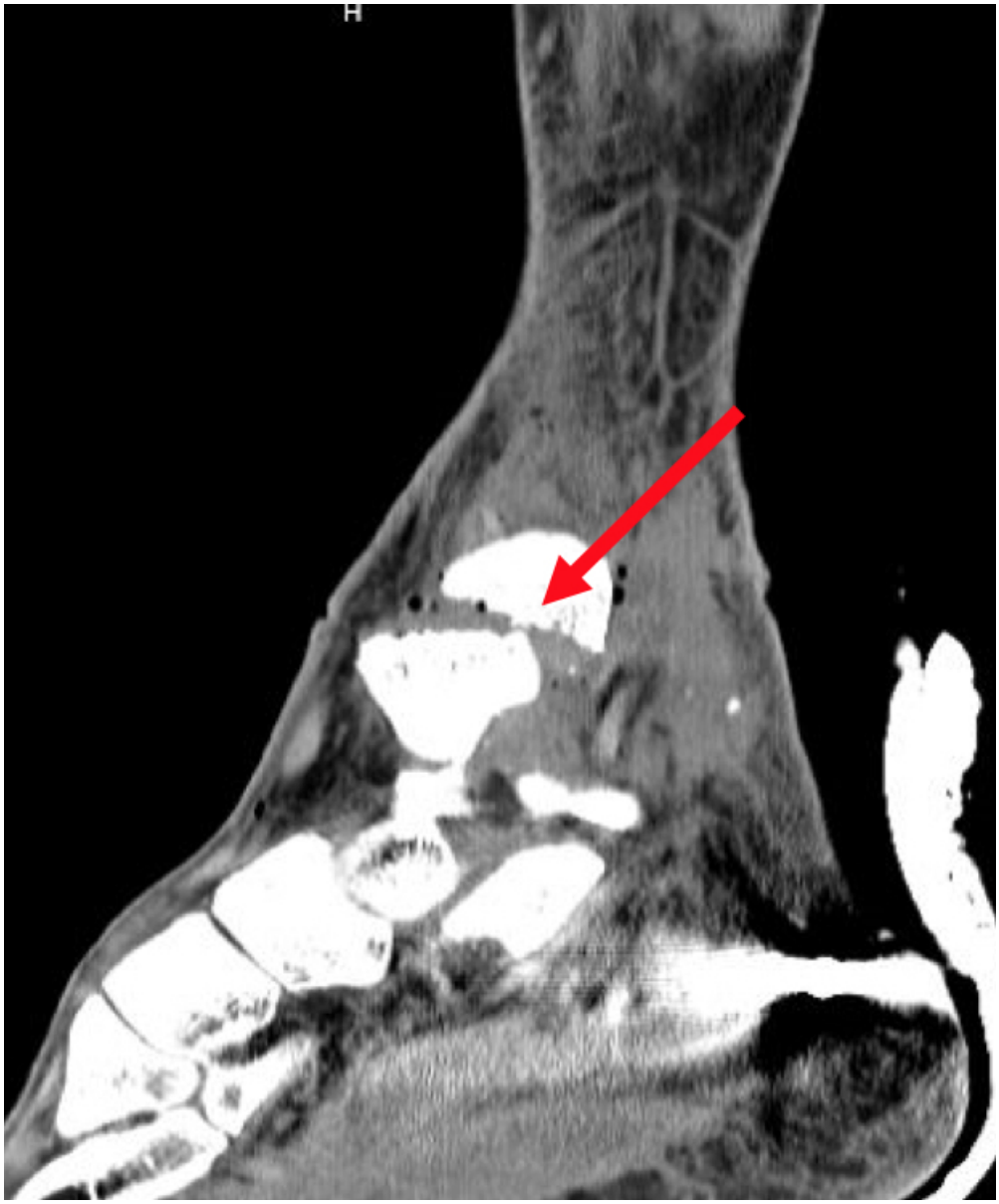

Figure 4c: Sagittal CT section showing PTT interposed between tibia and medial malleolar fragment blocking reduction.

109x131mm (144 x 144 DPI)

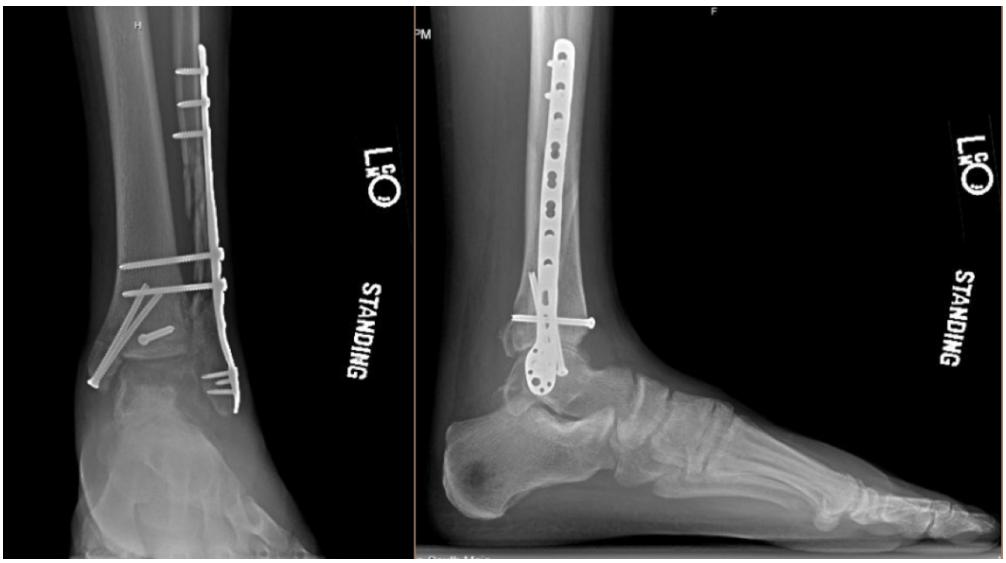

Figure 5: Weight bearing AP and lateral radiographs of the left ankle 3 months following internal fixation. Fibula fracture stabilized with bridge plating and syndesmotic screws. Medial and posterior malleoli anatomically reduced and fixed using lag screw technique.

212x117mm (144 x 144 DPI)

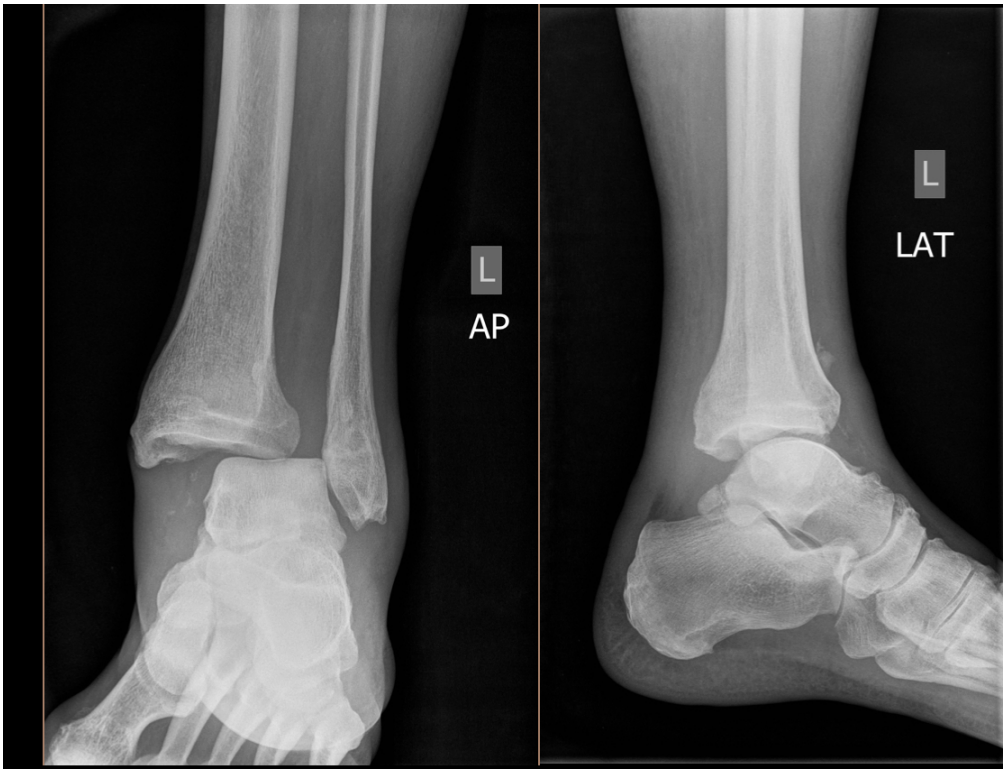

Figure 6a: AP and lateral radiographs of the left ankle demonstrating dislocation of the tibiotalar joint with anterolateral displacement of the talus and medial clear space widening.

195x149mm (144 x 144 DPI)

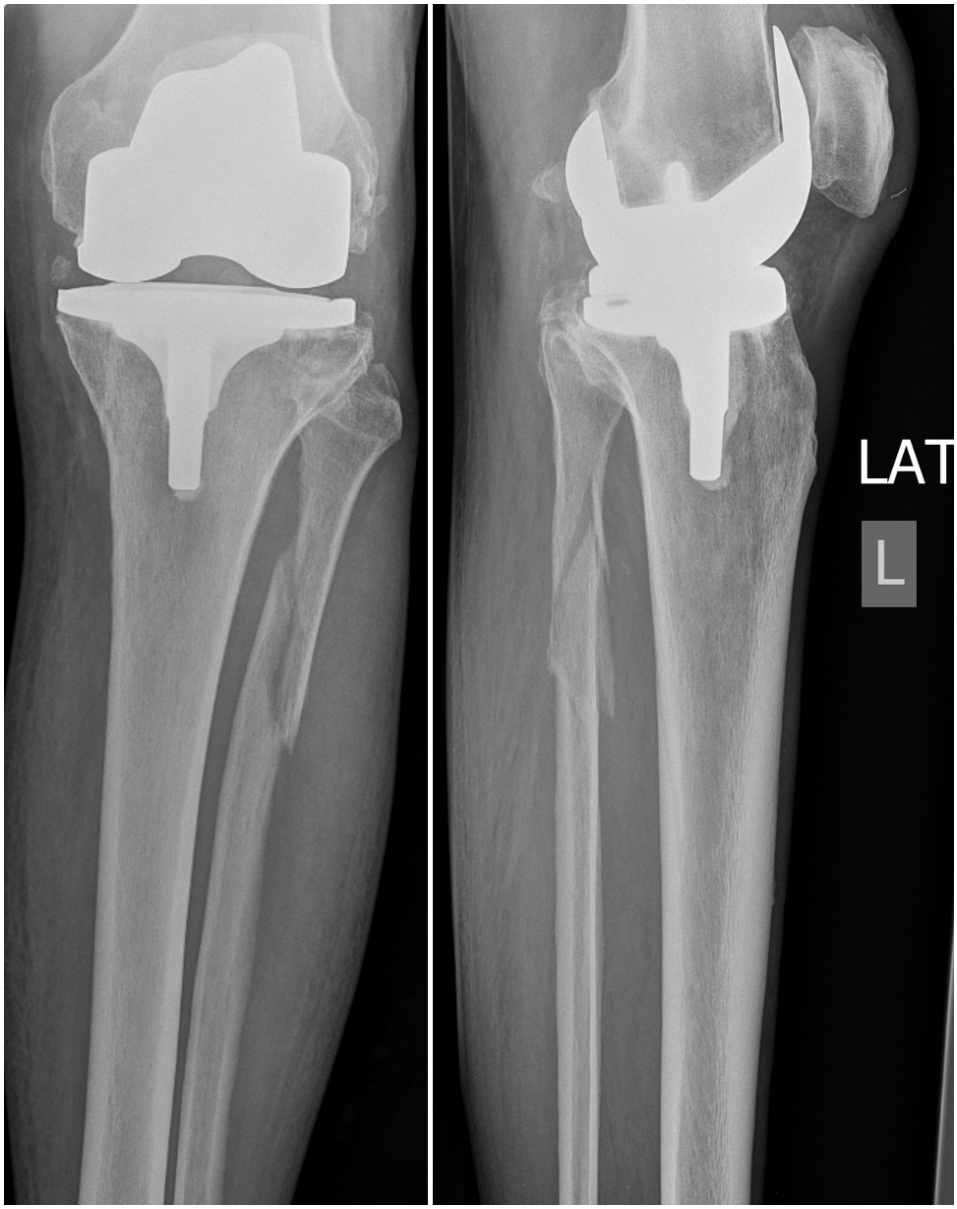

Figure 6b: AP and lateral radiographs of the left knee and proximal tibia and fibula demonstrating proximal fibular fracture consistent with Maisonneuve fracture mechanism.

170x214mm (144 x 144 DPI)

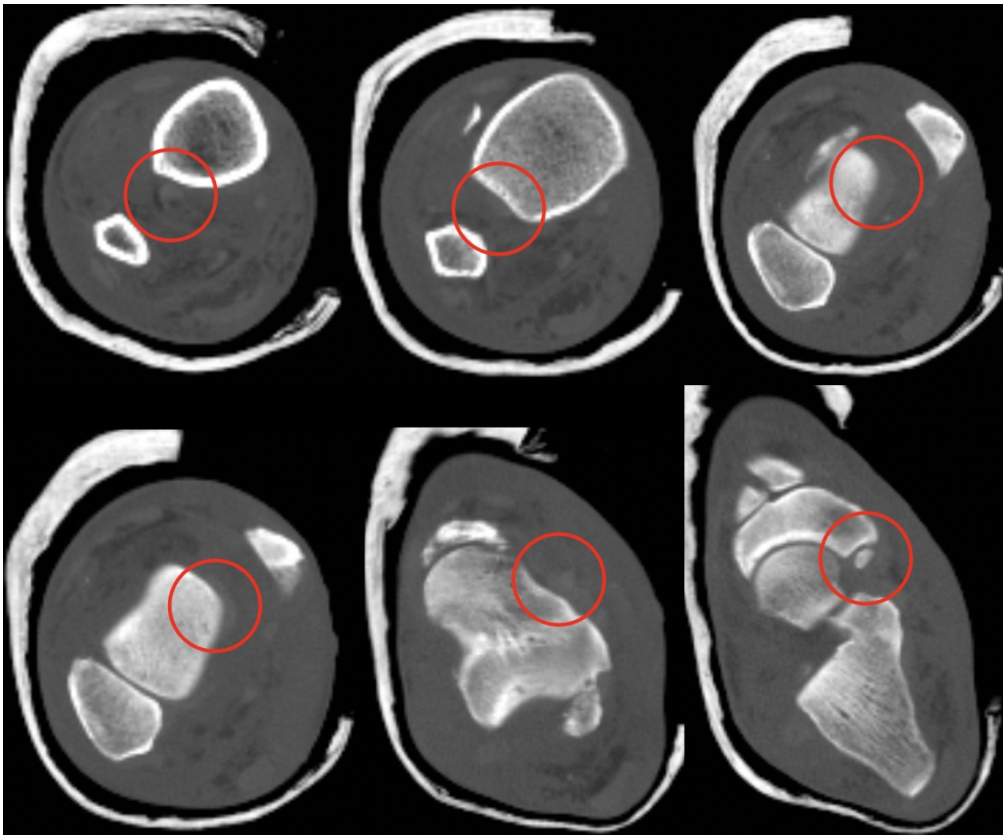

Figure 7a: Axial CT sections of ankle (proximal to distal in direction of top-left to bottom-right) demonstrating PTT within the interosseous space proximally. The tendon enters the tibiotalar joint space distally, displacing the talus anterolaterally.

334x277mm (144 x 144 DPI)

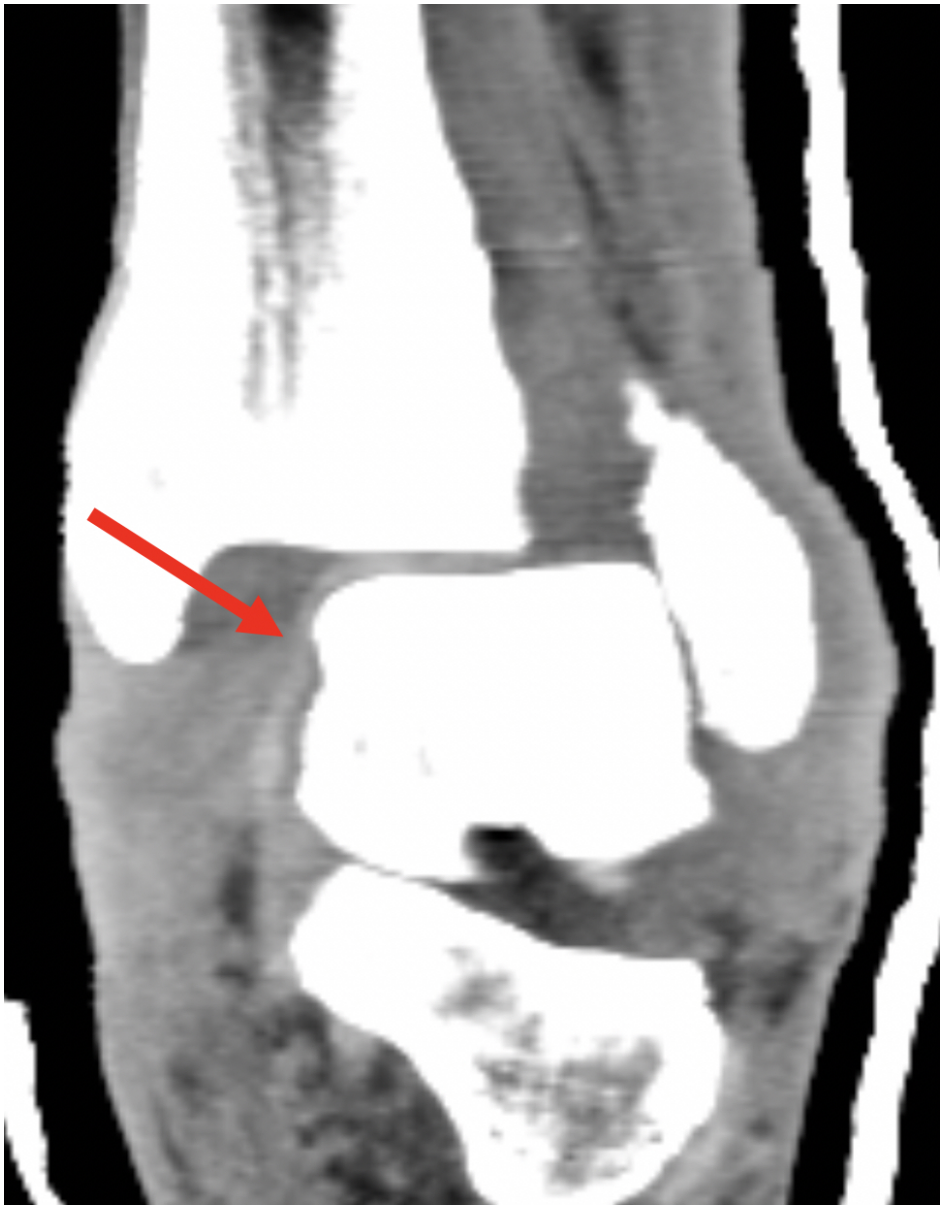

Figure 7b: CT in coronal plane demonstrating PTT entering tibiotalar joint space with anterolateral displacement of the talus.

170x218mm (144 x 144 DPI)

Figure 8: AP and lateral radiographs of the left ankle following open reduction and syndesmotic fixation demonstrating uniform spacing of the ankle mortise with no evidence of hardware loosening or failure.

141x151mm (144 x 144 DPI)