Technique Report

Use of a modified retrograde femoral rod as a custom length tibiotalocalcaneal nail

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Abstract:
There has been increasing interest in the use of hindfoot tibiotalocalcaneal (TTC) nails to treat ankle and distal tibia fractures in select patient populations who are at increased risk for soft tissue complications after open reduction and internal fixation with traditional plate and screw constructs. We describe a technique which uses a retrograde femoral nail as a custom length TTC nail. By using a simple modification of the insertion jig, we are able to achieve safe screw trajectories that allow for robust distal interlocking fixation. Review of implantation in multiple cadaveric specimens demonstrates safe placement of distal screw fixation in the calcaneus without risking injury to important neurovascular structures. Because of the 2-cm incremental length options of this particular device, we are able to achieve supraisthmal fixation in the tibia which may lessen the risk for fracture that may be more likely to occur at the tip of a short TTC nail option. Furthermore, a custom length TTC nail is more costly and also requires advanced notice to acquire for the case; retrograde femoral nails are readily stocked and accessible at our level 1 trauma center. This TTC technique offers anatomic restoration while also offering convenience, instrument familiarity, cost savings, and increased patient safety.

Keywords: diabetic ankle fracture, elderly ankle fracture, open pilon, tibiotalocalcaneal nail

1. Introduction

Hindfoot nailing is a useful tool when treating low-demand older patients with complex ankle trauma because it permits early weight bearing. Open reduction and internal fixation (ORIF) of fragility ankle fractures in this population has been associated with a 33.3% complication rate[1] and up to a 42.3% complication rate with additional comorbidities.[2,3] Nonoperative care of unstable tibiotalar fractures in high-risk patients leads to high complication rates (ie, malunion and nonunion).[4–7] Traditionally, hindfoot nailing was reserved for a select subset of patients when severity of bone, joint, and soft tissue injury was not amenable to more conventional reconstruction.[8]

Recently, there has been increasing interest in using hindfoot nails to treat tibiotalar fractures in diabetic and geriatric populations to minimize wound complications and allow immediate weight bearing.[9] The use of the tibiotalocalcaneal (TTC) nail was classically described as having advantages when treating chronic hindfoot conditions.[10] Hindfoot fusion nails, with or without joint preparation for fusion, have been used for patients at higher risk of postoperative complications, such as those with cognitive impairment, uncontrolled diabetes, American Society of Anesthesiologists classification greater than 2, soft tissue compromise, and declining independent mobility.[11]

Recent advantages have also been noted for the use of the TTC nails in selected acute traumatic injuries.[12] TTC nails can be particularly helpful in the setting of treating acute ankle fractures in neuropathic diabetics where wound breakdown can occur after traditional ORIF (Fig. 1A and B). In general, outcomes have been largely optimistic in the treatment of unstable periarticular ankle trauma in the geriatric population.[1,13–18] In the younger patient population, this treatment option occurs on a case-by-case basis and should be thought of as last resort for more severe injury patterns (Fig. 2A–E).[12] A custom length TTC device also provides the ability to stabilize any complex hindfoot trauma with associated proximal injuries, such as ipsilateral tibial shaft fractures.[19–25]

There are notable scenarios where a long supraisthmal TTC nail that spans the entire length of the tibia can be advantageous.[18] A recent series of 48 geriatric ankle fragility fractures treated with a long retrograde hindfoot nail demonstrated a 90% return to preinjury function without any periprosthetic fractures or nail failures.[18] Stress fractures at the tip of a short TTC nail have been described (Fig. 3).[26] One large series of 1046 ankle fusions reported a 1.4% occurrence of periprosthetic tibia stress fractures in patients undergoing ankle fusion. Patients at risk for this included patients with osteopenia, diabetes mellitus, tobacco smokers, and peripheral neuropathy.[27] Practitioners must maintain a high level of suspicion for tibial stress fractures when

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Our institutional affiliation of the Institutional Review Board (IRB) provided consent for the research and the protocol. The Principal Investigator name was submitted to the IRB for review of our research and we recieved a statement noting that our study was deemed exempt from IRB review.

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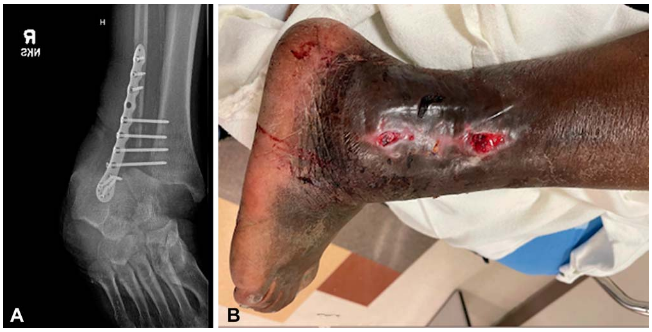

Figure 1. A and B, Postoperative x-ray and clinical image of an ankle fracture treated with plate and screws obtained after implant failure and wound healing issues in a diabetic patient 14 days after the index procedure.

Figure 2. A–E, Preoperative computed tomography and x-ray (A and B), postoperative x-ray (C), intraoperative image during nail insertion (D), and postoperative clinical photograph (E) of a patient treated with a retrograde femoral rod used as a TTC nail in the case of a grade 3 open pilon fracture in a low functional demand patient with multiple comorbidities. Note the 4° valgus curvature in C.

Figure 3. Stress fracture at the tip of a short (<200 mm) nail in a diabetic patient with pain preceding with pedestal formation at tip of the nail. This implant was revised to a long nail protecting the entire tibial shaft.

patients present with pain at the lower third of the leg after ankle arthrodesis, potentially corresponding with the proximal end of the implant.[27] Although no clear evidence exists for limiting the risk of peri-implant stress fractures, there has been evidence that ending the nail at the isthmus increases this risk.[18]

Hindfoot nailing also includes certain biomechanical advantages. TTC nails are durable load-sharing devices for supporting fracture union and/or hindfoot arthrodesis. They are biomechanically superior to extramedullary implants in this application.[28]

1.1. Technique

The specific implant used in this technique is the Stryker T2 supracondylar nailing system retrograde femoral nail (Kalamazoo, MI); however, other nailing systems could be considered. Our technique describes an off-label use of this commercially available product. This nail has an anterior bow based on a radius of curvature of 2 m. When performed appropriately, the nail can be turned 90° on insertion, changing the anterior bow into a medial bow, thus promoting valgus positioning of the hindfoot (Fig. 2C).

Normally, when used as a retrograde femoral rod, the aiming jig sits in a lateral, anterolateral, or anteromedial position depending on which option is selected, allowing for 4 different distal interlocking options. On the jig, locking positions 2 and 4 are the most distal. Option 4 is a lateral to medial screw option when used in the distal femur. When the nail is rotated 90° medially during hindfoot insertion, this trajectory becomes a posterior to anterior screw (Fig. 4A and B).

Locking option 2 normally exists as a lateral to medial oblique distal locking screw when used in the distal femur. Without any

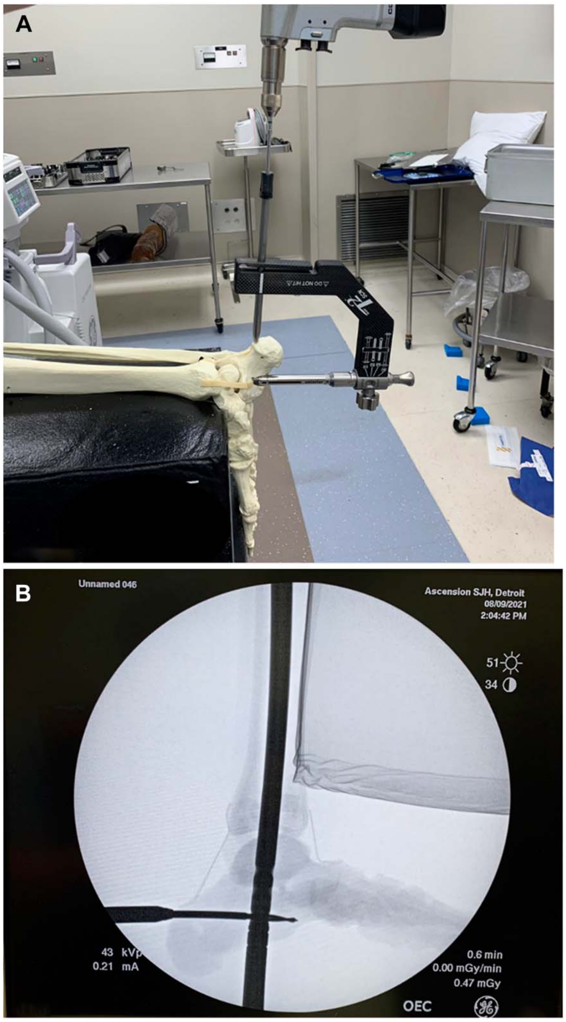

Figure 4. A and B, Photograph (A) and fluoroscopy radiograph (B) showing anterior-posterior locking screw 4 as a posterior to anterior locking screw in the calcaneus of a sawbones model.

modification, this locking option 2 would have a medial to lateral trajectory in the calcaneus when used in the hindfoot with 90° implant rotation as previously described. However, this is not a

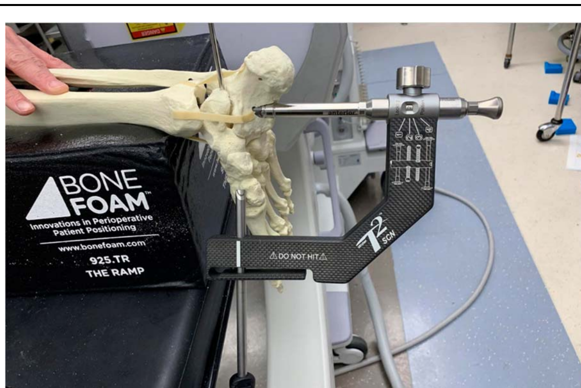

Figure 5. Photograph of a model that shows the original factory trajectory of the locking jig, which with our valgus nail orientation, would place medial-sided neurovascular structures at risk.

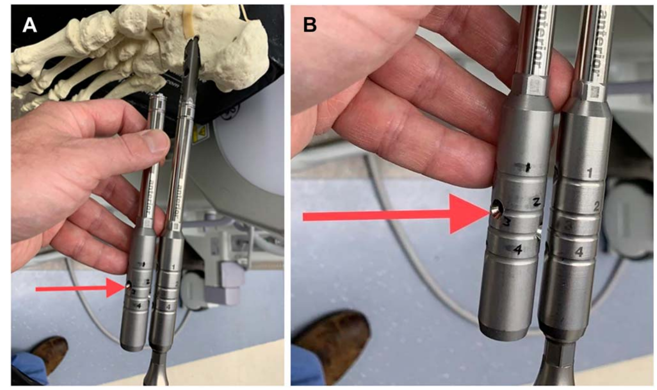

Figure 6. Zoomed out (A) and zoomed in (B) images of 2 jigs, 1 with (left jig) and 1 without (right jig) our described modification. A drill press was used with a metal cutting bit to drill out a 4-mm diameter dimple. This is 180° from the original dimple on line 2 and allows the ball bearing (see next figure) located in the jig to fall into the newly created dimple.

viable option because of nearby medial neurovascular structures, namely the tibial nerve and posterior tibial artery (Fig. 5).

To make distal locking option 2 avoid these risks, a modification was made to the distal interlocking jig. We used a drill press to countersink a divot for the jig's drill guide ball bearing to lock into. The drill press uses a metal cutting bit to drill out a 4-mm diameter dimple. This new divot is 180° from the original factory dimple on line 2, allowing the jig to engage this position, providing a new unique locking point (Figs. 6 and 7). A screw can now be placed using the new locking 2 option, which is now from a lateral to medial direction, thus avoiding

Figure 7. Demonstration of the depressable ball bearing that engages with the dimple to allow for in-line screw trajectory through the rod.

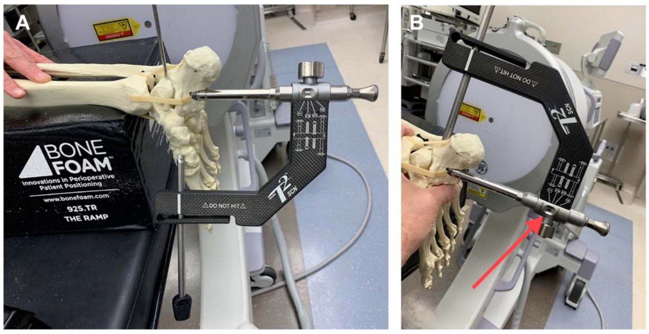

Figure 8. A and B, Photographs demonstrating the jig both before (A) and after (B) the jig modification allowing for a locking screw to be placed 180° from its original factory trajectory.

neurovascular structures (Figs. 8–11). Although this modification is relatively simple, it does require access to a reliable drill press with user familiarity. Alternatively, access to a machine shop may be needed to appropriately modify the jig as described.

This technique uses the anterior bow of a retrograde femoral nail to induce approximately 4° of hindfoot valgus. The geometry of this nail allows for lateral offset of the calcaneus in relation to the tibial shaft in the coronal plane.[4] Although there is a gradual bow to the nail throughout the entirety of its length, there is an additional more relatively acute angulation of 4° distally in the nail, just proximal to the distal interlock holes. As shown in Figure 2C, when used at a TTC nail as described, this creates an isolated 4° valgus moment in the hindfoot. Using this retrograde femoral nail option also provides varying lengths in 2-cm increments up to 48 cm, which is advantageous in scenarios where protection of the entire tibia is deemed important. It has recently been suggested that surgeons use the longest nail available, which ensures that the tip passes the isthmus and ends in the proximal metaphysis to minimize peri-implant fracture.[11]

Figure 9. Photograph showing modification of the jig which allows for the safe locking screw 2 to enter at 180° from the factory setting which places the screw lateral to medial, therefore avoiding neurovascular structures.

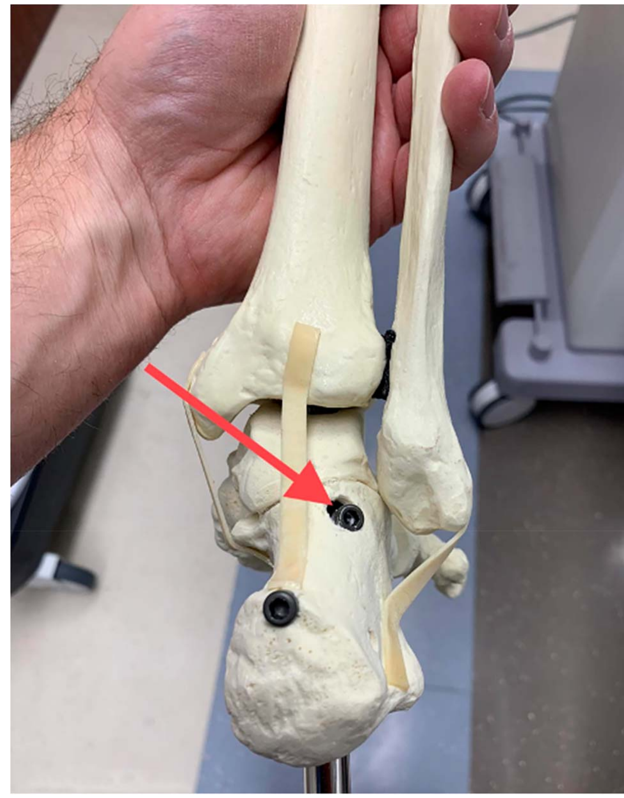

Figure 10. Photograph of screw 2 placed into a model through the described jig modification, demonstrating the fixation pattern in calcaneus.

Figure 11. Fluoroscopic radiograph of both screws in Figure 10 placed into the calcaneus in a model.

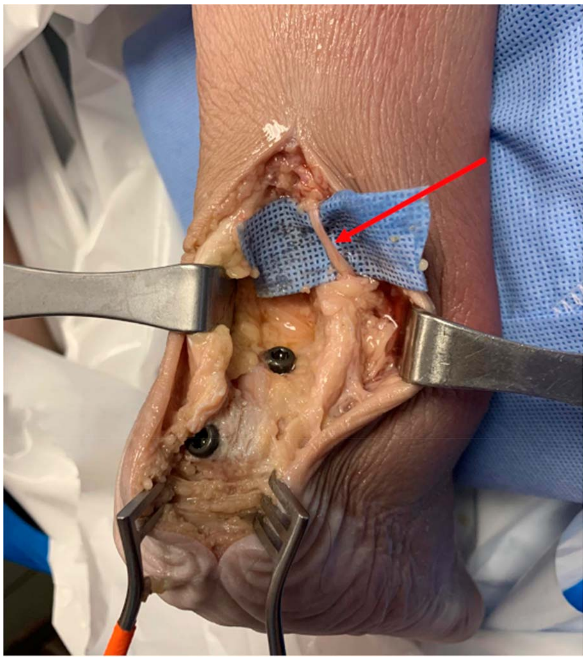

Figure 12. Cadaveric specimens were used to place 4 nails with fluoroscopy; after dissection was performed to evaluate at risk neurovascular structures, none were found. The closest was the sural nerve (arrow) on average 1.2 cm from the screw.

1.2. Anatomic Considerations

We deployed the device with the modified locking screws in 4 cadaveric limbs to further study the anatomic considerations of our modified technique (Fig. 12). After nail and screw insertion, we performed a dissection to note the proximity of any anatomic structures at potential risk. The short saphenous vein and sural nerve were the closest structures to locking screws 2 and 4, and on average, they were 1.4 cm and 2.3 cm away, respectively. These structures were not damaged in any of the cadaveric limbs. We found that the interlocking screws lay mainly in the posterolateral ankle interval, between the flexor hallucis longus and peroneus longus muscle (Fig. 12).

1.3. Cost Considerations

Certain companies offer custom long options for their TTC devices; however, these come with certain disadvantages. Owing to this customization, they must be ordered on a case-by-case basis and shipped in. This typically will delay surgery, therefore increasing the overall length of stay and associated costs. Importantly, there is also a direct cost difference for a custom length TTC implant versus a stocked retrograde femoral implant. In a review of 6 commonly used manufacturers of custom length long TTC nails in the United States, prices ranged from $1639 to $2900 US dollars (USD), while the Stryker T2 (supracondylar nailing system) retrograde femoral nail costs $1450 USD. Although these prices are subject to different hospital contracts, this retrograde femoral nail at our institution was cheaper than all custom long length TTC nails (Table 1). Price awareness may influence surgeons' choice of a specific model within the same implant class. This technique may be an opportunity to reduce surgical expenditures by enhancing cost

TABLE 2

Age, Sex, Comorbidities, and Injury Patterns of Patients Who Were Treated With Our Modified TTC Technique as Described Above

Age	Sex	Comorbidities	Injury
58	Male	Obesity, uncontrolled DM complicated by foot ulcers and toe amputations, ESRD on HD	Bimalleolar fracture dislocation
55	Female	COPD, hepatitis C, polysubstance abuse	Open pilon fracture
84	Female	COPD, CHF, CAD, PVD, CKD	Open bimalleolar fracture
56	Female	Bilateral peripheral neuropathy, ESRD on HD, COPD, CHF, hx of L first toe amputation	Trimalleolar fracture
48	Female	HTN, tobacco, GERD, depression	Trimalleolar fracture
34	Male	Spinal cord injury with bilateral LE motor and sensory deficits	Bilateral pilon fractures
50	Female	Bipolar disorder, depression, ETOH abuse, suicide attempts, ipsilateral calcaneus ORIF	Ipsilateral pilon and periprosthetic calcaneus fracture
53	Female	Infected nonunion s/p ORIF	Infectious nonunion of bimalleolar fracture
54	Male	DM, Charcot arthropathy	Infectious nonunion of trimalleolar fracture
62	Male	HTN, polysubstance abuse, infected nonunion s/p ORIF	Infectious nonunion of bimalleolar fracture
32	Female	ESRD, CHF, DM, HTN, obesity	Pilon and ipsilateral fibula fracture
37	Female	DKA, ESRD on HD, Charcot arthropathy	Trimalleolar fracture with implant failure because of patient non–weight-bearing noncompliance

CAD = coronary artery disease; CHF = chronic heart failure; CKD = chronic kidney disease; COPD = chronic obstructive pulmonary disease; DM = diabetes mellitus; ESRD = end-stage renal disease; ETOH = alcohol; GERD = gastroesophageal reflux disease; HD = hemodialysis; HTN = hypertension; LE = lower extremity; PVD = peripheral vascular disease.

TABLE 1

Costs of Short and Long Tibiotalocalcaneal Nails From Various Commonly Used Manufacturers Versus the Retrograde Femoral Nailing System Used in This Study

Manufacturer	Short TTC Length Options (mm)	Cost (USD)	Longest Custom TTC (mm)	Cost (USD)	Retrograde Femoral Nail Lengths (mm)	Cost (USD)
Stryker (Kalamazoo, MI)	150, 200	Length variable	300	1639.00	170–480	1450.00
DePuy Synthes (Raynham, MA)	150, 180, 240	Length variable	NA	1720.00	160–480	Variable
Smith & Nephew (Watford, England, United Kingdom)	160	1300.00	360	1744.00	180–500	1750.00
Wright (Memphis, TN)	150, 200, 250	Length variable	NA	1650.00	NA	NA
Paragon 28 (Englewood, CO)	150, 175, 200, 250	Length variable	300	2200.00	NA	NA
Zimmer Biomet (Warsaw, IN)	150–270	1400–1600	300	2100.00	160–440	Variable

TABLE 3

Mechanism of Injury and Follow-Up Results of the Patients Presented in Table 2 Who Were Treated With Our Modified TTC Technique as Described Above

Mechanism of Injury	POD of Survey Administration	FAAM Score	FAAM Score %
Pilon and ipsilateral fibula fracture	137	45/84	54
Bimalleolar fracture dislocation	240	48/72	67
Infectious nonunion of trimalleolar fracture	940	27/80	34
Open pilon fracture	*		
Open bimalleolar fracture	*		
Trimalleolar fracture	*		
Trimalleolar fracture	*		
Bilateral pilon fractures	*		
Ipsilateral pilon and periprosthetic calcaneus fracture	*		
Infectious nonunion of bimalleolar fracture		Resulted in BKA	
Infectious nonunion of bimalleolar fracture	*		
Trimalleolar fracture with implant failure because of patient non–weight-bearing noncompliance	*		
	Averages		
	439		52

BKA = below-knee amputation; POD = postoperative day.
* Lost to follow-up.

awareness.[29] In addition, if a custom TTC nail is purchased by the hospital and cannot be used (ie, cancellation), it cannot be returned. In this situation, the cost of the implant remains the responsibility of the hospital.

1.4. Clinical Series

The author discloses that any investigation involving human subjects or the use of patient data for research purposes was approved by the committee on research ethics at our institution where the research was conducted, in accordance with the Declaration of the World Medical Association (www.wma.net) and that any informed consent from human subjects was obtained as required.

The indications for the use of this TTC nail are reserved for individuals with significant comorbidities, especially in the acute trauma setting. After obtaining Institutional Review Board approval, we included a short case series of 12 patients with both acute and chronic pathology (Table 2). This includes 3 unilateral pilon fractures, 1 bilateral pilon fracture, 2 acute ankle fractures, and 4 previously failed bimalleolar or trimalleolar ankle fractures with implant failure because of infectious nonunion or weight-bearing noncompliance.

The average age in this series was 52 years; however, patient comorbidities increased the physiological condition of these patients. They were selected for TTC nailing for multiple reasons: multiple comorbidities, poor confidence in patient compliance, or as a salvage procedure for failed ORIF. Follow-up was conducted through phone using the 21-question Foot & Ankle Survey (FAAM) (Table 3). Four of the 12 patients were able to be reached by phone. One patient had vascular complications preceding the TTC fusion nail surgery and subsequently developed late vascular occlusion, involving heel pad necrosis which resulted in subsequent below knee amputation at 5 months postoperatively. The other 3 patients had an average follow-up of 439 days (1.2 years) and a FAAM score of 52.

2. Conclusion

The role of retrograde hindfoot nailing in the treatment of acute orthopedic trauma has expanded the indications for the TTC nail. Patients with poor bone, proprioception, sensation, and healing potential have been considered at risk with traditional ORIF. Hindfoot nailing of these tibiotalar fractures in the literature have been growing because it relates to these at-risk populations and has been a reliable option for hindfoot/distal tibia stabilization. We describe a novel option that uses a retrograde femoral nail by a simple modification of the insertion jig in place of a custom length TTC nail. This modification as described is considered to be an off-label use of the implant which may inherently be associated with varying degrees of institutional-dependent administrative hurdles or medical legal concerns. However, we think it does carry significant benefits worth considering. This novel, modified TTC technique offers anatomic restoration while also offering convenience, safe, and robust fixation in the calcaneus, instrument familiarity, cost savings, and patient safety.

References

1. Georgiannos D, Lampridis V, Bisbinas I. Fragility fractures of the ankle in the elderly: open reduction and internal fixation versus tibio-talo-calcaneal nailing: short-term results of a prospective randomized-controlled study. *Injury*. 2017;48:519–524.
2. McCormack RG, Leith JM. Ankle fractures in diabetics. Complications of surgical management. *J Bone Joint Surg Br*. 1998;80:689–692.
3. Aigner R, Salomia C, Lechler P, et al. Relationship of prolonged operative time and comorbidities with complications after geriatric ankle fractures. *Foot Ankle Int*. 2017;38:41–48.
4. Litchfield JC. The treatment of unstable fractures of the ankle in the elderly. *Injury*. 1987;18:128–132.
5. Beauchamp CG, Clay NR, Thexton PW. Displaced ankle fractures in patients over 50 years of age. *J Bone Joint Surg Br*. 1983;65:329–332.
6. Anand N, Klenerman L. Ankle fractures in the elderly: MUA versus ORIF. *Injury*. 1993;24:116–120.
7. Ali MS, McLaren CA, Rouholamin E, et al. Ankle fractures in the elderly: nonoperative or operative treatment. *J Orthop Trauma*. 1987;1:275–280.
8. Sanders RW. Commentary on: "acute hindfoot nailing for ankle fractures: a systematic review of indications and outcomes." *J Orthop Trauma*. 2021;35:590–591.
9. Cinats DJ, Kooner S, Johal H. Acute hindfoot nailing for ankle fractures: a systematic review of indications and outcomes. *J Orthop Trauma*. 2021;35:584–590.
10. Rammelt S, Pyrc J, Agren PH, et al. Tibiotalocalcaneal fusion using the hindfoot arthrodesis nail: a multicenter study. *Foot Ankle Int*. 2013;34:1245–1255.

11. Srinath A, Matuszewski PE, Kalbac T. Geriatric ankle fracture: robust fixation versus hindfoot nail. *J Orthop Trauma*. 2021;35:S41–S44.
12. Tarkin IS, Fourman MS. Retrograde hindfoot nailing for acute trauma. *Curr Rev Musculoskelet Med*. 2018;11:439–444.
13. Loosen S, Preuss S, Zelle BA, et al. Multimorbid patients with poor soft tissue conditions: treatment of distal tibia fractures with retrograde intramedullary nailing [in German]. *Unfallchirurg*. 2013;116:553–558.
14. Lemon M, Somayaji HS, Khaleel A, et al. Fragility fractures of the ankle: stabilisation with an expandable calcaneotalotibial nail. *J Bone Joint Surg Br*. 2005;87:809–813.
15. Amirfeyz R, Bacon A, Ling J, et al. Fixation of ankle fragility fractures by tibiotalocalcaneal nail. *Arch Orthop Trauma Surg*. 2008;128:423–428.
16. Fourman MS, Tarkin IS. Retrograde tibiotalocalcaneal hindfoot nail without joint preparation is a viable salvage technique for geriatrics with extensive comorbidities and minimal ambulatory status following major trauma. *Curr Rev Musculoskelet Med*. 2018;11:439–444.
17. Jonas SC, Young AF, Curwen CH, et al. Functional outcome following tibio-talar-calcaneal nailing for unstable osteoporotic ankle fractures. *Injury*. 2013;44:994–997.
18. Al-Nammari SS, Dawson-Bowling S, Amin A, et al. Fragility fractures of the ankle in the frail elderly patient: treatment with a long calcaneotalotibial nail. *Bone Joint J*. 2014;96-B:817–822.
19. Ochman S, Evers J, Raschke MJ, et al. Retrograde nail for tibiotalocalcaneal arthrodesis as a limb salvage procedure for open distal tibia and talus fractures with severe bone loss. *J Foot Ankle Surg*. 2021;51:675–679.
20. Guerrero-Maestre RG, Beaton-Comulada D, Colón-Miranda R, et al. Hindfoot fusion nail with adjuvant hybrid external fixation used as limb-salvage procedure after failed open reduction internal fixation of ankle fracture in a Charcot joint: a case report. *P R Health Sci J*. 2018;37: 235–238.
21. Ho B, Ketz J. Primary arthrodesis for tibial pilon fractures. *Foot Ankle Clin*. 2017;22:147–161.
22. Al-Ashhab ME. Primary ankle arthrodesis for severely comminuted tibial pilon fractures. *Orthopedics*. 2017;40:e378–e381.
23. Hsu AR, Szatkowski JP. Early tibiotalocalcaneal arthrodesis intramedullary nail for treatment of a complex tibial pilon fracture (AO/OTA 43-C). *Foot Ankle Spec*. 2015;8:220–225.
24. Mohammad H, A'Court J, Pillai A. Extruded talus treated with reimplantation and primary tibiotalocalcaneal arthrodesis. *Ann R Coll Surg Engl*. 2017;99:e115–e117.
25. Jain NS, Lopez GD, Bederman SS, et al. Surgical management of complex lower-extremity trauma with a long hindfoot fusion nail: a case report. *Foot Ankle Spec*. 2016;9:354–360.
26. Velasco BT, Briceño J, Miller CP, et al. Peri-implant fractures around hindfoot fusion nails: a systematic literature review and classification system. *Injury*. 2020;51:1497–1508.
27. Elghazy MA, Hagemeijer NC, Waryasz GR, et al. Tibial stress fracture following ankle arthrodesis. *Foot Ankle Int*. 2020;41:556–561.
28. Lee BH, Fang C, Kunnasegaran R, et al. Tibiotalocalcaneal arthrodesis with the hindfoot arthrodesis nail: a prospective consecutive series from a single institution. *J Foot Ankle Surg*. 2018;57:23–30.
29. Wasterlain AS, Melamed E, Bello R, et al. The effect of price on surgeons' choice of implants: a randomized controlled survey. *J Hand Surg*. 2017; 42:593–601.e6.