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Subtalar Joint Distraction Arthrodesis Utilizing a Titanium Truss: A Case Series

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ABSTRACT

Subtalar joint distraction arthrodesis has been recommended for the treatment of conditions such as nonunion or malunion of subtalar joint arthrodesis posttraumatic arthritis. Both conditions are difficult to treat, because the deformities created in the frontal and sagittal planes of these conditions are complex. If these malalignments are not addressed, ankle joint instability and wear occur over time. In general, either autograft or allograft bone has been used to perform distraction arthrodesis of the subtalar joint. Although studies have shown successful use, there have been complications. Autografts have resulted in donor site morbidity and limitations on graft size, and allografts have shown high nonunion rates. Both autografts and allografts have shown graft collapse over time. Recent literature has discussed the use of tantalum technology to span large defects in bone healing. Studies have shown that tantalum provides superior strength and bone incorporation compared with autografts and allografts. This case series presents 2 cases in which tantalum truss technology was used for distraction arthrodesis. Although this series is limited in patient numbers, both cases show effective graft incorporation with no loss in height over time and earlier return to activity compared with previous studies that used autograft and allograft wedges.

Subtalar joint distraction arthrodesis has been recommended for the treatment of isolated subtalar joint disorders such as primary subtalar joint arthritis, nonunion or malunion of previously attempted subtalar joint arthrodesis, and posttraumatic arthritis. This procedure has also been effective for the treatment of subtalar joint arthritis with associated posterior facet depression [1].

Deformity seen with calcaneal fractures is a result of both primary and secondary fracture lines, as previously discussed by Bohler [2]. In general, the calcaneus is shortened and flattened with varus malalignment after intra-articular, joint depression fractures. This is demonstrated radiographically by a decrease in Bohler's angle, an increase in Gissane's angle, and a horizontal position of the talus with a decreased talar declination angle on lateral radiographs. In addition, widening of the calcaneal body leads to displacement or dislocation of the peroneal tendons and varus position of the calcaneus on axial radiographs [1–7]. Unless these deformities are corrected, they will ultimately lead to symptomatic posttraumatic arthritis of the subtalar joint, anterior ankle impingement with associated pain, and limited ankle dorsiflexion [1,8,9].

Malunion and nonunion associated with subtalar joint arthrodesis also are challenging problems. Patients with varus or valgus malalignment and/or failed union after subtalar arthrodesis invariably require some type of bone graft, as well as structural support, to maintain realignment. Distraction arthrodesis of the subtalar joint is an option for restoring height, achieving realignment, and offloading the ankle joint [1].

Structural autograft from the iliac crest has been the gold standard for restoring calcaneal height in subtalar joint arthrodesis. This method, however, is associated with an up to 41% risk of donor site morbidity, large hematomas in 9.6% of patients, and wound dehiscence at the donor site in 2.7% of patients. Autografts have also been associated with longer hospital stay, limited quantity and size options, and poor quality in patients with poor protoplasm [10–16].

The use of allografts, particularly frozen femoral head allografts, has also been discussed at length within the literature as an acceptable alternative to using autografts for subtalar joint distraction arthrodesis. Although allograft use does limit the donor site morbidity seen with autograft use, both have been associated with graft collapse and a relatively high nonunion rate over the long term. This is secondary to the structural graft's inability to withstand the excessive forces from axial loading [15,16]. Although allograft use also carries the risk of disease transmission, the incidence is exceptionally low [13].

An alternative to structural bone grafts is the use of structural titanium trusses. These implants inherently prevent the donor site

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morbidity associated with autografts, as well as the collapse and failure seen with structural bone grafts in general. Titanium trusses, cages, and trabecular porous wedges have been discussed throughout the literature as successful means to bridge bony deficits. Reports in the orthopedic literature have shown successful use with bridging large bony defects for hip and knee arthroplasties, spinal fusions, cranioplasty plates, and pacemaker electrodes [17–20]. The use of titanium trusses within foot and ankle surgery is relatively new, with the earliest literature ranging from 2004 by Bouchard et al [13] to recent studies by Coriaty et al [21] and So et al [22]. All of the studies have shown excellent bony ingrowth with long-term stability [23–26].

We present a case series in which a titanium truss wedge was used in subtalar distraction arthrodesis in the treatment of posttraumatic arthritis after the failure of conservative treatment and nonunion of the subtalar joint after 2 previous attempts at arthrodesis.

Case Series

Patient 1

A 59-year-old active male patient with a past medical history of hypertension and gastroesophageal reflux disease and current 1-pack-per-day smoking history presented for evaluation of chronic hindfoot and ankle pain to the right lower extremity. He had sustained a calcaneal fracture approximately 3 years earlier, which was treated with nonoperative therapy, including cast immobilization. Before his presentation, he had been managing his pain with foot gear modifications, bracing, nonsteroidal antiinflammatory drugs, rest/ice/compression/elevation therapy, and activity modification. He related global pain to the lateral hindfoot and ankle. He had significant difficulty walking and getting through activities of daily living. He was unable to walk short distances or maintain any type of meaningful employment secondary to his right foot and ankle pain.

On physical examination, no evidence of neurovascular deficits was noted, with a healthy soft tissue envelope. The musculoskeletal examination revealed severe limitation of range of motion at both the ankle and subtalar joints with pain noted throughout full range of motion in the subtalar joint and at end-range dorsiflexion of the ankle joint. Furthermore, the peroneal tendons were full and tender with palpation. There was questionable subluxation of these tendons with manipulation of the ankle, although it was difficult to assess because of tenderness. There was severe forefoot varus with the entire forefoot supinated on the hindfoot; this was semireducible.

Radiographic examination revealed significant changes associated with the patient's previous calcaneal fracture. There was significant decrease in the calcaneal inclination, talar declination, lateral talocalcaneal angle, and Bohler's angle. There was an increase in the critical angle of Gissane. Radiography also demonstrated significant sclerosis and decrease in joint space within the subtalar joint, as well as anterior ankle impingement with spurring of the talar neck and moderate subchondral sclerosis of the talus within the ankle joint (Fig. 1 and Table 1). Magnetic resonance imaging demonstrated subluxation and tendinosis of the peroneal tendons with degenerative changes of the subtalar joint (Fig. 2). A noninvasive lower arterial examination demonstrated normal arterial perfusion.

Surgical intervention was then recommended as a reasonable next step in the treatment of this patient, to consist of distraction arthrodesis with a titanium truss augmented with autogenous and allograft bone grafts, orthobiologic materials, and bone marrow aspirate (BMA), along with repair of the subluxing peroneal tendons.

The patient was placed in a lateral decubitus position under general anesthesia with the use of a thigh tourniquet at 350 mm Hg. Before elevation of the tourniquet, BMA was harvested from the proximal tibia of the ipsilateral limb for later use.

A curvilinear incision was then made along the posterior medial aspect of the fibula extending distally toward the distal tip of the lateral malleolus of the right lower extremity. Dissection was carried down to the level of the calcaneus and subtalar joint. Any spurring noted within the local area and synovitis was removed with a combination of instruments.

With the use of fluoroscopy, the level of the subtalar joint was identified, and the joint was dissected and mobilized by using a Cobb periosteal elevator and osteotomes. A lamina spreader was used to distract the joint for cartilage removal and preparation. All articular cartilage was removed from the subtalar joint with the use of osteotomes and

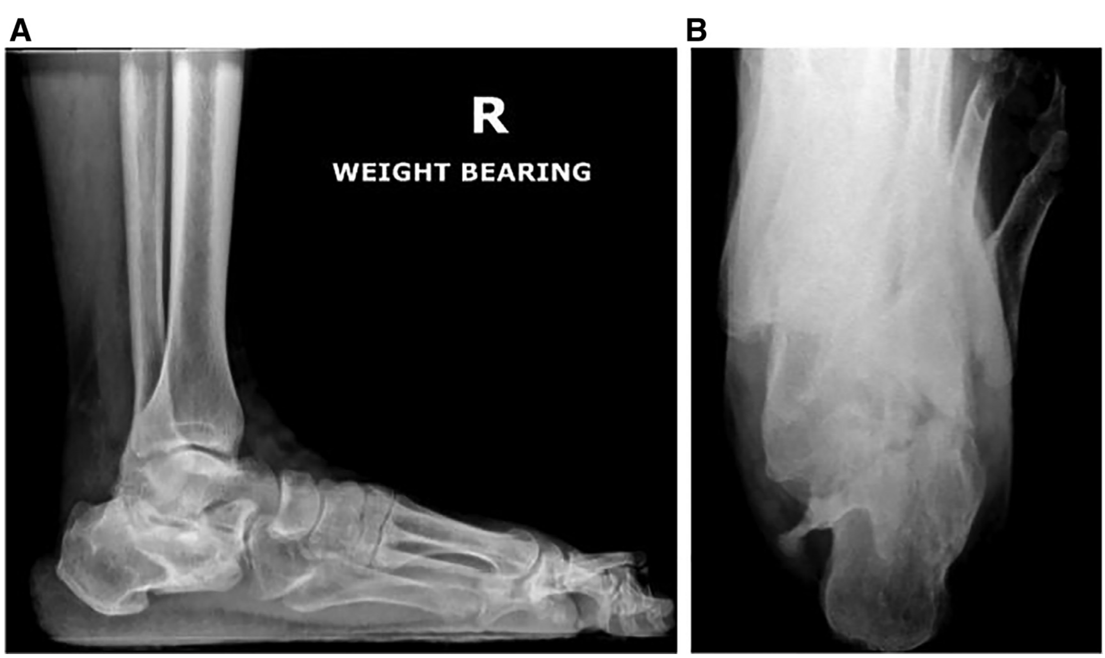

Fig. 1. Preoperative lateral ankle (*A*) and axial (*B*) radiographs.

Table 1
Comparison of preoperative and postoperative sagittal plane angles in patient 1

Angle Measured	Preoperative Angle (°)	Postoperative Angle (°)
Calcaneal inclination angle	13.6	17.5
Talar declination angle lateral	6.5	15.7
Talocalcaneal angle	18.4	33.5
Angle of Gissane	136.4	123.9
Bohler's angle	12.4	29.3

Fig. 2. Preoperative magnetic resonance scan showing peroneal tendon subluxation (*A*) and subtalar joint degeneration (*B*).

curettes. The joint was further prepared using both subchondral drilling and fish scaling techniques until a healthy cancellous substrate was developed.

The subtalar joint was then posteriorly distracted by using a smooth lamina spreader while visualizing the distraction under fluoroscopy on a lateral radiograph. The posterior aspect of the joint was distracted until the lateral radiograph demonstrated restoration of calcaneal height and reduction of both Bohler's and Gissane's angles (Fig. 3). Trial sizers for the titanium truss were then inserted into the subtalar joint to identify the proper truss size needed for the distraction arthrodesis. Bone graft was then packed within the anterior portion of the subtalar joint and into the truss. The bone graft consisted of autograft bone harvested from the ostectomy of the lateral calcaneal wall, morselized frozen femoral head allograft bone, BMA, and a stem cell–based orthobiologic material. A 12-mm medium-width titanium truss, packed with bone graft, was then placed into the posterior aspect of the subtalar joint under image intensification. The subtalar joint was then fixed using two 7.3-mm partially threaded cannulated compression screws. Both screws were delivered anterior to the truss extending into the neck and body of the talus (Fig. 4).

Attention was then directed anteriorly along the fibula through the same incision to identify the peroneal tendons. Both peroneal tendons were dislocated along the lateral aspect of the fibula. On evaluation, the peroneus brevis tendon appeared to be of remarkably poor quality with no available excursion. Furthermore, the muscle belly showed significant fatty infiltration. The peroneus brevis tendon was excised and transferred to the peroneus longus tendon distally with the proximal portion of the tendon and muscle belly excised in toto. The peroneal tendons were reduced to their groove by using a repair of the peroneal retinaculum with 2 suture anchors.

The patient was immobilized with the use of both a posterior splint and a short leg cast for 8 weeks until adequate bony incorporation into the truss was identified using standard radiographs of the hindfoot and ankle (Fig. 5). The patient was then transferred into a controlled ankle motion walking boot for progression to full weightbearing. The patient was transferred to full weightbearing in regular footgear after 4 weeks of protected weightbearing. No major or minor complications were

Fig. 3. Distraction of the subtalar joint before insertion of the truss for reduction.

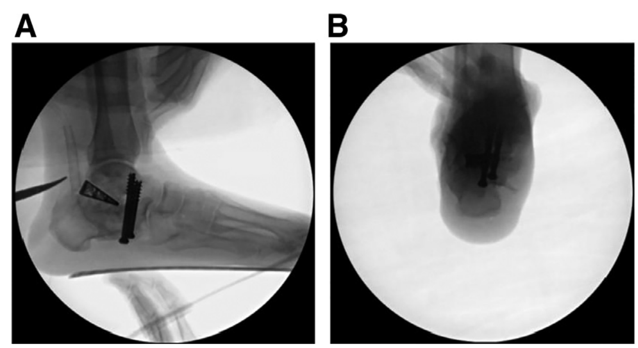

Fig. 4. Insertion of the truss with fixation lateral ankle (*A*) and axial (*B*) views.

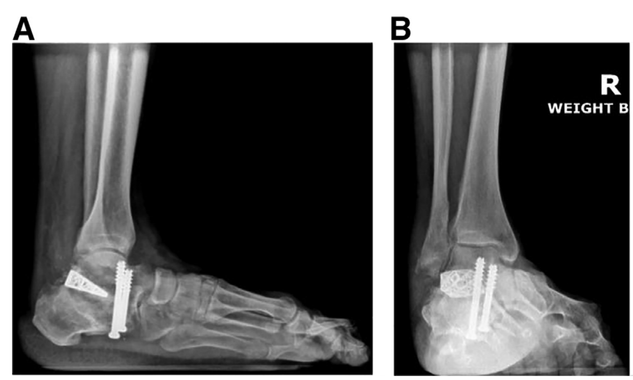

Fig. 5. Postoperative radiographs showing incorporation of the truss lateral ankle (*A*) and mortise ankle (*B*).

noted throughout the recovery process. The patient has continued to improve throughout the postoperative course and is able to bear weight without assistance in standard foot gear. Serial radiographs have demonstrated union of the subtalar joint and improvement in hindfoot alignment. The patient was followed and is 11 months status post distraction arthrodesis. He currently has been able to return to work with no restrictions and is able to ambulate pain free at this time.

Patient 2

A 49-year-old previously active female patient with a past medical history of anxiety, depression, and prediabetes and with no smoking history presented for evaluation of chronic left foot and ankle pain. She had undergone subtalar joint arthrodesis 4 years earlier for primary osteoarthritis and varus malalignment of the hindfoot. This procedure resulted in nonunion. She then underwent revision surgery for the nonunion 1 year before her current presentation to our service. This procedure also resulted in nonunion. Thereafter, she had been managed with hardware removal, activity modification, bracing, orthotic therapy, shoe gear modification, and antiinflammatory medication and injections, all of which provided minimal relief. She was employed as a nurse but had to discontinue working secondary to her pain and disability.

On physical examination, there was no evidence of neurovascular deficits noted, with a healthy soft tissue envelope. The musculoskeletal examination revealed decreased ankle joint range with no signs of crepitus or significant pain. However, her tritarsal motion was severely limited. Examination was difficult because of guarding. Palpation throughout her hindfoot reproduced some of her symptoms. Her gait was both apropulsive and antalgic, with circumduction noted throughout the swing phase of gait. The patient's vitamin D studies were within normal limits.

Radiographic examination demonstrated significant changes associated with nonunion of attempted subtalar joint arthrodesis procedures. The patient showed moderate decrease in calcaneal inclination, talar declination, and lateral talocalcaneal angle. Bohler's angle appeared to be on the low range of normal. She also had a mild increase in the critical angle of Gissane. She had significant sclerosis and decrease in joint space within the subtalar joint, as well as anterior ankle impingement with anterior spurring of the talar neck and moderate subchondral sclerosis of the talus within the ankle joint (Fig. 6 and Table 2). Computed tomographic (CT) scans confirmed nonunion of the subtalar joint with 0% of the joint being fused (Fig. 7). The CT scan demonstrated no evidence of avascular necrosis.

Fig. 6. Preoperative lateral ankle radiograph.

Table 2
Comparison of preoperative and postoperative sagittal plane angles in patient 2

Angle Measured	Preoperative Angle (°)	Postoperative Angle (°)
Calcaneal inclination angle	26.12	26.57
Talar declination angle lateral	8.45	18.67
Talocalcaneal angle	29.97	46.31
Angle of Gissane	138.74	130.47
Bohler's angle	27.5	35.38

Fig. 7. Preoperative computed tomography confirming nonunion of the subtalar joint (*A*–*C*) lateral to medial.

We recommended surgical management secondary to her chronic pain and multiple nonunions. The proposed surgical procedures included distraction arthrodesis with use of a titanium truss augmented with autogenous and allograft bone grafts, orthobiologic materials, and BMA.

The patient was placed in a lateral decubitus position under general anesthesia with the use of a thigh tourniquet at 350 mm Hg. Before elevation of the tourniquet, BMA was harvested from the proximal tibia of the ipsilateral limb for later use.

A posterolateral incision was performed, as in the previous case, splitting the distance between the Achilles tendon and fibula. The posterior capsule was dissected until evidence of joint fluid was found. An osteotome was then inserted into the joint and checked under image intensification to confirm the location. A lamina spreader was inserted into the subtalar joint to aid in the removal of all scar and fibrotic tissue. The joint was further prepared with both subchondral drilling and fish scaling techniques.

Similar to the previous case, a lamina spreader and trial wedges were used to determine the amount of distraction required to achieve realignment. This was confirmed on lateral and axial intraoperative images. It was determined that a 12-mm medium-width truss would be needed to reduce the previous deformity. Attention was then directed to the medial aspect of the ipsilateral ankle, where a linear incision was made just proximal and midline to medial malleolus. A corticocancellous autogenous

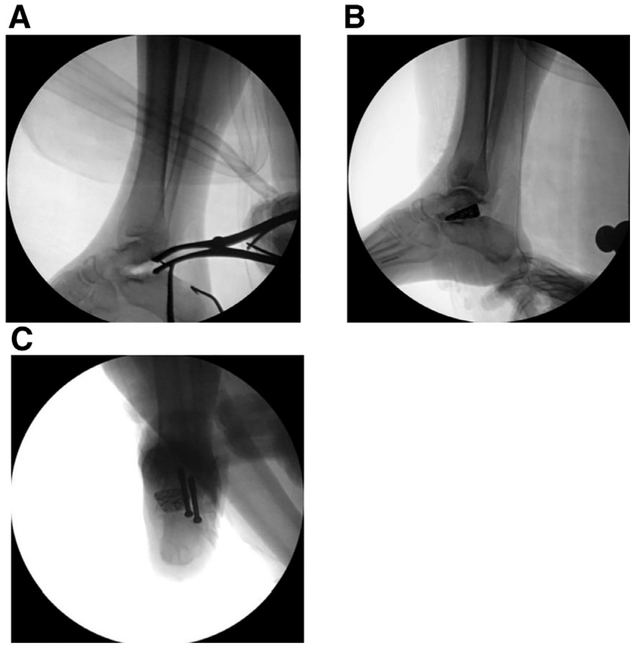

Fig. 8. Intraoperative images revealing distraction (*A*), lateral with insertion of the truss (*B*), and axial postfixation views (*C*).

bone graft was harvested from the distal tibial metaphysis, just proximal to the medial malleolus. This autogenous bone graft was morselized and mixed with frozen cancellous chips to increase volume, in addition to BMA and a stem cell–based orthobiologic material. A freeze-dried iliac crest allograft was placed into the cortical defect of the tibia to help prevent stress risers. The anterior portion of the subtalar joint was then packed with bone graft. The titanium truss was packed with bone graft and inserted within the posterior aspect of the subtalar joint. Placement was confirmed under image intensification, and fixation was accomplished by using two 7.3-mm partially threaded cannulated compression screws. These were both inserted anterior to the truss extending into the neck and body of the talus (Fig. 8).

Postoperatively, the patient was immobilized by using both a posterior splint and a short leg cast for 12 weeks until adequate bony incorporation into the truss was identified on standard radiographs of the hindfoot and ankle, in addition to CT evaluation (Figs. 9 and 10). The patient was then transferred into a controlled angle motion walking boot for progression to full weightbearing. The patient was transferred to full weightbearing in regular shoe gear after protected weightbearing for 4 weeks. No major or minor complications were noted throughout

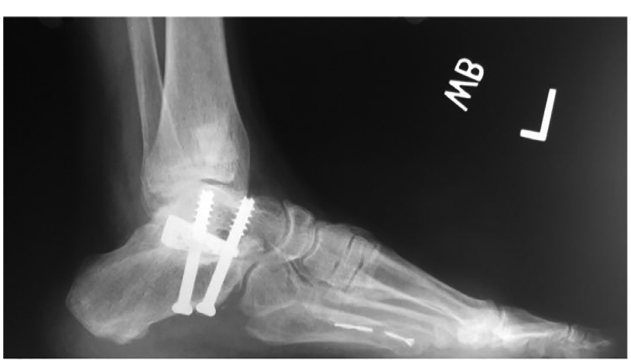

Fig. 9. Postoperative radiographs showing incorporation of the truss lateral ankle (*A*).

her recovery process. The patient has continued to improve throughout the postoperative course and is able to bear weight without assistance in standard foot gear. Serial radiographs have demonstrated complete union of the subtalar joint and improvement in hindfoot alignment. At 7 months postoperatively, the patient was able to return to work without limitation as a nurse and has continued working full-time since her return.

Discussion

The majority of cases of symptomatic subtalar joint arthritis can be treated with in situ arthrodesis. However, significant depression of calcaneal height after a fracture of the calcaneus makes in situ arthrodesis of the subtalar joint difficult in terms of hindfoot alignment. Traditionally, bone block arthrodesis of the subtalar joint using both autografts and allografts has been the gold standard in restoring calcaneal height and talar declination for subtalar joint arthrodesis in this setting.

Gallie [27] was the first to describe bone block arthrodesis using tibia allograft without fixation in 1943. He used this technique on 50 patients during a 6-year span and reported successful results with only 1 failed fusion. Carr et al [28] performed distraction subtalar joint arthrodesis on 16 feet with satisfactory results in 13 of 16 patients. Complications included nonunion, sural nerve neuroma, infection, and painful retained hardware. They also noted loss of calcaneal height in 2 patients and considered that failure to restore calcaneal height led to anterior ankle impingement, leading to a more rapid progression of degenerative changes within the ankle.

In a larger study, Bednarz et al [29] showed significant improvement in American Orthopaedic Foot and Ankle Society scores in 29 patients and significant reduction of radiographic deformity. They also noted smoking as the most significant factor leading to nonunion, as all 4 patients who developed a nonunion in their study were smokers.

Pollard and Schuberth [30] reviewed 22 patients who underwent bone block distraction arthrodesis of the subtalar joint using an autogenous posterior iliac crest graft with a minimum follow-up of 12 months. Of the 22 patients, 21 went on to radiographic and clinical fusion. Radiographs revealed significant restoration of calcaneal height. Complications included nonunion, wound dehiscence, varus malunion, and painful hardware.

Lee and Tallerico [31] reviewed the use of allografts for subtalar joint distraction arthrodesis in 15 consecutive patients. Fresh frozen femoral head allografts were used in 12 patients, and freeze-dried iliac crest allografts were used in 3 patients. Orthobiologic materials were used in every case. Mean follow-up time was 20.6 months. Complete union was achieved in 14 of 15 patients. One patient developed a nonunion with collapse of the graft, requiring revision with an autogenous iliac crest graft. Other minor complications included inferior heel pain, sural nerve paresthesia, and wound dehiscence.

Overall, results have been acceptable using both autograft and allograft bone for distraction arthrodesis of the subtalar joint. However, there are potential risks and disadvantages. Although the use of autograft provides excellent osteogenic, osteoinductive, and osteoconductive potential, it is associated with donor site morbidity in up to 48% of cases. Furthermore, autogenous structural bone grafts are at risk for collapse of the graft over time [32–34]. Alternatively, the use of allogenic bone avoids donor site morbidity. However, allograft use is also associated with risk of disease transmission and collapse of the graft as well [35].

To avoid donor site morbidity, risk of disease transmission, and possible collapse of the graft, we chose to use a noncustom titanium truss, augmented with bone graft, BMA, and orthobiologic materials for our patients. We observed no loss of deformity correction and no complications with both procedures.

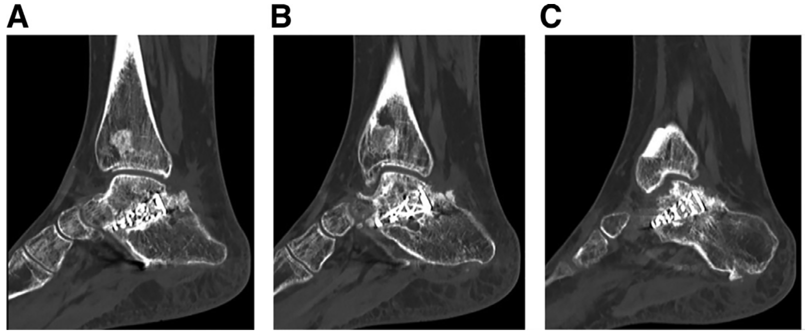

Fig. 10. Postoperative computed tomographic scan revealing incorporation of bony ingrowth into the titanium truss (*A–C*) lateral to medial.

Use of the titanium truss permits the use of compression screws, rather than distraction screws as typically recommended with either structural autogenous or allogenic bone grafts. Compression across the titanium truss does not risk loss of height. Compression enhances the stiffness of the construct and decreases micromotion at the host-graft interface, thereby promoting consolidation at the arthrodesis site.

Titanium truss technology uses porous tantalum metal that has been used extensively for orthopedic procedures of the spine, hip, knee, and foot. Tantalum is a biocompatible material with structural and mechanical properties similar to those of cancellous trabecular bone. Although similar to cancellous-type bone in structure, its modulus of elasticity is 50 times more than that of bone with superior strength and ductility. This allows for its structural integrity, preventing collapse over time at fusion sites. The surrounding proximal and distal bones to the fusion bridging sites are more likely to collapse than is the truss itself secondary to this strength and flexibility. Tantalum material also has inherently high friction and stability, supporting its ability to be highly osteoconductive, allowing bony ingrowth. Histological studies by Bobyn et al [36] revealed that at 16 and 52 weeks, the fusion sites that used porous tantalum with large pores showed complete bony incorporation and ingrowth with the development of Haversian systems at fusion sites in femoral bones of skeletally mature canines. This study also revealed no signs of collapse or decreased of bony ingrowth in any of their animal subjects between the 16- and 52-week marks, respectively. Sufficient bone ingrowth has been shown in both animal and human specimens. It is these assets that allow tantalum trusses to act as excellent scaffolds in the setting of joint arthrodesis [10,36].

Both of our patients went on to rapid and stable union, consistent with the findings of Papadelis et al [10], who used tantalum trabecular metal as a method of distraction to achieve fusion in all 18 of their patients with no loss in correction and significant improvement in pain. Our results also demonstrate significant improvement in hindfoot alignment and restoration of sagittal plane correction, with an absence of graft collapse in both patients.

There are significant limitations to this study. First is the limited number of patients within the case series. The lack of long -term follow-up of these 2 patients also is a weakness. Another limitation was the lack of a standard postoperative and surgical protocol with patients undergoing different ancillary procedures.

Further research that includes a larger cohort of patients and comparative results between truss use and autograft/allograft use are needed to determine the overall success of using a truss for distraction arthrodesis of the subtalar joint. In addition, further research that compares the overall results and costs for noncustom versus custom trusses would be of value. A custom truss might also address frontal plane deformity, such as residual calcaneal varus after calcaneal fracture. Custom trusses would be able to not only restore joint height but also provide frontal plane correction.

In conclusion, although the case series was limited in patient numbers, the results reveal that this procedure has potential to be an excellent alternative to bone grafting for distraction arthrodesis of the subtalar joint following malunion after intra-articular calcaneal fracture and nonunion of subtalar joint arthrodesis.

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