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CLINICAL RESEARCH

Hindfoot Arthrodesis with the Blade Plate: Increased Risk of Complications and Nonunion in a Complex Patient Population

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Abstract

Background Previous hindfoot surgeries present a unique challenge to hindfoot arthrodesis, as the patients may have multiple incisions around the hindfoot. In high-risk patients with compromised soft tissues, a posterior approach can provide an alternative for a fresh soft tissue plane for the surgery. The use of a blade plate construct is widely accepted; however, there are limited data supporting the use of a posterior approach.

Questions/purposes We asked (1) what proportion of patients treated with this technique achieved osseous union; (2) what complications were observed; (3) were any patient-demographic or health-related factors associated with the likelihood that a patient would have a complication develop?

Methods Between December 2001 and July 2014, 42 patients received a posterior blade plate. During the period in question, indications for hindfoot arthrodesis using posterior blade fixation were subtalar osteoarthritis below an ankle fusion, malunion or nonunion, failed tibiotalocalcaneal arthrodesis attributable to nonunion of the tibiotalar and/or subtalar joint; or tibiotalar and subtalar osteoarthritis in patients with impaired bone or soft tissue quality (particularly if the soft tissue problem was anterior). During that period, all patients who met those indications were treated with a posterior blade plate. Forty (95%) were included in this study, and two were lost to followup before the 1-year minimum required by the study. Demographics (age, gender, BMI, smoking status, and comorbidities) and surgical data (indication, previous treatment, and additional procedures) were analyzed. Of the 40 patients included, 27 (68%) were male and 13 (33%) were female, with a median of two previous hindfoot or ankle surgeries (range, 0–9 surgeries). The mean age of the patients was 56 ± 13 years. Followup averaged 47 ± 28 months (range, 14–137 months). Twenty-eight of 40 (70%) patients had a tibiotalocalcaneal arthrodesis as a primary (n = 6), primary staged (n = 10), revision (n = 9), or revision staged (n = 3) procedure. Eleven of 40 patients (28%) underwent ankle arthrodesis (primary n = 7, revision n = 4). One of the 40 patients (3%) underwent tibiotalocalcaneal arthrodesis for a failed total ankle arthroplasty. Weightbearing radiographs were used to assess fusion. Osseous fusion was defined as visible trabecular bridging on the lateral and AP ankle views within 6 postoperative months. Delayed union was defined as osseous fusion occurring between 6 and 12

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Each author certifies that his or her institution approved or waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.
This work was performed at the University of Utah, Salt Lake City, UT, USA.

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months. Nonunion was defined as no visible trabecular bridging at the latest followup (longer than 12 months). Clinic and surgery notes were reviewed for complications. Univariate analysis was performed to compare patient groups: patients with solid union versus nonunion, and patients with versus without complications.

Results Twenty-nine of 40 (73%) patients had osseous fusion within 6 postoperative months. Four of 40 (10%) patients had a delayed union between 6 and 12 months, and seven of the 40 (18%) patients had nonunions, which occurred in the ankle (n = 3), subtalar (n = 3), or both (n = 1) joints. There were 26 complications observed: 18 (69%) were considered major and eight (31%) were minor. With the numbers available, we did not identify any demographic or surgical factors associated with complications, delayed union, or nonunion.

Conclusions The proportion of patients treated with a posterior blade plate hindfoot fusion who had delayed union or nonunion is greater than that reported for patients in other series who underwent primary hindfoot arthrodesis with other approaches, and the proportion of patients who had complications develop is high. Further studies are needed to address alternative approaches to achieve hindfoot fusion in patients with complex hindfoot problems.

Level of Evidence Level IV, therapeutic study.

Introduction

Different surgical techniques, including intramedullary nails, screws, plates and screws, and external fixators, have been used to achieve hindfoot arthrodesis [20–22, 24, 25]. Often patients who undergo hindfoot fusion have had previous surgical procedures including open reduction and internal fixation (of the ankle, talus, and/or calcaneus), previous ankle arthrodesis, or total ankle arthroplasty. Patients may present with multiple incisions around the hindfoot. Additionally, patients with previous subtalar fusion likely have an additional lateral incision in the region of the sinus tarsi. The choice of the appropriate surgical approach for hindfoot arthrodesis in this setting can be difficult. Surgery is increasingly difficult and more demanding when performed on a limb that had previous hindfoot surgery, especially previous fusion surgery [3, 8, 11] or total ankle arthroplasty [10, 17, 18]. In high-risk patients with tenuous soft tissue envelopes undergoing salvage surgery, a posterior approach can provide a fresh soft tissue plane for surgery and good coverage of hardware [20].

Few studies have evaluated the use of a blade plate from a posterior approach in this patient population [1, 5, 9, 14–16, 19, 27, 28] (Table 1). Most of these studies are characterized by low number of patients and relatively short followup (Table 1). The two largest series included 14 and 20 patients, respectively [5, 28]. In both studies, patients with trauma who had nonreconstructable pilon fractures were included [5, 28]. This patient population was without severe medical comorbidities and lacked any history of major previous surgery about the hindfoot. We therefore wished to evaluate a relatively large and diverse population of patients who underwent either tibiotalocalcaneal arthrodesis or tibiotalar arthrodesis using a posterior approach with blade-plate fixation. Primary, staged, and revision procedures were included.

Specifically, we asked (1) what proportion of patients treated with this technique achieved osseous union, (2) what complications were observed, and (3) were any patient-demographic or health-related factors associated with the likelihood that a patient would have a complication develop?

Patients and Methods

The University of Utah institutional review board approved this retrospective study (IRB #71733), and informed consent was waived. Patients were identified by searching the University of Utah Department of Orthopaedics' medical database for the period from January 1, 2001, to July 31, 2014.

During the period in question, indications for hindfoot arthrodesis using posterior blade fixation were subtalar osteoarthritis below an ankle fusion, malunion, or nonunion, failed tibiotalocalcaneal arthrodesis attributable to nonunion of the tibiotalar and/or subtalar joint; or tibiotalar and subtalar osteoarthritis in patients with impaired bone or soft tissue quality (particularly if the soft tissue problem was anterior). During that period, all patients who met those indications were treated with a posterior blade plate. The database search yielded 42 patients who each underwent hindfoot arthrodesis (either tibiotalar or combined tibiotalar and subtalar) using a posterior blade plate for fixation through a posterior approach. Minimum followup for inclusion was 12 months (mean, 47 months; range, 14–137 months). A total of 95% (40 of 42 patients) were accounted for (Table 2). Two patients were excluded, one owing to an unrelated death during the early postoperative period and short followup (8 months) in the other patient. Twenty-seven of the 40 (68%) patients were male and 13 (33%) were female, with a mean age of 56 ± 13 years (range, 24–83 years) (Table 2). Major comorbidities included diabetes mellitus in 11 of 40 (28%) patients, peripheral neuropathy in 12 of 40 (30%), and tobacco use in 11 of 40 (28%). Patients had undergone a median of two previous hindfoot or ankle surgeries (range, 0–9 surgeries).

Table 1. Literature review regarding fusion rate and complications

Study	Type of study	Level of evi-dence	Number of patients (number of feet)	Indication for hindfoot arthrodesis	Surgical technique	Followup (months)	Fusion rate	Complications
Acosta et al., 2000 [1]	Retrospective, single center	IV	4 (4)	Polio with failed ankle arthrodesis and failed revision ankle arthrodesis (1), primary osteoarthritis (1), posttraumatic osteoarthritis with failed ankle arthrodesis (2)	Tibiotalar arthrodesis, 95° blade plate with cancellous bone autograft (1) tibiotalocalcaneal arthrodesis, 95° blade plate with cancellous bone autograft (3)	55 (range, 14–159)	100%	One patient with poor clinical results
Bozic et al., 2008 [5]	Retrospective, single center	IV	14 (14)	Nonreconstructable pilon fracture (14)	Tibiotalar arthrodesis, 4 to 10 holes, 40 to 50 mm, 90° cannulated titanium blade plate	10 (range, 5–20)	100%	Blade plate breakage (1, still achieved successful arthrodesis)
Cinar et al., 2010 [9]	Retrospective, single center	IV	4 (4)	Charcot arthropathy (4)	Talectomy with tibiocalcaneal arthrodesis, 4 to 5 holes, 50 to 60 mm, 95° AO blade plate	24 (range, 12–35)	75%	Stable fibrous ankylosis (1), wound infection (2)
Gruen and Mears, 1991 [14]	Retrospective, single center	IV	5 (5)	Hindfoot nonunion (5)	Tibiotalocalcaneal arthrodesis, 4 to 5 holes, 50 mm, 95° blade plate (5)	51 (range, 24–64)	100%	None
Hammit et al., 2006 [15]	Retrospective, single center	IV	33 (33)	Charcot neuropathic arthropathy (9), talus osteonecrosis (6), posttraumatic osteoarthritis (5), fracture nonunion (3), severe fracture dislocation (2), congenital tibia pseudarthrosis (1), rheumatoid osteoarthritis (1), chronically ruptured Achilles tendon (1), infected hindfoot fusion (1)	Tibiotalocalcaneal arthrodesis (22), talectomy with tibiocalcaneal arthrodesis (5), ankle arthrodesis (4), repair of fracture nonunion (2) reconstruction nail (17), blade plate (14)	24 (range, 12–73)	Not re-ported	Superficial eschar (1), deep infection (4)
Hanson and Cracchiolo, 2002 [16]	Retrospective, single center	IV	10 (10)	Primary osteoarthritis (2), rheumatoid osteoarthritis (1), polio (1, with failed ankle arthrodesis), posttraumatic osteoarthritis (6, 2 of them with failed ankle arthrodesis)	Tibiotalocalcaneal arthrodesis, 5 to 7 holes, 50 to 60 mm, 95° blade plate (10)	37 (range, 12–71)	100%	One patient with posterior tibial neurapraxia (resolved), one patient with skin graft, one patient with deep vein thrombosis in nonoperative leg
Morgan et al., 1999 [19]	Retrospective, multicenter	IV	6 (6)	Nonreconstructable tibial plafond fracture (6)	Tibiotalar arthrodesis, 30 to 50 mm 90° titanium cannulated blade plate (6)	5 (range, 3–7)	100%	None

Table 1. continued

Study	Type of study	Level of evi-dence	Number of patients (number of feet)	Indication for hindfoot arthrodesis	Surgical technique	Followup (months)	Fusion rate	Complications
Zelle et al., 2006 [27]	Case report, single center	V	1 (1)	Severely comminuted malaligned distal tibia fracture	Tibiotalar arthrodesis, 14 holes, 4.5-mm, 95° blade plate (1)	8	100%	None
Zelle et al., 2014 [28]	Retrospective, single center	IV	20 (20)	Severely comminuted high-energy pilon fracture (20)	Tibiotalar arthrodesis, 95° blade plate (20)	Minimum 24	95%	Delayed union (1), deep vein thrombosis (1), cellulitis (1)

During the study period, numerous other patients underwent hindfoot fusions using other approaches. In general, as noted above, the patients with more-complex disorders were treated using a posterior approach and a blade plate. The patients undergoing tibiotalar and subtalar osteoarthritis who had better bone and soft tissue quality were treated mostly with tibiotalocalcaneal arthrodesis using intramedullary nail fixation. During the study period, in total, 455 hindfoot arthrodeses (isolated tibiotalar arthrodesis or tibiotalocalcaneal arthrodesis) were performed. The approaches for these procedures were as follows: screws (n = 264; 58%), plate(s) (n = 89; 20%), external fixator (n = 35; 8%), intramedullary nail (n = 25; 6%), and the patients in the current series who underwent surgery using a blade plate (n = 42, or 9% of the hindfoot fusions performed during the period in question). The patients who underwent fixation using a posterior blade plate were considered not to be good candidates for more-traditional means of fixation owing to loss of bone stock or major soft tissue issues on the anterior aspect of the ankle.

All procedures were performed by three of the authors, all experienced and fellowship-trained orthopaedic foot and ankle surgeons (FN, TCB, CLS). Two authors (TMG, AB), who did not operate on any of the patients, independently reviewed chart records and patients' radiographs regarding union rate and possible complications, and performed clinical assessment in the outpatient clinic.

Patients with primary tibiotalocalcaneal arthrodesis underwent primary arthrodesis of the ankle and subtalar joint during the index procedure. Patients with staged tibiotalocalcaneal arthrodesis had successful arthrodesis of the ankle or subtalar joint previously and then had the other joint fused during the index procedure. Patients with revision tibiotalocalcaneal arthrodesis had nonunion of the ankle and subtalar joints after previously attempted tibiotalocalcaneal arthrodesis and underwent revision tibiotalocalcaneal arthrodesis. Finally, patients with revision-staged tibiotalocalcaneal arthrodesis had a previous attempt at a tibiotalocalcaneal arthrodesis in which one of the joints fused but the other progressed to nonunion. Twenty-eight of 40 (70%) patients had a tibiotalocalcaneal arthrodesis in a primary (n = 6), primary-staged (n = 10), revision (n = 9), or revision-staged (n = 3) setting (Fig. 1). Eleven of 40 (28%) patients had ankle arthrodesis, with seven and four patients having primary and revision ankle arthrodesis, respectively (Fig. 2).

Thirty-eight of 40 (95%) patients had a popliteal block placed by the anesthesia team preoperatively [2]. An intraoperative "single-shot" antibiotic prophylaxis was performed using intravenous cefazolin unless the patient had an allergy or intraoperative cultures were desired.

After general anesthesia was induced, the patient was placed in the prone position. All surgeries were performed

Table 2. Demographic data and surgical details of 40 patients who underwent hindfoot arthrodesis using a posterior blade plate

Patient number	Age (years)	Gender	BMI (kg/m^2)	Diabetes mellitus	Smoking	Peripheral neuropathy	Indication for the surgery	Previous procedures	Procedure performed
1	61	Male	30	No	Yes	No	Ankle nonunion, subtalar osteoarthritis	Ankle arthrodesis (transfibular approach, 3-screw fixation) and subtalar débridement, complicated by infection with ×3 irrigation and débridement and removal of hardware	Revision ankle arthrodesis and subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
2	50	Male	28	No	Yes	No	Secondary ankle and subtalar osteoarthritis	None	Primary tibiotalocalcaneal arthrodesis
3	65	Female	23	Yes	No	No	Ankle and subtalar nonunion	Tibiotalocalcaneal arthrodesis with intramedullary nail	Removal of hardware, revision tibiotalocalcaneal arthrodesis with iliac crest bone marrow autograft
4	53	Female	28	No	No	Yes	Ankle nonunion, subtalar osteoarthritis	Arthroscopic ankle arthrodesis, removal of hardware	Revision ankle arthrodesis and subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
5	52	Male	28	No	No	No	Ankle nonunion, talar neck nonunion, subtalar osteoarthritis	Ankle arthrodesis, open reduction internal fixation of talar neck	Revision ankle arthrodesis, subtalar arthrodesis (tibiotalocalcaneal arthrodesis), open reduction internal fixation of talar neck
6	59	Male	33	Yes*	No	No	Ankle nonunion, calcaneocuboid nonunion, subtalar arthrodesis	Subtalar arthrodesis with consequent nonunion, subtalar valgus wedge osteotomy (subtalar joint healed), ankle arthrodesis, calcaneocuboid arthrodesis	Revision ankle arthrodesis (tibiotalocalcaneal arthrodesis)
7	44	Male	29	No	Yes	No	Ankle osteoarthritis, subtalar arthrodesis	Triple arthrodesis, arthroscopic ankle débridement, calcaneus osteotomy, ankle distraction arthroplasty	Ankle arthrodesis (tibiotalocalcaneal arthrodesis)
8	55	Male	38	Yes	Yes	Yes	Ankle nonunion	Ankle arthrodesis, revision ankle arthrodesis	Revision ankle arthrodesis
9	52	Female	36	No	No	Yes	Subtalar osteoarthritis, ankle arthrodesis	Ankle arthrodesis arthrodesis, ×2 revision ankle arthrodesis	Subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
10	66	Male	23	No	Yes	No	Subtalar osteoarthritis, ankle arthrodesis	Ankle arthrodesis, revision ankle arthrodesis	Subtalar arthrodesis (tibiotalocalcaneal arthrodesis)

Table 2. continued

Patient number	Age (years)	Gender	BMI (kg/m^2)	Diabetes mellitus	Smoking	Peripheral neuropathy	Indication for the surgery	Previous procedures	Procedure performed
11	44	Male	29	No	Yes	No	Ankle nonunion	Open reduction internal fixation open tibial plafond fracture, arthroscopic ankle arthrodesis	Ankle revision arthrodesis
12	64	Male	28	No	No	No	Ankle nonunion, subtalar osteoarthritis	Ankle arthrodesis	Revision ankle arthrodesis, subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
13	68	Male	27	No	No	No	Ankle and subtalar nonunion	Ankle arthrodesis, tibiotalocalcaneal arthrodesis using intramedullary nail	Revision ankle and subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
14	29	Male	25	No	Yes	No	Subtalar osteoarthritis, ankle arthrodesis	Open reduction internal fixation pilon/talux fracture, ankle arthrodesis, deep infection requiring irrigation and débridement	Subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
15	59	Male	27	No	Yes	No	Subtalar osteoarthritis, ankle arthrodesis	Ankle arthrodesis	Subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
16	49	Female	29	No	No	No	Subtalar osteoarthritis, ankle arthrodesis	Arthroscopic ankle arthrodesis	Subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
17	57	Male	29	No	No	No	Subtalar osteoarthritis, ankle arthrodesis	Ankle arthrodesis	Subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
18	73	Male	37	No	No	Yes	Ankle and subtalar nonunion	Subtalar arthrodesis, tibiotalocalcaneal arthrodesis with intramedullary nail	Ankle and subtalar revision arthrodesis (tibiotalocalcaneal arthrodesis)
19	60	Female	25	Yes	No	Yes	Ankle malunion and subtalar osteoarthritis	Open reduction internal fixation ankle fracture, ankle arthrodesis	Tibial osteotomy, ankle arthrodesis, subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
20	76	Female	38	Yes	No	Yes	Subtalar nonunion, ankle osteoarthritis	Subtalar arthrodesis, triple arthrodesis	Ankle arthrodesis, subtalar revision arthrodesis (tibiotalocalcaneal arthrodesis)
21	38	Female	25	Yes	Yes	Yes	Charcot arthropathy	Open reduction internal fixation ankle	Tibiotalocalcaneal arthrodesis

Table 2. continued

Patient number	Age (years)	Gender	BMI (kg/m^2)	Diabetes mellitus	Smoking	Peripheral neuropathy	Indication for the surgery	Previous procedures	Procedure performed
22	49	Female	19	No	No	Yes	Ankle osteoarthritis with distal tibia nonunion	Open reduction internal fixation pilon, ×2 irrigation and débridement	Ankle arthrodesis
23	68	Male	27	No	No	No	Infected total ankle replacement, subtalar osteoarthritis	Total ankle replacement, revision total ankle replacement, ×3 irrigation and débridement, total ankle replacement explantation and cement spacer	Tibiotalocalcaneal arthrodesis with femoral head allograft
24	53	Male	32	No	No	Yes	Ankle osteoarthritis, subtalar arthrodesis	Subtalar arthrodesis	Ankle arthrodesis with iliac crest bone marrow autograft (tibiotalocalcaneal arthrodesis)
25	56	Male	30	No	No	No	Tibiocalcaneal osteoarthritis	Talectomy	Tibiocalcaneal arthrodesis
26	59	Male	30	Yes	No	No	Ankle malunion, subtalar osteoarthritis	Open reduction internal fixation ankle, ankle arthrodesis, subtalar débridement	Tibial osteotomy, subtalar arthrodesis (tibiotalocalcaneal arthrodesis)
27	73	Female	42	Yes	No	No	Ankle osteoarthritis	Open reduction internal fixation ankle	Ankle arthrodesis
28	72	Male	26	No	No	No	Ankle and subtalar osteoarthritis	None	Tibiotalocalcaneal arthrodesis
29	83	Female	25	Yes	No	Yes	Ankle osteoarthritis	Open reduction internal fixation ankle	Ankle arthrodesis
30	33	Male	26	No	No	No	Subtalar and talonavicular osteoarthritis, ankle arthrodesis	Ankle arthrodesis	Subtalar arthrodesis (tibiotalocalcaneal arthrodesis), talonavicular débridement
31	53	Male	34	No	No	Yes	Ankle and subtalar osteoarthritis	Multiple clubfoot surgeries in childhood	Tibiotalocalcaneal arthrodesis
32	75	Male	34	No	No		Ankle osteoarthritis	Open reduction internal fixation ankle	Ankle arthrodesis
33	60	Male	37	Yes	Yes		Ankle nonunion	Open reduction internal fixation ankle, irrigation and débridement, ankle arthrodesis, hardware failure	Ankle revision arthrodesis
34	66	Female	41	No	No		Ankle osteoarthritis	Open reduction internal fixation ankle, irrigation and débridement	Ankle arthrodesis

Table 2. continued

Patient number	Age (years)	Gender	BMI (kg/m^2)	Diabetes mellitus	Smoking	Peripheral neuropathy	Indication for the surgery	Previous procedures	Procedure performed
35	44	Male	32	No	Yes		Ankle osteoarthritis	None	Ankle arthrodesis
36	34	Female	24	Yes	No		Charcot arthropathy	None	Ankle arthrodesis
37	54	Male	30	No	No		Ankle nonunion	Open reduction internal fixation ankle, ankle arthrodesis, ankle revision arthrodesis	Ankle revision arthrodesis
38	61	Female	18	No	Yes		Ankle and subtalar osteoarthritis	None	Tibiotalocalcaneal arthrodesis
39	69	Male	32	No	No		Ankle nonunion, subtalar arthrodesis	Open reduction internal fixation ankle, ankle and subtalar arthrodesis	Ankle revision arthrodesis (tibiotalocalcaneal arthrodesis)
40	24	Male	20	No	No		Ankle nonunion, subtalar arthrodesis	Open reduction internal fixation ankle, ankle arthrodesis, ankle revision arthrodesis, x2 irrigation and débridement	Ankle revision arthrodesis, subtalar arthrodesis (tibiotalocalcaneal arthrodesis)

* Diabetes developed during followup.

with application of a thigh tourniquet. If previous hardware was going to interfere with posterior blade-plate insertion, the hardware was removed from the most-appropriate previous incision.

A 10- to 12-cm straight, midline, posterior incision was made over the Achilles tendon down to the level of the paratenon (Fig. 3). The paratenon was incised longitudinally and then full-thickness flaps were retracted medially and laterally. A Z-type lengthening of the Achilles tendon then was performed either in the coronal or sagittal plane to achieve neutral alignment of the hindfoot in the sagittal plane. Dissection was carried down to the level of the deep posterior compartment, identifying the fascia over the flexor hallucis longus. The fascia then was opened and the flexor hallucis longus tendon was mobilized medially. By keeping the flexor hallucis longus tendon medially retracted, the neurovascular bundle was protected.

The posterior capsules of the ankle and subtalar joints then were identified and incised. To improve observation of the ankle in procedures involving tibiotalar arthrodesis, the posterior portion of the plafond was removed with an osteotome. The articular surfaces to be fused were then debrided. A 2-mm drill was used to perforate the subchondral bone. An osteotome was used to partially remove the posterior malleolus of the tibia and part of the posterior aspect of the talus to allow the blade plate to fit flush against the posterior tibia. The posterior malleolus was morselized and placed in the arthrodesis site.

An osteotomy of the distal tibia was performed in two ankles with malunion of a previously performed ankle fusion to correct the malalignment (internal rotation and plantar flexion) before additional arthrodesis of the subtalar joint.

After joint surfaces were prepared and bone graft was placed, the hindfoot was reduced to the desired position with the ankle neutral in the sagittal plane, external rotation similar to the healthy contralateral side, and the subtalar joint with approximately 5° valgus. The alignment was stabilized preliminarily using Steinmann pins, introduced percutaneously from the posteroinferior aspect of the heel. A 3.5-mm cannulated 90° blade plate (Synthes, West Chester, PA, USA) then was contoured to the posterior aspect of the tibia and slightly bent so the blade would end up just inferior to the sustentaculum tali for cases including the subtalar joint. The guidewire for the blade plate was placed in the calcaneus, and its position was checked on AP, lateral, and axial fluoroscopic images. When the desired position was confirmed, the guidewire was measured to determine the length of the blade. Most often a six-hole, 50-mm blade plate was used (Table 3). Once the proximal portion of the plate was flush against the tibia, a 3.5-mm cortical screw was placed in the calcaneus—from the medial tibial to the

Fig. 1A–P A 53-year-old man had (**A**) ankle and subtalar osteoarthritis and a complex valgus hindfoot deformity as evident on the AP and (**B**) lateral radiographic views. (**C**) AP and (**D**) lateral radiographs were obtained after the patient underwent primary tibiotalocalcaneal arthrodesis using a posterior blade plate. (**E**) Subtalar osteoarthritis after a revision tibiotalar arthrodesis in a 52-year-old female patient is seen on the AP and (**F**) lateral radiographic views. (**G**) A mortise view of the patient's ankle was obtained after a primary-staged tibiotalocalcaneal arthrodesis. (**H**) A lateral view shows the tibiotalocalcaneal arthrodesis with a posterior blade plate. For a 64-year-old male patient, the (**I**) AP and (**J**) lateral view radiographs show a tibiotalar nonunion and subtalar osteoarthritis (**K**) A postoperative radiograph obtained after a revision tibiotalocalcaneal arthrodesis is shown. (**L**) The lateral view radiograph shows the revision tibiotalocalcaneal arthrodesis with a posterior blade plate. A 67-year-old male patient experienced (**M**) tibiotalar nonunion after an attempted tibiotalocalcaneal arthrodesis using intramedullary fixation as seen on the AP and (**N**) lateral view radiographs. The patient underwent a revision-staged tibiotalocalcaneal arthrodesis using a posterior blade plate. (**O**) postoperative mortise and (**P**) lateral view radiographs show the tibiotalocalcaneal arthrodesis.

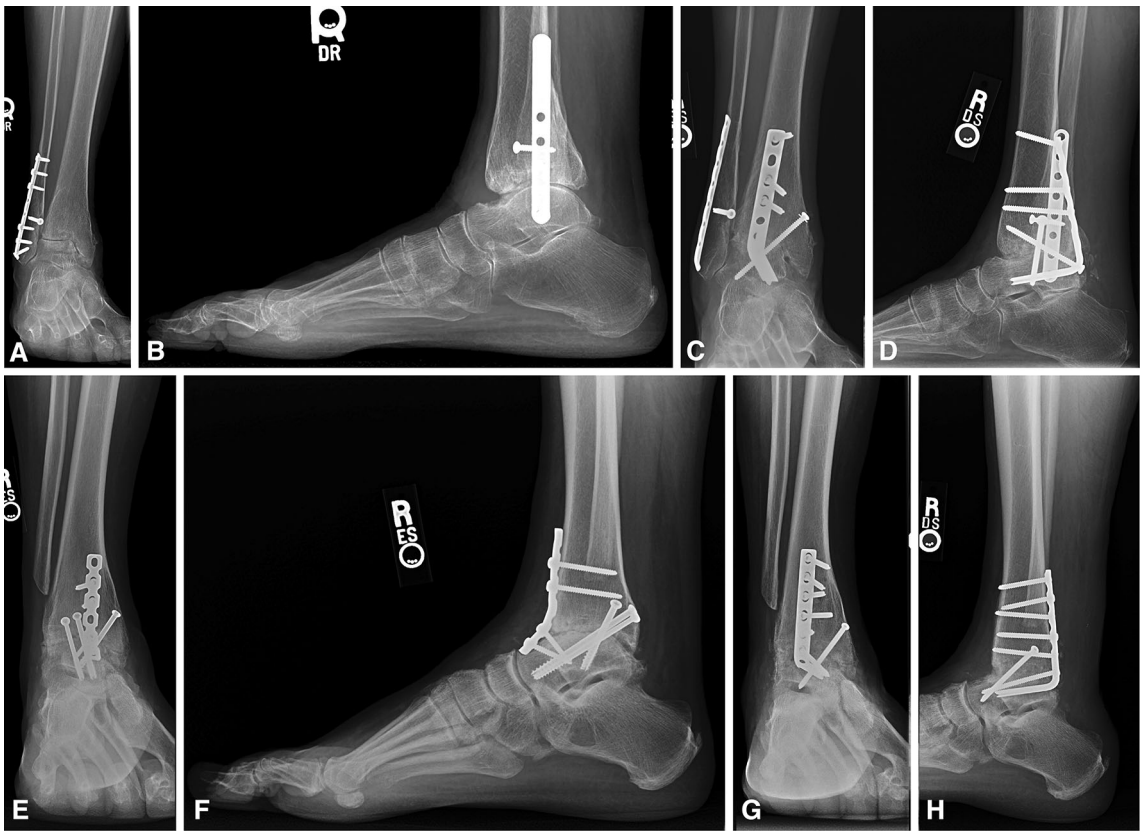

Fig. 2A–H (**A**) Preoperative mortise and (**B**) lateral view radiographs of the ankle of an 83-year-old female patient with posttraumatic tibiotalar osteoarthritis are shown. (**C**) The mortise and (**D**) lateral view radiographs of the patient's ankle after undergoing primary tibiotalar arthrodesis are shown. (**E**) AP and (**F**) lateral view radiographs show a tibiotalar nonunion in a 55-year-old male patient. He underwent a revision tibiotalar arthrodesis with a posterior blade plate as seen on his (**G**) postoperative AP and (**H**) lateral view radiographs.

anterolateral talus—adjacent to the blade to supplement fixation. Additional 3.5-mm cortical screws then were placed in the more proximal screw holes to provide compression across the arthrodesis site. Before tightening the proximal screws completely, the Steinmann pin was removed to allow for maximal compression. Screws then were placed in the talus through the plate. In cases in which only a posterior ankle arthrodesis was performed, the blade was placed in the talus, rather than the calcaneus, using the same technique to achieve compression as described previously.

In almost all of these procedures, some additional fixation was used around the blade plate for additional stability (Table 3). The most common additional fixation was one or two 7-mm, fully threaded screws placed from the plantar posterior tuberosity across the subtalar joint and ankle. In cases of primary or revision ankle arthrodesis in which the lateral gutter was arthritic, a separate lateral incision was made over the fibula. A portion of the fibula proximal to the syndesmosis was excised with a small reciprocating saw to decouple the distal fibula. The syndesmosis was taken down and the lateral ankle gutter was débrided from the posterior approach. Two 4-mm cortical screws then were placed from the lateral incision to fuse the syndesmosis with one screw gaining purchase in the tibia and the other in the talus.

After all the hardware was inserted, the Achilles tendon was repaired in a lengthened state with a nonabsorbable suture. The paratenon was closed with a running 2–0 absorbable suture and finally, the skin with a 3–0 nylon suture.

Then a well-padded, below-the-knee splint was placed for 2 weeks and the patients were kept nonweightbearing. At 2 weeks a cast was applied and the patients were kept nonweightbearing for an additional 4 to 8 weeks. Between 6 to 10 weeks, patients were transitioned to wearing a below-knee walker boot with the timing of transition determined by radiographic evidence of bone healing. If radiographs showed evidence of early consolidation, then progressive partial weightbearing was initiated. The boot was used for 12 to 16 weeks, with the goal of transitioning from the boot at that time.

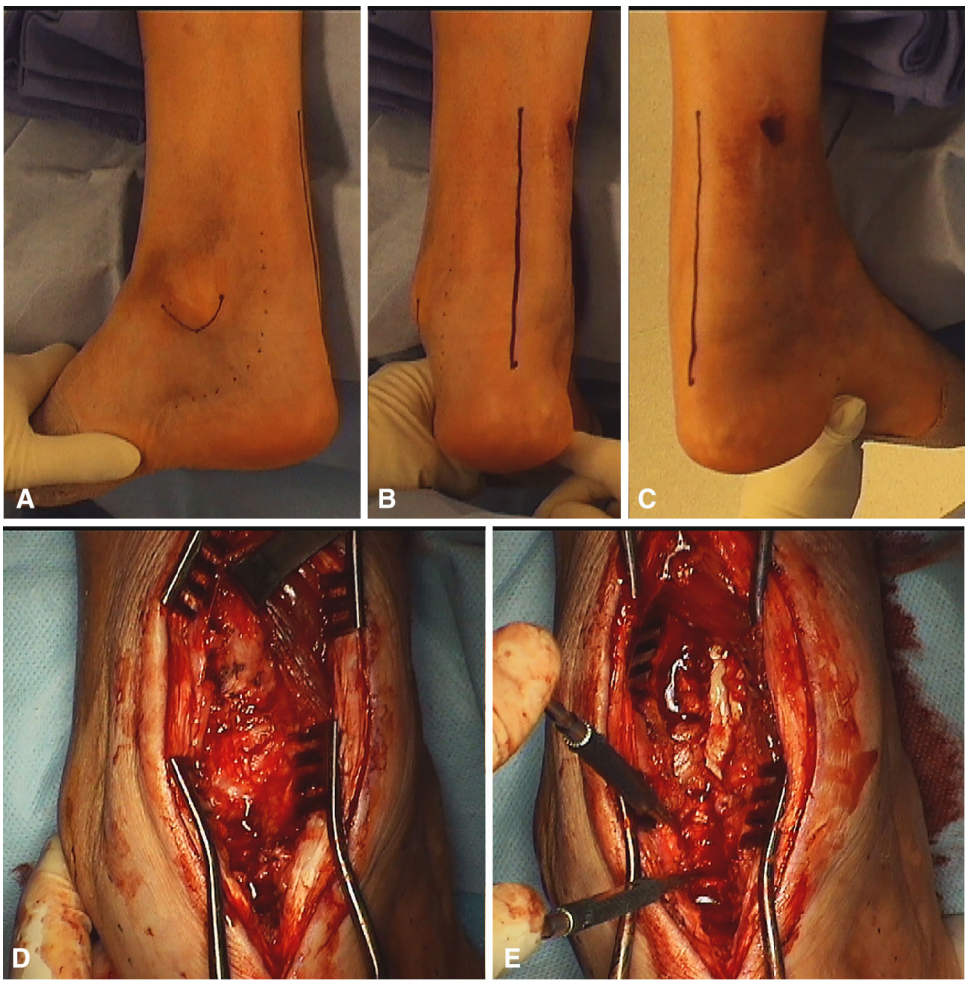

Fig. 3A–E Anatomic landmarks for a 10-cm straight midline posterior incision were marked on the (**A**) lateral, (**B**) dorsal, and (**C**) medial aspects of the ankle. A (**D**) transtendinous approach was performed using a Z-type lengthening of the Achilles tendon. (**E**) The posterior capsules of the ankle and subtalar joins were incised.

Affected ankles were evaluated based on weightbearing radiographs in two planes (AP and lateral ankle views) at 6 weeks (nonweightbearing radiographs), 3 months, 6 months, 1 year, and then annually thereafter. Fusion was defined as satisfying clinical criteria (no pain, no warmth, improvement in swelling, and stability to stress) and radiographic criteria (visible trabecular bridging across the arthrodesis site and no lucency around the hardware). All radiographs including weightbearing AP and lateral views of the ankle were evaluated by two orthopaedic surgeons (TMG, AB), each of whom was blinded to all other patient data. Additionally, original radiology reports were reviewed. Appropriate osseous union was defined as trabecular bridging across the arthrodesis within 6 postoperative months. Delayed osseous union was defined as arthrodesis between 6 and 12 months. Nonunion was defined as missing osseous union at the latest followup, at least 12 months after surgery. Findings were considered valid when consensus was achieved among all observers. When indicated, CT was performed to assess for union and was evaluated by independent radiologists at the University of Utah.

Nonunion, delayed union, deep infection resulting in a secondary procedure, severe persisting pain syndrome, and deep vein thrombosis were considered major complications. Superficial infection, delayed wound healing, stress fracture not resulting in a secondary procedure, and peripheral neuritis were considered minor complications.

Independent variables included age, gender, BMI, diabetes mellitus, history of smoking, peripheral neuropathy, type of surgery, and use of BMP (rhBMP-2, Medtronic, Minneapolis, MN, USA). Dependent variables were fusion date and postoperative complications. All data were extracted by independent chart and radiograph review by qualified authors (TMG, ML, AB) who had not performed the operations. Followup periods were based on standard of care visits at 3 weeks, 6 weeks, 12 weeks, 6 months, 1 year, and annually thereafter. Any additional visits recommended by the provider or requested by the patient also were reviewed.

Table 3. Surgical technique and details in 40 patients who underwent hindfoot arthrodesis using a posterior blade plate

Patient number	Removal of hardware	Fixation	Distal tibiofibular fusion	Autograft/allograft	Additional procedures
1	No	Six holes, 40-mm 95° blade plate with 5 screws (4 tibia, 1 calcaneus) Two 6.5 fully threaded screws	No (after distal fibula resection)	Morselized bone from posterior tibia	Achilles tendon lengthening, excision tarsal coalition
2	No	Ten holes, 40-mm 95° blade plate with 7 screws (4 tibia, 2 talus, 1 calcaneus) One 6.5-mm partially threaded screw Three 4.0-mm fully threaded screws	Yes	Morselized bone from posterior tibia and talus	Achilles tendon lengthening, relocation of peroneal tendons
3	Yes	Six holes, 50-mm 95° blade plate with 6 screws (3 tibia, 2 talus, 1 calcaneus) Three 4.0-mm fully threaded screws	Yes	Morselized bone from posterior tibia, allograft croutons, 2-cc bone marrow aspiration from iliac crest	None
4	No	Four holes, 40-mm 95° blade plate with 4 screws (3 tibia, 1 talus) Four 4.0-mm fully threaded screws	Yes	Morselized bone from posterior tibia	Achilles tendon lengthening, excision of heel complex cyst
5	Yes	Six holes, 40-mm 95° blade plate with 6 screws (4 tibia, 1 talus, 1 calcaneus) One 6.5-mm fully threaded screw Two 4.0-mm fully threaded screws	Yes	Morselized bone from posterior tibia, INFUSE® BMP sponges	Revision of talar neck nonunion
6	Yes	Five holes, 50-mm 95° blade plate with 5 screws (3 tibia, 1 talus, 1 calcaneus) Two 6.5-mm fully threaded screws Two 4.0-mm fully threaded screws 2.4-mm plate	Yes	INFUSE® BMP sponges	Revision of calcaneocuboid nonunion
7	No	Four holes, 50-mm 95° blade plate with 4 screws (3 tibia, 1 talus) Two 6.5-mm fully threaded screws	No	Allograft	None
8	Yes	Six holes, 40-mm 95° blade plate with 6 screws (5 tibia, 1 talus) One 4-mm fully threaded screw	No (distal fibula resection)	INFUSE® BMP sponges	None
9	No	Six holes, 35-mm 95° blade plate with 5 screws (3 tibia, 1 talus, 1 calcaneus) One 4-mm fully threaded screw	No (after distal fibula resection)	Morselized bone from posterior tibia	Achilles tendon lengthening, great toe interphalangeal joint arthrodesis, extensor hallucis longus tendon transfer to the metatarsal neck
10	No	Five holes, 50-mm 95° blade plate with 5 screws (3 tibia, 1 talus, 1 calcaneus) One 6.5-mm fully threaded screw One 4-mm fully threaded screw	After fusion	Allograft	Achilles tendon lengthening, hammertoe repair

Table 3. continued

Patient number	Removal of hardware	Fixation	Distal tibiofibular fusion	Autograft/allograft	Additional procedures
11	Yes	Six holes, 40-mm 95° blade plate with 6 screws (4 tibia, 1 talus, 1 calcaneus) Two 4-mm fully threaded screws	Yes	Morselized bone from posterior tibia	None
12	Yes	Eight holes, 50-mm 95° blade plate with 7 screws (4 tibia, 2 talus, 1 calcaneus) Three 6.5-mm fully threaded screws	After fusion	INFUSE® BMP sponges	None
13	Yes	Six holes, 40-mm 95° blade plate with 6 screws (4 tibia, 1 talus, 1 calcaneus)	After fusion	Morselized bone from posterior tibia	None
14	No	Six holes, 40-mm 95° blade plate with 5 screws (4 tibia, 1 talus)	No	3 × 1-cm cortical cancellous autograft from distal tibia, INFUSE® BMP sponges	None
15	No	Six holes, 40-mm 95° blade plate with 5 screws (4 tibia, 1 talus)	No	Morselized bone from posterior tibia	None
16	No	Six holes, 45-mm 95° blade plate with 5 screws (4 tibia, 1 talus) One 6.5-mm fully threaded screw Three 4.0-mm fully threaded screws	Yes	Morselized bone from posterior tibia	None
17	No	Six holes, 50-mm 95° blade plate with 6 screws (4 tibia, 2 talus) Two 6.5-mm fully threaded screws	After fusion	Morselized bone from posterior tibia, INFUSE® BMP sponges	Achilles tendon lengthening
18	Yes	Eight holes, 45-mm 95° blade plate with 8 screws (6 tibia, 1 talus, 1 calcaneus) Two 6.5-mm fully threaded screws	No (after distal fibula resection)	Morselized bone from posterior tibia, INFUSE® BMP sponges	Achilles tendon lengthening, open reduction of talonavicular joint dislocation with talonavicular arthrodesis
19	No	Six holes, 45-mm 95° blade plate with 6 screws (3 tibia, 2 talus, 1 calcaneus)	No (after distal fibula resection)	Morselized bone from posterior tibia	Achilles tendon lengthening, tibia osteotomy
20	Yes	Eight holes, 35-mm 95° blade plate with 8 screws (5 tibia, 2 talus, 1 calcaneus) Three 6.5-mm fully threaded screws One 7.3-mm partially threaded screw	No	Morselized bone from posterior tibia, INFUSE® BMP sponges	Achilles tendon lengthening
21	Yes	Six holes, 35-mm 95° blade plate with 6 screws (4 tibia, 1 talus, 1 calcaneus) One 6.5-mm fully threaded screw	No	Allograft croutons, INFUSE® BMP sponges	Achilles tendon lengthening
22	Yes	Six holes, 45-mm 95° blade plate with 5 screws (4 tibia, 1 talus) Two 4-mm fully threaded screws	Yes	Morselized bone from posterior tibia, INFUSE® BMP sponges	None
23	Yes (total ankle replacement)	Ten holes, 45-mm 95° blade plate with 6 screws (4 tibia, 1 talus, 1 calcaneus) Two 6.5-mm fully threaded screws Two 4-mm fully threaded screws	Yes	Allograft (morselized femoral head), INFUSE® BMP sponges	None

Table 3. continued

Patient number	Removal of hardware	Fixation	Distal tibiofibular fusion	Autograft/allograft	Additional procedures
24	Yes	Six holes, 40-mm 95° blade plate with 6 screws (4 tibia, 2 talus) Two 6.5-mm fully threaded screws	No (after distal fibula resection)	Morselized bone from posterior tibia, 2-cc bone marrow aspiration from iliac crest	Achilles tendon lengthening
25	No	Six holes, 45-mm 95° blade plate with 6 screws (4 tibia, 2 talus) Two 4-mm fully threaded screws Two 6.5-mm fully threaded screws	Yes	Morselized bone from posterior tibia	Achilles tendon lengthening, tenolysis of peroneus longus and brevis tendons
26	No	Eight holes, 45-mm 95° blade plate with 7 screws (4 tibia, 2 talus, 1 calcaneus) Two 6.5-mm fully threaded screws	No (after distal fibula resection)	Morselized bone from posterior tibia, INFUSE® BMP sponges	Achilles tendon lengthening, tibia osteotomy
27	No	Six holes, 45-mm 95° blade plate with 4 screws (3 tibia, 1 talus)	No	Morselized bone from posterior tibia, INFUSE® BMP sponges	Achilles tendon lengthening
28	No	Eight holes, 45-mm 95° blade plate with 8 screws (5 tibia, 2 talus, 1 calcaneus) Two 6.5-mm fully threaded screws	No	Morselized bone from posterior tibia	Achilles tendon lengthening
29	Yes	Six holes, 40-mm 95° blade plate with 5 screws (3 tibia, 2 talus)	No	Cancellous allograft, INFUSE® BMP sponges	None
30	No	Five holes, 40-mm 95° blade plate with 8 screws (3 tibia, 1 talus, 1 calcaneus) One 6.5-mm fully threaded screw	After fusion	Morselized bone from posterior tibia	Achilles tendon lengthening, talonavicular synovectomy and débridement
31	No	Six holes, 45-mm 95° blade plate with 6 screws (4 tibia, 1 talus, 1 calcaneus) One 6.5-mm fully threaded screw Three 3.5-mm fully threaded screws	Yes	Morselized bone from posterior tibia and distal fibula	Achilles tendon lengthening
32	Yes	Six holes, 50-mm 95° blade plate with 4 screws (3 tibia, 1 talus) One 6.5-mm fully threaded screw Two 3.5-mm fully threaded screws	Yes	Morselized bone from posterior tibia	Achilles tendon lengthening
33	Yes	Eight holes, 50-mm 95° blade plate with 6 screws (5 tibia, 1 talus)	No (after distal fibula resection)	Morselized bone from posterior tibia	Achilles tendon lengthening
34	No	Six holes, 45-mm 95° blade plate with 5 screws (4 tibia, 1 talus)	No	Morselized bone from posterior tibia, INFUSE® BMP sponges	Achilles tendon lengthening
35	No	Six holes, 45-mm 95° blade plate with 5 screws (4 tibia, 1 talus) One 4-mm fully threaded screw	No	Morselized bone from posterior tibia, autograft cancellous bone from the proximal tibia	Achilles tendon lengthening

Table 3. continued

Patient number	Removal of hardware	Fixation	Distal tibiofibular fusion	Autograft/allograft	Additional procedures
36	No	Six holes, 40-mm 95° blade plate with 5 screws (4 tibia, 1 talus) Two 4-mm fully threaded screw	Yes	Morselized bone from posterior tibia, INFUSE® BMP sponges	None
37	No	Five holes, 45-mm 95° blade plate with 5 screws (4 tibia, 1 talus)	No	Morselized bone from posterior tibia, INFUSE® BMP sponges	None
38		Six holes, 40-mm 95° blade plate with 6 screws (4 tibia, 1 talus, 1 calcaneus) Two 4-mm fully threaded screws	Yes	Morselized bone from posterior tibia	Achilles tendon lengthening
39	Yes	Six holes, 50-mm 95° blade plate with 5 screws (4 tibia, 1 talus) Two 3.5-mm fully threaded screws	No (after distal fibula resection)	Morselized bone from posterior tibia	None
40	Yes	Eight holes, 40-mm 95° blade plate with 5 screws (5 tibia) One 6.5-mm fully threaded screw	No (after distal fibula resection)	Morselized bone from posterior tibia, autograft cancellous bone from iliac crest	None

INFUSE®, Medtronic, Minneapolis, MN, USA.

Statistical Analysis

A Kolmogorov-Smirnov normality test was performed to determine if data were normally distributed. A univariate regression for comparison of two groups—those with complications and those without—was performed with the following factors: age, gender, BMI, diabetes mellitus, smoking, peripheral neuropathy, type of surgery, and use of BMP. A p value of 0.05 or less was considered statistically significant. Data were analyzed using IBM® SPSS® Statistics Version 22 (IBM Corporation, Armonk, NY, USA) and SigmaPlot Version 12.5 (Systat Software Inc, San Jose, CA, USA).

Results

Fusion was achieved by 83% of the patients in this series (33 of 40) (Table 4). Four of the 33 patients (12%) with ultimate union had a delayed union. All patients who experienced a nonunion (seven of 40; 18%) had undergone a tibiotalocalcaneal arthrodesis: primary tibiotalocalcaneal arthrodesis in two cases, primary-staged tibiotalocalcaneal arthrodesis in four cases, and revision tibiotalocalcaneal arthrodesis in one case.

The seven nonunions included three ankle nonunions (43%), three subtalar nonunions (43%), and a combined nonunion in one patient (14%) (Table 5). In one patient, nonunion was associated with a deep infection resulting in two irrigations and débridements, lateral calcaneal artery rotational flap coverage, and hardware removal. The subtalar joint united in this patient and the patient functions with the ankle nonunion with preserved hindfoot alignment.

Another patient with ankle nonunion presented with failed hardware (one broken screw). Despite the nonunion, he was asymptomatic and refused revision surgery. In the third patient with an ankle nonunion, hardware removal and revision arthrodesis using an intramedullary nail was performed 9 months after the index surgery. At the latest followup, 13 months after the revision arthrodesis, a solid fusion was observed.

In one patient with subtalar nonunion, revision surgery was performed 11 months after the index surgery, which resulted in complete osseous healing. Another patient with subtalar nonunion had few symptoms and a well-aligned hindfoot; therefore, no revision surgery was indicated. In the third patient, revision of the painful subtalar nonunion was performed 10 months after the index surgery. However, union still was not observed, and the patient presented with worsening symptoms. Five months later, a below knee amputation was performed.

In the patient with combined ankle and subtalar nonunions, hardware failure with plate breakage resulted in substantial

Table 4. Postoperative outcome including fusion and complications in 40 patients who underwent hindfoot arthrodesis using a posterior blade plate

Patient number	Intraoperative complications	Osseous fusion†	Postoperative complications	Secondary procedures
1	None	Yes	Hardware failure (but solid fusion)	None
2	None	Ankle no, subtalar yes	Deep wound infection, ankle nonunion	Irrigation and debridement ×2, flap coverage, removal of hardware
3	None	Yes	None	None
4	None	Yes	Deep wound infection	Irrigation and débridement, below knee amputation 8 months postoperative
5	None	Yes	None	None
6	None	Ankle no, calcaneocuboid joint yes	Ankle nonunion, hardware failure	None
7	None	Yes	Persisting pain	Below knee amputation 49 months postoperatively
8	None	Yes	Deep wound infection	Irrigation and debridement ×2
9	None	Yes	Superficial wound infection	None
10	None	Yes	None	None
11	None	Yes	None	None
12	None	Yes	Delayed wound healing	None
13	None	Yes	None	None
14	None	Yes (delayed)	Delayed union	None
15	None	Yes	Deep vein thrombosis, late deep infection	Irrigation and débridement, below knee amputation 20 months postoperatively
16	None	No	Subtalar nonunion, sural and tibial neuritis	Subtalar revision arthrodesis
17	None	No	Subtalar nonunion	None
18	None	Yes (delayed)	Painful hardware, persistent pain	Partial removal of hardware 12 months postoperatively; below knee amputation 44 months postoperatively
19	None	Yes	Periimplant tibia fracture*	None
20	None	Yes	Superficial wound infection, periimplant tibia fracture*	None
21	None	Yes	None	None
22	None	Yes	None	None
23	None	No	Hindfoot nonunion, hardware failure and exposure	Below knee amputation 6 months postoperatively
24	None	No	Superficial wound infection, hardware failure, ankle nonunion	Revision tibiotalocalcaneal arthrodesis using intramedullary nailing 9 months postoperatively
25	None	Yes	None	None
26	None	Yes	None	None
27	None	Yes	None	None
28	None	Yes (delayed)	Delayed union	None
29	None	Yes	None	None

Table 4. continued

Patient number	Intraoperative complications	Osseous fusion†	Postoperative complications	Secondary procedures
30	None	No	Subtalar nonunion	Subtalar revision arthrodesis 10 months postoperatively; below knee amputation 15 months postoperatively
31	None	Yes	None	None
32	None	Yes (delayed)	Delayed union	Tibiofibular syndesmotic arthrodesis 24 months postoperatively
33	None	Yes (delayed)	Delayed union	None
34	None	Yes	None	None
35	None	Yes	None	None
36	None	Yes	None	None
37	None	Yes	None	None
38	None	Yes	None	None
39	None	Yes	None	None
40	None	Yes	None	None

† Osseous fusion was defined as visible trabecular bridging on the lateral and AP ankle views within 6 postoperative months. Delayed union was defined as osseous fusion occurring between 6 and 12 months. Nonunion was defined as no visible trabecular bridging at the latest followup (longer than 12 months). *Treated conservatively with a cast.

varus collapse of the hindfoot. A below knee amputation was performed 6 months after the initial fusion attempt.

With the numbers available, we identified no demographic or health-related patient factors associated with nonunion (Table 5).

Complications were common in this series. We observed 18 major and eight minor complications as earlier defined. When accounting for the occurrence of more than one complication in some patients, a total of 40% of patients (16 of 40) experienced one or more major complication and a total of 18% (seven of 40) experienced one or more minor complication.

Including the delayed unions and nonunions as described previously, 21 of 40 patients (53%) had complications (Table 4). Eighteen complications were considered major (seven nonunions, four deep infections, four delayed unions, two severe persisting pain syndromes, one deep vein thrombosis) and eight complications were considered minor (three delayed wound healings, two tibial stress fractures, one superficial infection, one neuritis, one hardware failure but solid fusion). Patients with or without complications were comparable in terms of demographic data and surgical details (Table 6).

Four of 40 patients (10%) had a deep infection treated by secondary surgery and intravenous antibiotics. One of the deep infections was associated with nonunion of the ankle as described previously. In another patient, irrigation and débridement was performed to treat the deep infection; however, infection and pain could not be resolved and a below knee amputation was performed. The third deep infection occurred 18 months after the index procedure in a 58-year-old patient who was a smoker and also had liver cirrhosis. This patient also had a deep vein thrombosis develop. Limb salvage was attempted with irrigation and débridement; however owing to persistent infection and pain, a below knee amputation was performed. The fourth deep infection occurred in a 55-year-old patient with diabetes and neuropathy who smoked. This patient underwent two irrigation and débridement procedures and the infection was resolved.

One patient had persistent pain without reflex sympathetic dystrophy despite successful fusion as confirmed by CT. After all conservative treatment options failed, a below knee amputation was performed 49 months after the index surgery. Another patient also reported severe, persistent pain without reflex sympathetic dystrophy. Twelve months after the index surgery, partial hardware removal was performed. However, this did not result in pain relief; therefore, 44 months after the initial surgery, a below knee amputation was performed.

The most serious superficial wound issue was a dehiscence that occurred 6 weeks after surgery associated with a superficial infection. The patient was treated successfully for the infection with oral antibiotics and wet-to-dry dressing changes.

Table 5. Demographic data and surgical details of 36 patients*

Parameter	Patients with solid union	Patients with nonunion	p value	Power analysis[$]
Number of patients (ankles)	29 (29)	7 (7)	–	
Mean age (years; range)	55 (24–76)	57 (52–66)	0.674[†]	0.108
Gender: male:female	20:9	5:2	0.641[‡]	0.049
Mean BMI (kg/m^2; range)	29 (18–42)	29 (26–33)	0.969[†]	0.069
Diabetes mellitus, yes:no	9:20	1:6	0.645[‡]	0.134
Smoking, yes:no	8:21	3:4	0.650[‡]	0.115
Peripheral neuropathy, yes:no	11:18	1:6	0.384[‡]	0.206
Arthrodesis ankle:tibiotalocalcaneal	8:21	0:7	0.309[‡]	0.333
Arthrodesis, primary:revision	16:13	4:3	0.925[‡]	0.048
Use of recombinant human BMP-2, yes:no	13:16	2:5	0.674[‡]	0.114

* Four patients with delayed osseous union were excluded from this analysis; [$]post priory power analysis with an α of 0.05; [†]unpaired t-test; [‡]Fisher's exact test.

Table 6. Demographic data and surgical details of 40 patients

Parameter	Patients without complications	Patients with minor complications	Patients with major complications	p value*
Number of patients (ankles)	19 (19)	6 (6)	15 (15)	–/–
Mean age (years; range)	55.6 (23.7–83.2)	56.6 (28.5–75.5)	57.3 (33.0–74.9)	0.715[†]/ 0.887[†]
Gender, male:female	11:8	3:3	13:2	0.128[‡]/ 0.734[‡]
Mean BMI (kg/m^2; range)	29.3 (18.1–41.9)	30.4 (24.6–38.2)	28.6 (22.5–38.0)	0.739[†]/ 0.728[†]
Diabetes mellitus, yes:no	6:13	2:4	3:12	0.697[‡]/ 0.936[‡]
Smoking, yes:no	4:15	2:4	5:10	0.462[‡]/ 0.606[‡]
Peripheral neuropathy, yes:no	5:14	4:2	3:12	0.666[‡]/ 0.142[‡]
Arthrodesis ankle:tibiotalocalcaneal	8:11	3:12	0:6	0.271[‡]/ 0.129[‡]
Arthrodesis, primary:revision	12:7	2:4	10:5	0.832[‡]/ 0.350[‡]

* Without complications versus with minor complications/without complications versus major complications; [†]unpaired t-test; [‡]Fisher's exact test.

Two tibial stress fractures occurred at the top of the blade plate, one at 4 months and the other at 4.5 months after the index procedure. Both patients were treated with a below knee cast for 4 weeks and were nonweightbearing. Both stress fractures healed without additional complications.

Another minor complication included one case of tibial and sural neuritis, which was completely resolved at the 6-month postoperative followup.

With the numbers available, we identified no demographic or health-related patient factors associated with the development of complications (Table 6).

Discussion

The use of a blade plate is a well-accepted fixation treatment for hindfoot arthrodesis. However, few articles have addressed clinical outcomes in patients who underwent hindfoot arthrodesis using a blade plate from a posterior approach (Table 1), and these are limited by small patient populations and shorter followup (Table 1). In the current study, we asked: (1) What proportion of patients treated with this technique achieved osseous union? (2) What complications were observed? (3) Were any patient-

demographic or health-related factors associated with the likelihood that a patient would have a complication develop? We found that the proportion of patients treated with a posterior blade-plate hindfoot fusion who had delayed union and nonunion was greater than that reported for patients in other series who underwent primary hindfoot arthrodesis with other approaches, and the proportion of patients with complications was high. With the numbers available, we did not identify any demographic or surgical factors associated with complications, delayed union, or nonunion.

Our study has numerous limitations. First, it is retrospective. The outcomes reported in this study rely on accuracy of the clinic notes. Surgeon bias may have influenced the clinical records. We cannot know to what extent this form of bias might have affected our assessment of outcomes. However, all radiographic assessments were performed independently anew for this study. Second, it does not include patient-reported clinical outcomes. We can only surmise that for some patients who had revision or secondary procedures, including amputations, the outcomes for them from the posterior ankle/subtalar blade-plate surgery were inadequate. Third, in our study, weightbearing conventional radiographs were used to evaluate the fusion status. CT scans have been shown to have high reliability in determining the degree of successful fusion of the hindfoot [6]. However, in our study, only patients with a suspected nonunion or delayed union underwent CT, as it would be impractical to obtain CT in all patients. Fourth, the number of patients treated by posterior blade-plate arthrodesis was relatively small. Therefore, with the available number, we were not able to identify any demographic or surgical factors associated with complications, delayed union, or nonunion.

Available studies including patients with posterior blade-plate arthrodesis included less-complicated patient populations with no surgical history in the affected ankle and who were without significant medical comorbidities. One of the first reports of the use of posterior blade plates was by Gruen and Mears [14], who described their technique for the posterior approach and posterior blade plating for arthrodesis of the ankle and subtalar joints in five patients. More recently, posterior blade plating has been used successfully for definitive treatment of nonreconstructable pilon fractures [5, 19, 27, 28]. Bozic et al. [5] treated 14 patients with ankle incongruence after nonreconstructable tibial pilon fractures with primary ankle arthrodesis using a posterior blade plate. In a 2010 report, Cinar et al. [9] performed tibiocalcaneal arthrodesis using a posterior blade plate in four patients with diabetes and with Charcot arthropathy.

Delayed union and nonunion were more common in our study than in others that have used posterior blade-plate hindfoot arthrodesis (Table 1). In the report by Gruen and Mears [14], all patients experienced complete osseous union and no complications were described. Similarly, Hanson and Cracchiolo [16] reported 100% union at an average followup of 37 months; however, two patients experienced delayed union, and complications were reported in five (50%). Cinar et al. [9] reported the development of solid fusion in three of four patients at a mean followup of 24 months. However, two of the four patients experienced wound infections, and one patient underwent hardware removal [9]. Bozic et al. [5] reported that all 14 patients receiving treatment for traumatic pilon fractures using a posterior blade plate achieved fusion at an average of 15 weeks, with osseous union being defined as full weightbearing with minimal pain and radiographic evidence of arthrodesis on conventional radiographs. There was one deep infection which resulted in implant removal and intravenous antibiotics. One patient had a broken plate but achieved successful fusion without reoperation [5].

Complications, likewise, were more common in our series than in others using the posterior approach with a blade plate for hindfoot arthrodesis [1, 5, 9, 14–16, 19, 27, 28]. A possible explanation for this finding may be that most of our patients had at least one previous surgery compromising soft tissues around the ankle. With the numbers available, we did not identify any factors associated with postoperative complications or nonunion. Although sources are limited regarding the use of rhBMP-2 in patients with foot and ankle disorders, some authors suggest it is effective in aiding union after arthrodesis [4, 13, 23]. Seventeen of our patients received rhBMP-2 during the index procedure either exclusively or in combination with local bone grafting. Bibbo et al. [4] and Rearick et al. [23] did not find the presence or absence of grafting to have an effect on union rates when used with rhBMP-2. Analysis of our patients showed no difference in union rates with and without the use of rhBMP-2 with the numbers available. More investigation is necessary to determine if rhBMP-2 has a role in hindfoot and ankle fusion surgery. Previous arthrodesis of the adjacent joint is a risk factor for nonunion of the tibiotalar joint (with a previously fused subtalar joint) [7] or of the subtalar joint (with a previously fused tibiotalar joint) [12, 26]. Easley et al. [11], whose study included only patients who underwent revision arthrodesis, reported a union rate that was comparable to the rate in our patients. At the time of the most recent follow up—an average of 50 months—the union rate was 89%. We did not observe a positive effect of rhBMP-2 most likely owing to the low number of patients in our study. In our patient cohort, six of seven patients (86%) with primary isolated ankle arthrodesis had a complete osseous union. Another possible explanation for the high number of patients with nonunion or delayed union is

the possibly high invasiveness of this fixation method. It is not clear whether a blade plate may disrupt intraosseous blood supply of the talus which would increase the risk of compromised osseous healing.

Our patients undergoing hindfoot arthrodesis through a posterior blade plate were a diverse and challenging group. Most of the patients had one or more previous ankle or hindfoot surgeries. Nonunion was more common than reported in other series [1, 5, 9, 14–16, 19, 27, 28] and complications also were more common [1, 5, 9, 14–16, 19, 27, 28]. However, specifically in patients with compromised anterior, medial, and lateral soft tissue envelopes, a posterior approach with blade-plate fixation can be considered a viable surgical option. Further clinical studies are necessary to address alternative approaches, such as hybrid fixation types external and internal, to achieve better results and higher union rate in patients with complex hindfoot problems.

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