JB&JS Essential Surgical Techniques

SURGICAL TECHNIQUES

Tibiotalar Arthrodesis Conversion to Total Ankle Arthroplasty

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Published outcomes of this procedure can be found at: *J Bone Joint Surg Am*. 2015 Dec 16;97 (24):2004-13.

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Introduction

Although conversion of the painful ankle arthrodesis to total ankle arthroplasty remains controversial, this surgical modality has satisfactorily expanded the treatment armamentarium for addressing this pathology.

Painful ankle arthrodesis refers to an ankle nonunion or malunion in the short-term follow-up. Although these patients can be satisfactorily addressed with salvage procedures, such as revision ankle arthrodesis or realignment osteotomies, favorable outcomes may not always be achieved[1-5]. With longer follow-up, pain related to an ankle arthrodesis may represent the development of adjacent hindfoot arthritis. Extending the fusion to the hindfoot may increase the nonunion rate and, hence, undermine the results of the procedure, while limiting function[6-8].

Given the complexity of this clinical situation, conversion total ankle arthroplasty has arisen as a valid treatment alternative. Ankle arthrodesis takedown with conversion to total ankle arthroplasty has been proposed to patients with pain related to an ankle arthrodesis in an effort to improve functional outcomes.

Indications & Contraindications

Indications

- Painful tibiotalar nonunion or malunion[1,2].
- Tibiotalar arthrodesis with symptomatic subtalar and/or talonavicular articular degeneration[1,2].
- Subtalar nonunion in attempted tibiotalocalcaneal arthrodesis.

Contraindications

- Lack of the distal end of the fibula[1,2].
- Active infection.
- Osteonecrosis of the talus.

Disclosure: The authors indicated that no external funding was received for any aspect of this work. On the **Disclosure of Potential Conflicts of Interest** forms, *which are provided with the online version of the article,* one or more of the authors checked "yes" to indicate that the author had a relevant financial relationship in the biomedical arena outside the submitted work.

- Severe deformity precluding congruent alignment of the total ankle arthroplasty implant with conversion from tibiotalar arthrodesis.
- Neuromuscular disease with a lack of adequate muscle function around the ankle, in particular, dorsiflexion.
- Peripheral vascular disease.
- Poor skin and soft-tissue quality around the ankle.
- Peripheral neuropathy or neuroarthropathy.
- Inadequate bone stock to support the implant.

Step 1: Preoperative Preparation and Surgical Planning

Preoperative preparation and planning is similar to that for a primary total ankle arthroplasty, and implants designed for primary arthroplasty can be used in most patients managed with conversion to total ankle replacement.

- Carefully plan the surgical approach, particularly if a prior anterior ankle approach has been utilized (Figs. 1-A and 1-B).
- For most of the available total ankle arthroplasty designs, use an anterior approach between the tibialis anterior and extensor hallucis longus tendons.
- Remove arthrodesis hardware crossing the ankle joint; however, doing so may leave large bone defects, jeopardizing the stability of the tibial or talar component. A staged conversion total ankle replacement with hardware removal and bone-grafting may be considered in particular patients.
- In planning for the procedure, include a thoughtful evaluation of the preoperative radiographs to ensure that the articular joint line is reestablished as close as possible to the native line to optimize function of the implant (Figs. 2-A through 2-E).

Fig. 1-A

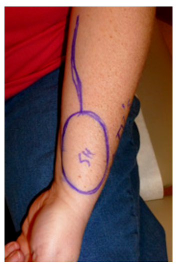

Fig. 1-B

Fig. 2-A

Fig. 2-B

Fig. 2-C

Fig. 2-D

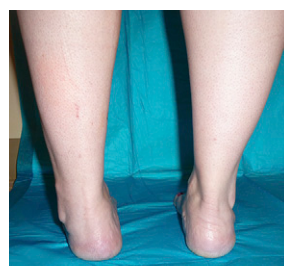

Fig. 2-E

Figs. 1-A and 1-B A patient with a history of delayed healing and drainage. **Fig. 1-A** Clinical photograph demonstrating an anterior ankle scar. **Fig. 1-B** The patient underwent a successful ipsilateral radial forearm flap procedure prior to conversion total ankle arthroplasty.

Figs. 2-A through 2-E A 58-year-old woman with hindfoot pain after an attempted ankle arthrodesis. **Figs. 2-A through 2-D** Preoperative anteroposterior (**Fig. 2-A**), mortise (**Fig. 2-B**), lateral (**Fig. 2-C**), and hindfoot (**Fig. 2-D**) radiographs. **Fig. 2-E** Clinical photograph demonstrating varus malalignment of the hindfoot, which was confirmed with the hindfoot alignment radiograph.

- Use preoperative computed tomography (CT) to identify tibial or talar bone defects, to confirm tibiotalar and/or subtalar nonunion, and to evaluate hindfoot arthritis when considering conversion total ankle arthroplasty (Figs. 3-A and 3-B). When hardware is present, a metal-suppression protocol is recommended.
- Ensure that the recreation of the articular line provides sufficient talar bone support to the implant, even if this necessitates translating the initial cut slightly more proximal than the native joint line. However, perform this translation judiciously, as the tibia narrows considerably and the risk of medial malleolar stress fracture may increase.
- During preoperative templating of the talar component, consider an implant 1 size smaller than that clinically predicted to ensure adequate gutter preparation.
- If the optimal tibial slope is difficult to achieve, particularly in a patient with a tibiotalar arthrodesis that is malunited in equinus, postpone talar preparation until the preparation of the tibial cut and gutters is completed and the ankle can be moved through its range of motion to achieve parallelism between the tibial and talar cuts.
- Consider performing associated procedures concomitant to conversion total ankle arthroplasty, if necessary, to achieve a balanced and plantigrade foot.
- Although hindfoot arthrodesis and total ankle arthrodesis can be performed simultaneously, extensive talar and gutter preparation in combination with hindfoot exposure can jeopardize talar vascularization and compromise implant support. Therefore, we recommend performing these operations in a staged manner and limiting the subtalar arthrodesis to the posterior facet only.
- Workup protocol:
    - As for any painful ankle, perform laboratory work to rule out infection, including routine blood work sent for patients with a concern for infection.
    - Perform a CT scan to (1) identify an ankle nonunion that is not evident on radiography, (2) evaluate for a potential stress fracture not evident on radiography, and (3) determine the extent of arthritis in the hindfoot articulations.
    - If there is a solid arthrodesis and minimal or no hindfoot arthritis, carefully consider a neurogenic origin of pain such as complex regional pain syndrome. Typically, this is evident on clinical examination, but with prior ankle arthrodesis it is not always obvious.
    - Do not routinely order a magnetic resonance imaging (MRI) scan or a nuclear white blood-cell scan unless an obvious soft-tissue abnormality is suspected or infection is suggested on blood work.


Fig. 3-A


Fig. 3-B

Figs. 3-A and 3-B CT scans demonstrating nonunion of the tibiotalar joint. **Fig. 3-A** Coronal view suggesting varus malalignment of the talus relative to the tibia. **Fig. 3-B** Sagittal view demonstrating nonunion.

Step 2: Patient Positioning

Position the patient as for a primary total ankle replacement.

- Place the patient in the supine position on the operating-room table with the heel approaching the edge of the table.
- Place support under the ipsilateral hip.
- Have the foot rest at a right angle to the table.
- The anesthesia team routinely uses a popliteal catheter for regional anesthesia.
- Prepare and drape the operatively treated extremity to the knee.
- Perform exsanguination by wrapping the extremity with an elastic bandage beyond the drapes at the knee.

Step 3: Remove Hardware and Insert Prophylactic Malleolar Screws

Preserve exsanguination time by removing hardware prior to inflating the tourniquet.

- Remove transarticular screws or screws anticipated to interfere with implant positioning before inflating the tourniquet (Fig. 4).
- Inflate the thigh tourniquet.
- In ankles that had arthrodesis performed with anterior plating, inflate the tourniquet before proceeding with the anterior approach to the ankle.
- Assuming that the malleoli have been stress-shielded in ankle arthrodesis, perform prophylactic fixation of both malleoli to avoid intraoperative fractures.
- Use percutaneous cannulated 3.5-mm-diameter screws to preserve tourniquet time for the arthroplasty and improve stability. Place the screws as close to the cortex as possible in anticipation of gutter preparation (Fig. 5).

Fig. 4

Fig. 5

Fig. 4 Fluoroscopic view of hardware removal. Removal of the posterior-to-anterior screw is challenging. After passing the guide pin over the screw from posterior to anterior, a small incision was performed in the anteromedial part of the foot to pass the screwdriver in a retrograde manner. This maneuver provides counterpressure to the screw, facilitating its removal. We usually perform hardware removal without a tourniquet to preserve tourniquet time for conversion total ankle arthroplasty.

Fig. 5 Prophylactic malleolar screws are placed in anticipation of recreating the ankle joint; the placement is often performed without a tourniquet.

Step 4: Recreate the Tibiotalar Joint

Recreate the native joint line, which can be relatively easy in selected patients and challenging in others.

- Define the native articular line, which can be straightforward when the ankle anatomy has been adequately preserved, such as in ankles after an arthroscopic arthrodesis and particularly in ankles with a nonunion (Figs. 6-A, 6-B, and 6-C).
- Although the joint line can be identified clinically, place small-diameter Kirschner wires as a reference to define the joint line fluoroscopically.
- For patients with symptoms related to ankle arthrodesis, especially ones with a solid fusion, reestablishing the tibiotalar joint line may be difficult. In some patients, use radiographs of the contralateral, uninvolved ankle to serve as a reference for determining the joint line in the affected ankle. Measure the distance from the medial malleolus to the natural joint line to guide recreation of the joint line in the affected ankle. The implant used for ankle arthrodesis may also serve as a reference for determining the ideal level for reestablishing the joint line. A particular screw or hole in a plate often serves as a useful reference point when determining an ideal level for reestablishing the joint line radiographically; this reference point is often easily identified clinically.
- Preserve the talar body, which we have found to be essential. If necessary, err on the side of a slightly more proximal joint line to avoid leaving too little talus on which to rest the talar component. Avoid excessive proximal translation, since the more proximal the resection, the narrower the tibia and the greater the risk for malleolar stress fracture.

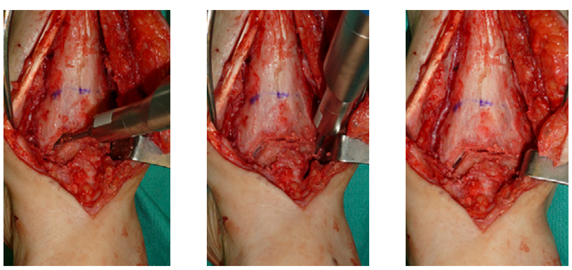

Fig. 6-A Fig. 6-B Fig. 6-C

Figs. 6-A, 6-B, and 6-C Photographs showing reestablishment of the native joint line, which can be relatively straightforward if the anatomy has been adequately preserved. **Figs. 6-A and 6-B** A small reciprocating saw is utilized to recreate the medial gutter (**Fig. 6-A**) and the lateral gutter (**Fig. 6-B**). **Fig. 6-C** The joint line and gutters have been adequately prepared.

- For implants with independent tibial and talar preparation, select the proper resection level, rotation, and slope as is done for a primary total ankle arthroplasty (Figs. 7-A through 7-E).
- Perform the initial tibial preparation with the same cutting guide used for a primary total ankle arthroplasty, with a capture guide to protect the malleoli.
- As the ankle has been previously operatively treated, the posterior soft tissues may be adhered to the posterior aspect of the tibia. Use a lateral fluoroscopic view, which may help to confirm that the saw blade has not overcome the posterior tibial bone.
- Extract the resected bone from the joint (Figs. 8-A, 8-B, and 8-C).

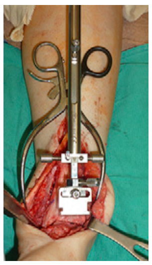

Fig. 7-A

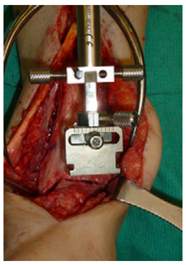

Fig. 7-B

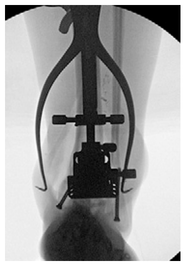

Fig. 7-C

Fig. 7-D

Fig. 7-E

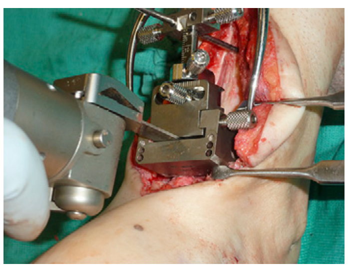

Fig. 8-A

Fig. 8-B

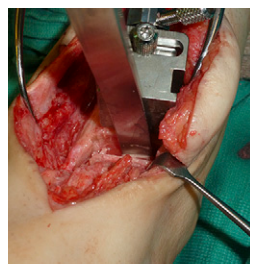

Fig. 8-C

Figs. 7-A through 7-E Use of the tibial alignment guide. **Fig. 7-A** Note that the anatomic axis of the tibia determines the alignment and not the coronal plane of the reestablished tibial plafond. **Fig. 7-B** This patient had preoperative varus malalignment with the talus malpositioned in the ankle mortise. The guide is being moved proximally to the appropriate resection level. **Fig. 7-C** Fluoroscopic confirmation of the tibial guide positioning. **Fig. 7-D** The tibial guide is aligned with the tibial shaft. **Fig. 7-E** Fluoroscopic confirmation of resection level and slope.

Figs. 8-A, 8-B, and 8-C Tibial preparation. **Fig. 8-A** Malleoli are protected through the capture guide, and the initial tibial cut is performed with the oscillating saw. **Fig. 8-B** A lateral fluoroscopic image, which we recommend, confirms the saw blade position since the soft tissues may be adherent to the posterior aspect of the tibia. **Fig. 8-C** Resected bone is extracted from the joint.

Step 5: Set the Optimal Talar Slope

Set the optimal talar slope, which can be challenging, particularly when the ankle arthrodesis is malunited in equinus.

- To avoid excessive posterior talar slope, perform the initial talar preparation independent of the dedicated guide. This approach is particularly important when the surgeon is using a monoblock cutting guide to prepare the tibia and the talus.
- After performing the tibial preparation, recreate the gutters using a small reciprocating saw to allow gentle manipulation of the ankle joint. Place the ankle in dorsiflexion, which will optimize the talar position for adequate preparation (Figs. 9-A through 9-F).

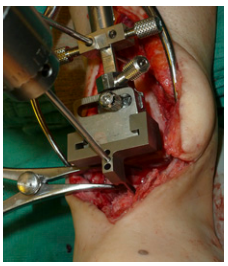

Fig. 9-A

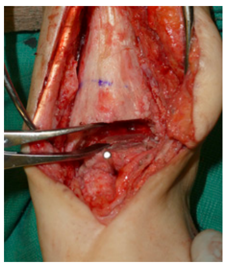

Fig. 9-B

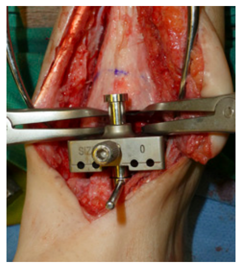

Fig. 9-C

Fig. 9-D

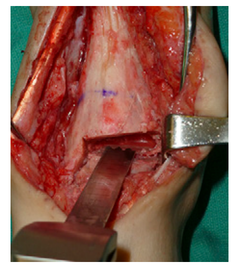

Fig. 9-E

Fig. 9-F

Figs. 9-A through 9-F Talar preparation. **Fig. 9-A** Positioning of the reference pin for initial talar preparation. **Fig. 9-B** The pin will guide the posterior chamfer cut. After this step, the tibial alignment guide can be removed. **Fig. 9-C** Positioning of the posterior chamfer cutting guide with lamina spreaders. **Fig. 9-D** Intraoperative fluoroscopic view suggesting excessive resection of the posterior residual talar dome. **Fig. 9-E** In this particular case, we elected to perform the cut freehand. **Fig. 9-F** Fluoroscopic view of the posterior chamfer preparation.

Step 6: Recreate the Medial and Lateral Gutters

Because the former medial and lateral articulations between the talus and the malleoli can be difficult to define, use careful surgical technique to avoid compromise of the malleoli and excessive talar resection.

- Place small-diameter Kirschner wires in the anticipated location of the native gutters and confirm fluoroscopically.
- Because monoblock instrumentation may be difficult for evaluating the malleoli and residual talar bone, use a smaller monoblock than may be suggested on intraoperative evaluation to recreate the gutters. An adequate intramedullary reference in this system is critical to placing the cutting guide in an optimal position.
- In a critical step of the surgical procedure, maintain the ankle in a stable position regardless of the ankle system being used until the gutters have been adequately recreated. Failure to achieve stability of the ankle may result in a malleolar fracture during distraction or mobilization.
- Recreate the gutters using a small reciprocating saw to remove approximately 2 to 3 mm of bone slightly more toward the malleoli rather than the talar bone. This approach should ensure that sufficient talar dome will support the talar component (Fig. 10).
- Additionally, because some ankle designs require resection of the lateral and/or medial talar dome, avoid overly generous talar resection.

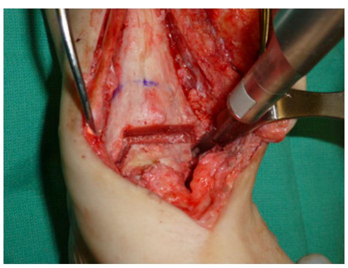

Fig. 10

Fig. 10 Medial and lateral gutter preparation. The gutters cannot be simply recut; they must be recreated. Typically, we remove approximately 2 to 3 mm from the malleoli rather than from the talar dome.

Step 7: Mobilize the Ankle and Use Bone Graft in Defects from Previous Hardware

To avoid potential malleolar fractures, mobilize the ankle only after the prophylactic malleolar screws have been placed; the tibial and talar cuts, completed; the gutters, reestablished; all resected bone, removed; and scar tissue from the posterior aspect of the ankle, excised; thereafter, conversion total ankle arthroplasty is similar to a primary total ankle replacement, with the exception of potential bone defects where prior hardware was positioned.

- If the ankle remains locked, then more release is needed.
- Apply distraction to assess whether the created joint space will accommodate the implant. Occasionally, further bone resection may be needed. Use the small reciprocating saw to remove incongruities of the bone surfaces.
- Despite adequate bone preparation and elevation of scar tissue, motion may be limited in an ankle arthrodesis takedown. Access to the posterior part of the ankle may be difficult.
- Use bone-grafting in defects caused by previous hardware to prevent later cyst formation or bone weakening.

Step 8: Talar Preparation

Perform the routine steps for primary total ankle arthroplasty, often ignoring bone defects from the ankle arthrodesis hardware, but plan to repair the defects with bone-grafting before implanting the final talar component.

- Despite satisfactory bone preparation and elevation of scar tissue, note that access to the posterior aspect of the ankle joint can be challenging.
- This situation is less of a concern when a system designed for a flat-cut talus is used and more challenging when the talar preparation involves a posterior chamfer cut.
- Moreover, in some ankle systems, talar preparation starts with the posterior chamfer, and the trajectory of this cut has to be determined in the absence of physiologic references of the native talar dome.
- Perform talar preparation in a manner similar to that for primary total ankle arthroplasty. For this procedure, after milling the anterior chamfer, a bone defect can be obvious. Take the location of the bone defect into consideration when selecting the ankle design. If the bone defect is laterally based, use an ankle design with a medial talar stem and a lateral chamfer cut, thereby reducing the bone defect without compromising implant stability (Figs. 11-A through 12-C).


Fig. 11-A

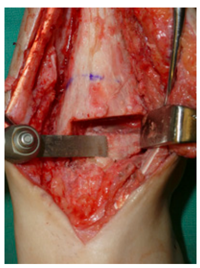
Fig. 11-B


Fig. 11-C

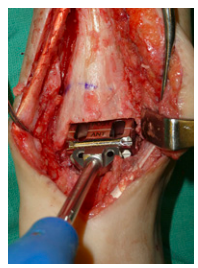
Fig. 11-D


Fig. 11-E

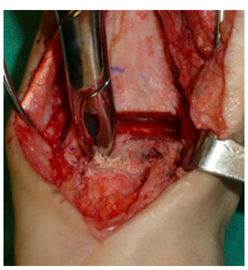
Fig. 11-F


Fig. 11-G

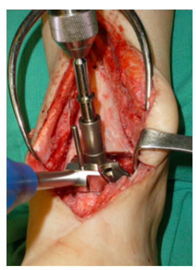
Fig. 12-A


Fig. 12-B

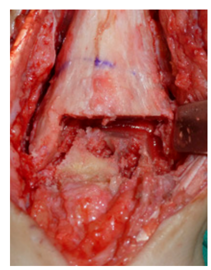
Fig. 12-C

Figs. 11-A through 11-G Preparation of the anterior chamfer. **Fig. 11-A** Osteophytes in the talar neck are removed with a rongeur in order to move the talar component more posteriorly. **Fig. 11-B** We smooth the planned chamfer with a microsagittal saw to ensure that the anterior chamfer milling guide will sit appropriately and in optimal rotation in relation to the second metatarsal axis. **Fig. 11-C** The anterior part of the talar body is then prepared for the anterior chamfer guide. **Fig. 11-D** The guide position suggests that the sagittal position of the talar component will be satisfactory. **Fig. 11-E** Anterior chamfer preparation. **Fig. 11-F** After completing preparation, a lateral talar defect from hardware placed during the ankle arthrodesis is evident. **Fig. 11-G** This defect has to be grafted.

Figs. 12-A, 12-B, and 12-C This particular system utilizes a medially based talar stem. **Fig. 12-A** After securing the lateral chamfer guide flush on the talus, the stem hole is drilled. **Fig. 12-B** Preparation of the lateral chamfer with a microsagittal saw. **Fig. 12-C** The prepared talus showing the residual lateral dome defect that will require bone-grafting. The remnant bone support was judged sufficient to perform conversion to a total ankle arthroplasty. At this point, the posterior capsule can be easily accessed and mobilized, while protecting the neurovascular structures.

- At this point, the posterior capsule can be easily accessed and mobilized judiciously using an elevator to protect the neurovascular bundle and the malleoli.
- Although we used 3 different implant systems to perform the conversion from ankle arthrodesis to total ankle replacement, we do not have a particular preference for an implant. In our opinion, provided that physiologic alignment is maintained or reestablished, any one of the implant systems represents a reasonable option for conversion.

Step 9: Tibial Preparation and Definitive Components

Perform tibial preparation in a manner similar to that used for primary total ankle arthroplasty.

- Plan for a talar component 1 size smaller than the tibial component to ensure (1) adequate gutter debridement and (2) sufficient bone support in anticipation of talar dome bone loss during arthrodesis takedown.
- The tibial component rarely has to be downsized unless there is concern for medial malleolar stress fracture in patients with relatively small ankles (Figs. 13-A through 14-E).
- After definitive components have been adequately implanted, assess ankle stability, ankle range of motion, and foot alignment.
- If concomitant ancillary procedures can be safely performed during the same operation, do so. In general, hindfoot arthrodesis is staged to avoid jeopardizing talar blood supply and implant osseointegration.

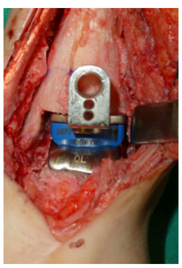
Fig. 13-A


Fig. 13-B


Fig. 13-C

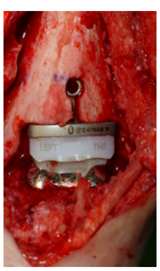
Fig. 14-A


Fig. 14-B


Fig. 14-C

Fig. 14-D

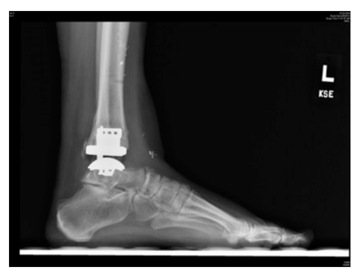

Fig. 14-E

Figs. 13-A, 13-B, and 13-C Trial components in place demonstrating adequate alignment. **Fig. 13-A** Adequate hindfoot position, stability, and range of motion have to be achieved at this point. **Fig. 13-B** Coronal fluoroscopy demonstrates adequate alignment and no stress fracture. **Fig. 13-C** Lateral fluoroscopy suggests satisfactory position of the components and optimal coverage of the tibial surface, potentially avoiding impingement because of the overhanging of the tibial component.

Figs. 14-A through 14-E Final components. **Fig. 14-A** Intraoperative view of the conversion total ankle arthroplasty. **Fig. 14-B** Coronal fluoroscopic view showing the prophylactic fixation with screws. **Fig. 14-C** Lateral fluoroscopic view showing adequate position and absence of posterior tibial component liftoff. **Fig. 14-D** Anteroposterior ankle radiograph, made at the time of follow-up, showing satisfactory alignment and correction of varus malalignment. **Fig. 14-E** Sagittal view with the ankle in neutral position showing restoration of dorsiflexion.

Results

We performed 23 conversion total ankle arthroplasties in patients who had an ankle arthrodesis, including those with pain despite successful fusion and those with painful nonunions[9]. The implant survival rate was 87% (20 of 23 patients) at a mean follow-up of 33.1 months (range, 12 to 101 months) (Video 1). Seven patients (30%) needed an additional operation, with 3 of them presenting with symptomatic progressive aseptic talar component loosening that was managed with talar component revision.

Two patients lacking the distal end of the fibula demonstrated progressive valgus talar tilt and lateral translation at the time of follow-up. Both patients had a successful reconstruction with lateral malleolar allograft and talar component revision, both of which successfully stabilized the valgus deformity.

Pitfalls & Challenges

- An ankle arthrodesis should have preserved the physiologic anatomy to be considered for conversion total ankle arthroplasty; the lack of the distal end of the fibula is a contraindication for the procedure.
- Ankle nonunion with a preserved fibula is a reasonable indication for the procedure.
- In conversion total ankle arthroplasty of an ankle fused in equinus, excessive posterior talar dome resection should be avoided as it may jeopardize talar component support.
- Consideration should be given to a staged hindfoot arthrodesis and conversion total ankle arthroplasty, ensuring that only the posterior facet of the subtalar joint is arthrodesed. This approach should minimize the risk of devascularization of the talar dome and should avoid talar component subsidence.
- Prophylactic fixation with screws in the malleoli should diminish the risk of stress fracture. We usually place 3.5-mm, fully threaded, cannulated screws.
- To limit the risk of malleolar stress fracture, no attempt should be made to move the ankle before adequately completing (1) tibial and talar preparation, (2) gutter recreation, and (3) release of scar tissue and capsule surrounding the recreated joint.
- The talar component should be downsized to ensure adequate talar bone support and satisfactory gutter recreation, preserving the malleoli and avoiding impingement.
- Injury to the neurovascular bundle and the flexor hallucis longus tendon can be avoided with careful tibial and talar preparation. Additionally, lateral intraoperative fluoroscopy can monitor the depth of the saw blade. Consider placing a retractor between the posterior fused tibiotalar joint and the soft tissues.
- Wound complications can be avoided by handling the soft tissue carefully, using deep retraction with no direct tension on the skin margins. Closure of the extensor retinaculum should reduce skin pressure from the underlying tendons. Postoperative mobilization should be delayed until complete wound-healing.
- Careful preoperative planning, adequate use of primary alignment and reference guides, and the use of intraoperative fluoroscopy should diminish malalignment and malpositioning of prosthetic components.

Video 1 A patient demonstrating the functional outcome of the ankle after conversion of a tibiotalar ankle arthrodesis to a total ankle arthroplasty.

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References

1. Greisberg J, Assal M, Flueckiger G, Hansen ST Jr. Takedown of ankle fusion and conversion to total ankle replacement. Clin Orthop Relat Res. 2004 Jul;424:80-8.

2. Hintermann B, Barg A, Knupp M, Valderrabano V. Conversion of painful ankle arthrodesis to total ankle arthroplasty. J Bone Joint Surg Am. 2009 Apr;91(4):850-8.

3. Easley ME, Montijo HE, Wilson JB, Fitch RD, Nunley JA 2nd. Revision tibiotalar arthrodesis. J Bone Joint Surg Am. 2008 Jun;90(6):1212-23.

4. Levine SE, Myerson MS, Lucas P, Schon LC. Salvage of pseudoarthrosis after tibiotalar arthrodesis. Foot Ankle Int. 1997 Sep;18(9):580-5.

5. Katsenis D, Bhave A, Paley D, Herzenberg JE. Treatment of malunion and nonunion at the site of an ankle fusion with the Ilizarov apparatus. J Bone Joint Surg Am. 2005 Feb;87(2):302-9.

6. Hendrickx RP, Stufkens SA, de Bruijn EE, Sierevelt IN, van Dijk CN, Kerkhoffs GM. Medium- to long-term outcome of ankle arthrodesis. Foot Ankle Int. 2011 Oct;32(10):940-7.

7. Coester LM, Saltzman CL, Leupold J, Pontarelli W. Long-term results following ankle arthrodesis for post-traumatic arthritis. J Bone Joint Surg Am. 2001 Feb;83(2):219-28.

8. Fuchs S, Sandmann C, Skwara A, Chylarecki C. Quality of life 20 years after arthrodesis of the ankle. A study of adjacent joints. J Bone Joint Surg Br. 2003 Sep;85(7):994-8.

9. Pellegrini MJ, Schiff AP, Adams SB Jr, Queen RM, DeOrio JK, Nunley JA 2nd, Easley ME. Conversion of tibiotalar arthrodesis to total ankle arthroplasty. J Bone Joint Surg Am. 2015 Dec 16;97(24):2004-13