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Tibiotalocalcaneal Arthrodesis Using a Retrograde Intramedullary Nail without Subtalar Joint Preparation after Failed Total Ankle Arthroplasty

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Background: Tibiotalocalcaneal (TTC) arthrodesis is a viable salvage option for failed total ankle arthroplasty (TAA), but it is typically a complex procedure associated with a high complication rate. This study analyzed outcomes of salvage TTC arthrodesis using a retrograde intramedullary (IM) nail without subtalar joint preparation after failed TAA.

Methods: This study included 18 patients (18 ankles) who underwent TTC arthrodesis without subtalar joint preparation for failed TAA from July 2008 to March 2023 and were followed up for at least 2 years. Visual analog scale pain scores and Ankle Osteoarthritis Scale pain and disability scores were used to assess functional outcomes. Radiographic union, time to union, complications, and clinical success—defined as pain improvement without the need for revision surgery or amputation—were also evaluated.

Results: The mean follow-up duration after TTC arthrodesis was 79.8 months (range, 26–199 months). Tibiotalar joint union was achieved in 13 ankles (72.2%) at a mean of 7.5 months after TTC arthrodesis. Subtalar joint union was achieved in 7 ankles (38.9%). All functional scores improved significantly from preoperatively to the last follow-up. The overall clinical success rate was 83.3% (15 ankles).

Conclusions: TTC arthrodesis using a retrograde IM nail without subtalar joint preparation produced favorable outcomes in patients with failed TAA. No complications associated with the subtalar joint were observed in any patient during follow-up. Therefore, TTC arthrodesis using a retrograde IM nail without subtalar joint preparation may be a considerable salvage option for failed TAA.

Keywords: *Ankle, Failed total ankle arthroplasty, Tibiotalocalcaneal arthrodesis, Intramedullary nail, Subtalar joint*

Total ankle arthroplasty (TAA) has become one of the most popular surgical options for painful end-stage ankle arthritis, serving as a motion-preserving alternative to ankle arthrodesis. In recent meta-analyses, survivorship of modern TAAs was approximately 90% at intermediate-term follow-up and 80% at long-term follow-up.[1,2] Reported functional outcomes were comparable to those of ankle arthrodesis.[3]

Despite promising TAA outcomes, joint survival rates after TAA remain inferior to those after knee or hip arthroplasty. The most frequent cause of prosthesis failure is aseptic loosening, mainly secondary to periprosthetic osteolysis.[4-6] Other causes include component subsidence, deep infection, and uncorrectable malalignment.[4-6] When prosthesis failure is confirmed, revision TAA or conversion to tibiotalocalcaneal (TTC) arthrodesis is required. However, revision TAA is not always possible because of a severe bone defect, poor soft tissue envelope, or combined hindfoot malalignment. Furthermore, revision TAA is associated with a high risk of failure when deep infection is present.[4] TTC arthrodesis is a viable surgical option for

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failed TAA with significant bone loss and combined hindfoot pathology.[7] Various techniques have been proposed to achieve a stable plantigrade foot and minimize complications after salvage TTC arthrodesis.[8,9]

In our center, we perform TTC arthrodesis using a retrograde intramedullary (IM) nail via the previous anterior incision and without subtalar joint preparation as a salvage procedure for patients with failed TAA. Several authors have described a similar surgical technique, but none have reported the results of this technique exclusively for patients with failed TAA.[10-12] The purpose of this study is to report the clinical and radiologic outcomes of TTC arthrodesis using a retrograde IM nail without subtalar joint preparation for failed TAA. We hypothesized that our technique would result in significant clinical improvements in patients with failed TAA and that subtalar joint preparation is not essential for achieving successful clinical outcomes.

METHODS

This study was approved by the Institutional Review Board of Severance Hospital (IRB No. 4-2025-0177), which waived the requirement for informed consent because of the retrospective study design.

Between July 2008 and March 2023, 21 consecutive patients underwent TTC arthrodesis after failed TAA. The senior author (JWL) performed all procedures at a single center. A straight TTC nail (DLA nail; U&I Corp.) was used for fixation in all patients. Indications for TTC arthrodesis were failed TAA with severe bone defect, especially of the talus. To be included in the final cohort, patients must have been followed up for at least 2 years postoperatively.

Surgical Technique

All procedures were performed under general or spinal anesthesia via a previous anterior ankle incision. Gutter debridement, synovectomy, and polyethylene inlay removal were followed by careful extraction of all metal TAA components to minimize bone loss. Fibrous tissue, metallosis, and necrotic bone were thoroughly debrided. The subtalar joint was not prepared. A fresh-frozen bulk allograft (talus or femoral head) was sized to the defect and impacted. The ankle was aligned in neutral dorsiflexion, 5° hindfoot valgus, and external rotation to achieve a plantigrade foot. Alignment was maintained manually or with temporary K-wires. A guide pin was inserted through a separate plantar incision at the junction of the third ray and anterior-to-middle thirds of the heel pad. Image intensification confirmed proper calcaneal engagement and avoidance of tibial or medial calcaneal wall fracture. Reaming was performed until cortical chatter was observed, then extended 0.5–1 mm beyond the desired nail diameter. The nail was inserted over the guide pin, followed by 2 tibial, 1 talar, and 1 calcaneal interlocking screws for fixation. Residual defects were filled with autologous iliac and allograft chip bone; no bone graft substitutes or osteobiologics were used.

Postoperative Care

All patients wore a below-knee cast and were restricted to non-weight-bearing for 6 weeks postoperatively. After this, partial and progressive weight bearing was permitted while wearing an ankle boot brace for an additional 6 weeks. Radiographs were monitored closely, and if radiologic signs of bone union were not observed, the period of limited weight bearing was lengthened. No patients received adjunctive bone stimulation during the postoperative period.

Radiologic Evaluation

All patients underwent standing anteroposterior and lateral radiographs preoperatively and at each postoperative visit. Union was defined as bridging trabeculae visualized on both the anteroposterior and lateral radiographs.[13] Stable pseudoarthrosis was defined as clinical union despite the presence of radiolucency at the tibiotalar joint, as well as lack of pain while ambulating and the absence of progressive collapse or implant loosening on radiographs.[14] Time to union of the tibiotalar joint and the development of adjacent joint arthritis were recorded. All radiologic findings were reviewed by 2 foot and ankle fellowship–trained surgeons who were blinded to the patient's clinical information (YKY and DWS).

Clinical Evaluation

Each patient's baseline characteristics, such as age, sex, body mass index, and mode of TAA failure, were collected from the electronic medical records. Visual analog scale pain scores and Ankle Osteoarthritis Scale pain and disability subscores[15] were evaluated to assess functional outcomes. These scores were assessed preoperatively; at 3, 6, and 12 months postoperatively; and annually thereafter. Two independent observers (2 registered nurses), blinded to the purpose of the study, assessed functional scores. All postoperative complications and additional surgeries were recorded. Surgical results were classified as either success or failure. Success was defined as achievement of a stable, functional limb with the ability to ambulate without pain,

and included patients with stable pseudoarthrosis.[13,14] Failure was defined as the presence of an unstable and painful nonunion, the development of a deep infection, or the need for below-knee amputation.

Statistical Analysis

The Kolmogorov-Smirnov test was used to assess normality of the distribution of data for each variable. A paired *t*-test was used to assess changes in functional scores from preoperatively to the final follow-up evaluation. All statistical analyses were performed using IBM SPSS software version 26.0 (IBM Corp.). The threshold for statistical significance was a p-value < 0.05.

RESULTS

Patient baseline characteristics are presented in Table 1. Three patients were excluded for not meeting the inclusion criteria of at least 2 years of follow-up without clinical and radiologic signs of failure, leaving 18 patients (and 18 ankles) included in the final analysis. Fifteen primary TAAs (83.3%) and 3 revision TAAs (16.7%) were converted to TTC arthrodesis. The most common mode of TAA failure was progressive periprosthetic osteolysis (15 ankles, 83.3%), followed by deep infection (2 ankles, 11.1%), and malalignment (1 ankle, 5.6%). Two ankles with infected TAA underwent 2-stage conversion to TTC arthrodesis. The mean time from TAA to TTC arthrodesis was 68.8 months (range, 6–304 months), and the mean follow-up duration after TTC arthrodesis was 79.8 months (range, 26–199 months).

Radiologic and Clinical Outcomes

Tibiotalar joint union was achieved in 13 of the 18 ankles (72.2%), and subtalar joint union was achieved in 7 ankles (38.9%) (Figs. 1 and 2). The mean time to tibiotalar union was 7.5 months (range, 3–12 months). Among the 5 ankles with tibiotalar joint nonunion, 2 ankles (11.1%) met the criteria for stable pseudoarthrosis, characterized by the absence of pain during ambulation and no radiologic signs of collapse throughout the follow-up period. Talonavicular joint arthritis developed in 2 ankles (11.1%). All functional scores improved significantly from preoperatively to final follow-up (all p < 0.001) (Table 2).

Complications and Reoperations

The overall complication rate was 38.9% (7 / 18), and the reoperation rate was 22.2% (4 / 18) (Table 3). Three patients (16.7%) had painful tibiotalar nonunion with radiographic signs of collapse. Two of these patients (11.1%)

Table 1. Patient and Surgical Characteristics

Characteristic	Value
No. of patients	18
No. of ankles	18
Type of failed TAA surgery	
Primary TAA	15 (83.3)
Revision TAA	3 (16.7)
Age at TTC arthrodesis (yr)	66.0 (41.0–78.0)
Sex	
Female	14 (77.8)
Male	4 (22.2)
Body mass index at TTC arthrodesis (kg/m^2)	26.0 (19.5–32.9)
Etiology of initial arthritis (pre-TAA)	
Posttraumatic osteoarthritis	10 (55.5)
Degenerative osteoarthritis	3 (16.7)
Inflammatory arthritis	5 (27.8)
Type of TAA prosthesis	
Hintegra	15 (83.3)
Standard component	13 (72.2)
Revision component	2 (11.1)
Salto	2 (11.1)
Unknown	1 (5.6)
Mode of TAA failure	
Progressive periprosthetic osteolysis	15 (83.3)
Aseptic loosening	3 (16.7)
Subsidence of metal component	12 (66.7)
Deep infection	2 (11.1)
Malalignment	1 (5.6)
Time from TAA to TTC arthrodesis (mo)	68.8 (6–304)
Follow-up duration after TTC arthrodesis (mo)	79.8 (26–199)
Type of structural allograft	
Talus	12 (66.7)
Femoral head	5 (27.8)
Talus plus femoral head	1 (5.5)
Height of structural allograft	27.6 (22.2–46.5)

Values are presented as a number (%) or mean (range).
TAA: total ankle arthroplasty, TTC: tibiotalocalcaneal.

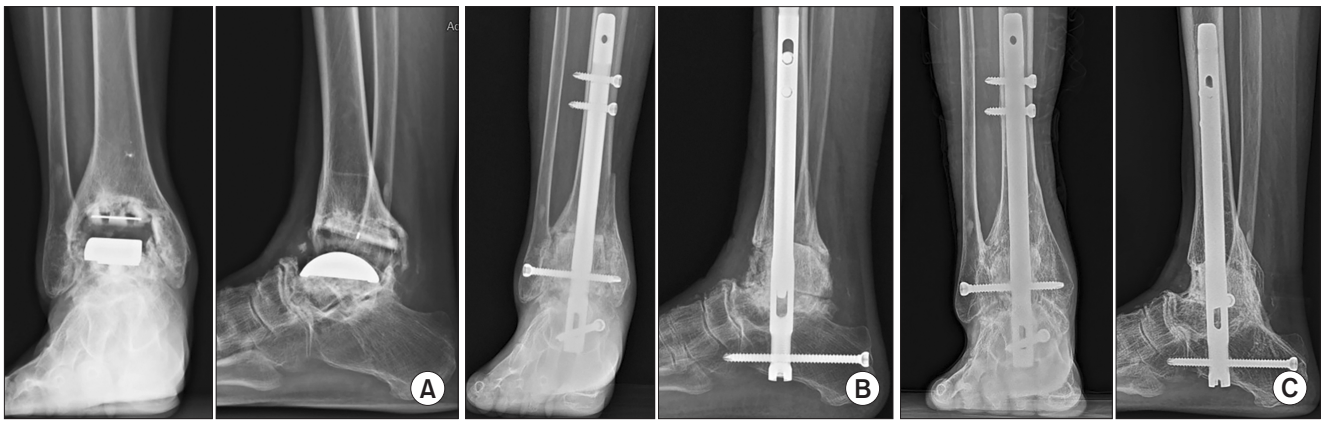

Fig. 1. Radiographs of a 65-year-old woman treated with tibiotalocalcaneal arthrodesis. (A) Preoperative radiograph showing a failed primary total ankle arthroplasty with talar component subsidence. (B) Postoperative radiograph after tibiotalocalcaneal arthrodesis with bulk allograft. (C) Radiograph at 12.7-year follow-up showing complete union of both the tibiotalar and subtalar joints.

Fig. 2. Radiographs of a 60-year-old woman treated with tibiotalocalcaneal arthrodesis. (A) Preoperative radiograph showing a failed revision total ankle arthroplasty with tibial component loosening. (B) Postoperative radiograph after tibiotalocalcaneal arthrodesis with bulk allograft. (C) Radiograph at 3-year follow-up showing complete union of the tibiotalar joint and asymptomatic nonunion of the subtalar joint, without implant loosening or breakage.

Table 2. Clinical Outcomes

Variable	Preoperative	Postoperative	*p*-value*
Visual analog scale pain score	8.8 ± 1.1	2.9 ± 2.2	< 0.001
Ankle Osteoarthritis Scale pain score	60.8 ± 10.4	19.2 ± 14.2	< 0.001
Ankle Osteoarthritis Scale disability score	74.5 ± 5.9	52.4 ± 11.9	< 0.001

Values are presented as mean ± standard deviation.
*Statistically significant at $p < 0.05$.

underwent subsequent revision arthrodesis with plate and screw fixation. One patient achieved union after revision arthrodesis, while the other progressed to a stable pseudoarthrosis without further symptoms. The remaining patient (5.6%) declined further surgical treatment. Three patients (16.7%) had symptoms of hardware irritation, which was managed with entire nail removal (1 patient, 5.6%), calcaneal screw removal (1 patient, 5.6%), or conservative

Table 3. Complications and Reoperations

Variable	Ankle
Complication	7 (38.9)
Symptomatic tibiotalar nonunion	3 (16.7)
Hardware irritation	3 (16.7)
Superficial infection	1 (5.6)
Reoperation	4 (22.2)
Revision arthrodesis	2 (11.1)
Hardware removal	2 (11.1)

Values are presented as number (%). A total of 18 ankles were included in the study.

treatment (1 patient, 5.6%). Superficial wound infection occurred in 1 patient (5.6%) and resolved completely with local wound care and oral antibiotics. No patient developed complications associated with the subtalar joint, had deep infection, or required amputation. The overall surgical success rate was 83.3% (15 ankles).

DISCUSSION

To our knowledge, this is the first study to report the outcomes after TTC arthrodesis using a retrograde IM nail without subtalar joint preparation exclusively in patients with failed TAA. Our results showed that TTC arthrodesis using a retrograde IM nail without subtalar joint preparation in this patient population yielded favorable outcomes. The tibiotalar joint union rate was 72.2%, and the overall surgical success rate was 83.3%. These findings suggest that TTC arthrodesis using a retrograde IM nail is a feasible salvage option for failed TAA with significant bone defects, and that subtalar joint preparation may not be necessary in all cases for achieving satisfactory outcomes.

As the number of TAA procedures continues to increase, the frequency of failed TAA and need for subsequent revision surgery also increase. Recent systematic reviews and meta-analyses revealed intermediate- to long-term revision rates after TAA of 16.0% to 20.5%.[1,4,16] Although revision TAA is a motion-preserving surgical option for failed TAA, it is typically contraindicated in patients with severe bone loss or a history of deep infection, and clinical outcomes are inferior to those of primary TAA in terms of functional outcomes, complication rates, and joint survival rates.[4,17]

TTC arthrodesis remains a viable salvage option for failed TAA with significant bone loss, infection, or intractable hindfoot deformity.[7] In their 2013 systematic review, Donnenwerth and Roukis[8] reported a nonunion rate of 24.2% and a complication rate of 62.3% in 62 failed TAAs treated with TTC arthrodesis using a retrograde IM nail. Gross et al.[9] reviewed 193 salvage arthrodesis procedures and reported an overall union rate of 84% and 71% for TTC arthrodesis, with a mean follow-up of 34.8 months. Jennison et al.[18] later reported a surgical success rate of 92% and a radiologic union rate of 87%. In contrast, a recent national registry analysis showed a 22.1% failure rate after salvage TTC arthrodesis for failed TAA.[19] Another meta-analysis published in 2022, focusing on TTC arthrodesis with structural allograft for large bone defects, reported an overall union rate of 67.4% and a salvage rate of 92.5%.[20]

Compared with previous results, the union rate and success rate observed in this study are satisfactory. Our union rate of 72.2% is lower than that of some recent studies, but the most important goal of salvage arthrodesis is to achieve a plantigrade foot that enables independent ambulation without pain. If the ankle remains stable without progressive collapse or persistent pain during ambulation, this stable pseudoarthrosis can be considered a successful salvage result and simply observed (albeit with careful radiologic follow-up).[13,14,20] Of course, achieving solid union is important and using various osteobiologics may help achieve successful union in complex situations involving massive bone defects surrounded by devitalized scar and necrotic tissue.

The original concept of TTC arthrodesis was to achieve union of both the tibiotalar joint and subtalar joint thorough debridement of all residual cartilage. Several approaches have been used for TTC arthrodesis, including a lateral approach with distal fibular resection, an anterolateral approach extended to the sinus tarsi, an anterior approach with an additional sinus tarsi approach, and a posterior approach. In our technique, we used only the previous anterior incision without an additional sinus tarsi approach for subtalar joint preparation. Most currently available TAA systems were designed to use the anterior approach. In patients with failed TAA, using the previous anterior incision may enable easier thorough debridement of the tibiotalar joint and explantation of TAA components, while minimizing bone loss.

With regard to subtalar joint preparation while performing TTC arthrodesis, various approaches have been described in the literature. Moore et al.[21] reported a 63.2% subtalar nonunion rate in 19 cases treated with or without subtalar joint preparation using a retrograde IM nail; however, all cases were asymptomatic. Dujela et al.[22]

found a 22% nonunion rate in 66 TTC arthrodesis with subtalar preparation, also without symptoms. Similarly, Halverson et al.[23] observed 1 asymptomatic subtalar nonunion in their analysis of 5 patients. Nevertheless, symptomatic subtalar joint nonunion has also been reported. Boer et al.[10] observed a 4% symptomatic nonunion rate in 50 cases without subtalar preparation, all managed conservatively. In their retrospective case series of 30 TTC arthrodesis procedures using a retrograde IM nail without subtalar joint preparation, Gross et al.[11] found a subtalar joint nonunion rate of 26%, with half of the joints requiring reoperation. Mulhern et al.[12] performed TTC arthrodesis without subtalar joint preparation in 40 ankles, only 1 (2.5%) of which required subsequent subtalar fusion for painful subtalar nonunion. Recently, Ozkul et al.[24] compared results of TTC arthrodesis with and without subtalar joint preparation (n = 20 and n = 28, respectively). While tibiotalar fusion rates and mid-term functional outcomes were similar, the non-preparation group showed fewer midterm complications. However, their long-term functional outcomes were inferior. The authors concluded that subtalar joint preparation may be omitted in carefully selected cases. In a prospective study of 20 salvage TTC arthrodesis with nonunion or septic complications, Pessey et al.[25] reported favorable outcomes without subtalar preparation in most cases, suggesting its reliability in high risk patients. Overall, the rate of symptomatic subtalar joint nonunion, especially nonunion severe enough to require reoperation, seems to be low after TTC arthrodesis, regardless of whether subtalar joint preparation is performed. The subtalar joint union rate was 38.9% in our current study, but all patients with subtalar joint nonunion were asymptomatic throughout the follow-up period, even in the intermediate- to long-term. This finding suggests that subtalar joint preparation may not be necessary during salvage TTC arthrodesis using a retrograde IM nail after failed TAA. However, the potential for symptomatic subtalar nonunion or implant failure may impact long-term outcomes, particularly in young and active patients. Therefore, careful patient selection should involve a comprehensive assessment of age, activity level, soft tissue condition, and overall medical status. Patients with failed TAA commonly meet these criteria, which may justify a simplified surgical approach without subtalar joint preparation.

Salvage arthrodesis for failed TAA is a complex, technically demanding procedure that requires a long operation time, compared with primary arthrodesis.[26] Additionally, the results of salvage arthrodesis are inferior to those of primary arthrodesis in terms of both functional outcomes and postoperative complications, such as nonunion and infection.[26] The most important goal of this type of surgery is to achieve a stable tibiotalar joint on the first attempt. This requires preserving the talar bone stock and vascularity around the talus. Previous subtalar arthrodesis is a known risk factor for nonunion following open ankle arthrodesis.[27] Conversely, previous ipsilateral ankle arthrodesis is a risk factor for nonunion after subtalar arthrodesis.[28,29] It has been suggested that disruption of the vascular supply to the talus and the presence of avascular subchondral bone induced by the adjacent joint arthrodesis may impede the biologic potential for union.[27-29] Additionally, the role of subtalar joint fixation in salvage TTC arthrodesis is to anchor the fixation construct onto the calcaneus instead of the talus, rather than directly treating the subtalar joint pathology. Thus, TTC arthrodesis without subtalar joint preparation may have some benefits in terms of simplifying the procedure and preserving the biologic potential for tibiotalar joint union, without increasing the risk of complications associated with the subtalar joint.

This study has some limitations. First, the retrospective design introduces a potential for assessment bias. To minimize this, we used prospectively collected data from consecutive patients and blinded both the senior author (JWL) and 2 independent observers to data collection and clinical scoring. Second, the sample size was small. Third, the follow-up period was heterogeneous. Fourth, union assessment relied primarily on plain radiographs, with computed tomography scans performed only when union status was unclear. Lastly, the study lacked a control group treated with alternative techniques, such as TTC arthrodesis with formal subtalar joint preparation. Future prospective, comparative studies with larger cohorts are needed to identify the optimal salvage arthrodesis method for failed TAA.

In conclusion, TTC arthrodesis using a retrograde IM nail without subtalar joint preparation produced favorable clinical and radiologic outcomes with or without subtalar joint union in patients with failed TAA. No complications associated with the subtalar joint were observed in any patient. Our findings suggest that TTC arthrodesis using a retrograde IM nail without subtalar joint preparation may be a considerable salvage option for failed TAA.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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