Foot and Ankle Surgery 25 (2019) 390–397

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Tibiotalocalcaneal arthrodesis with distal tibial allograft for massive bone deficits in the ankle☆

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ARTICLE INFO

Article history:
Received 10 October 2017
Received in revised form 3 February 2018
Accepted 5 February 2018

Keywords:
Tibiotalocalcaneal arthrodesis
Bone loss
Allograft
Ankle

ABSTRACT

Background: The purpose of this study was to assess the outcomes of distal tibial structural allograft to obtain a stable TTC fusion.
Methods: Retrospectively, ten patients were carried out with a minimum one year follow-up. The median age was 72 (33–81). The median BMI was 28 (24–33). Indications for TTC arthrodesis included failed total ankle arthroplasty (n = 7 patients), prior nonunion (n = 2 patients), and a trauma injury.
Results: Union rate was 80%. The median initial height of the distal tibial allograft was 19 mm (14–24 mm). In seven cases the allograft did not lose height. The AOFAS score median was 69 (31–84). SF-12 median physical component was 39 (30–53), and 59 (23–62) for mental component. The VAS median was 2 (0–8).
Conclusions: TTC using distal tibial allograft shows a lower rate of collapse than other structural grafts and provides a fusion rate higher or in accordance with the literature.
Level of evidence: Level IV, retrospective case series.

1. Introduction

Tibiotalocalcaneal (TTC) arthrodesis in patients with severe deformity and bone loss presents a substantial challenge to successful reconstruction [1–4]. Common indications include posttraumatic osteoarthritis, inflammatory arthropathies, neuroarthropathies, neuromuscular deformities, talar avascular necrosis, nonunion of an ankle arthrodesis, or failed total ankle arthroplasty (TAR) [5]. Options for surgical management of these challenging problems include primary TTC arthrodesis with shortening, talectomy with TTC arthrodesis and extreme shortening, distal fusion with proximal Ilizarov bone transport to restore length, and below knee amputation [6]. TTC arthrodesis with intercalary structural autograft or allograft has been reported in small series in the literature, with fusion rates between 48% and 93% [1–10]. Advantages of this procedure include restoration of limb length and improved soft tissue tension, with resultant preservation of musculotendinous function. Disadvantages of bone block TTC arthrodesis include additional bone interfaces that are required to heal, the potential late collapse of the structural graft, and the fact that the bone block graft either slowly or never fully incorporates into the host [6,11].

The structural graft options most commonly used in TTC arthrodesis with large bone defects are autologous iliac crest [1,3,12–14] and freeze-dried femoral head allograft [4–11,15]. Only Berkowitz et al. [8] reports the use of freeze-dried distal tibial allograft in two out of twelve patients for this procedure (Fig. 1). To our knowledge, this is the largest report using freeze-dried distal tibia structural allograft to obtain a stable TTC without losing limb length. We performed a retrospective review of allograft bone TTC arthrodesis with a minimum follow-up of 12 months in two foot and ankle centers.

2. Materials and methods

We conducted a retrospective patient chart review by two fellowship-trained foot and ankle investigators in two academic institutions to determine patient demographics, preoperative diagnosis, comorbidities, indications, fixation methods, adjuvants used, weightbearing time and functional outcomes in this group of cases. Our objective was to determine the effectiveness of achieving a solid arthrodesis and evaluate complications of TTC arthrodesis with a massive distal tibial allograft. Also, we wanted to analyze the

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https://doi.org/10.1016/j.fas.2018.02.007
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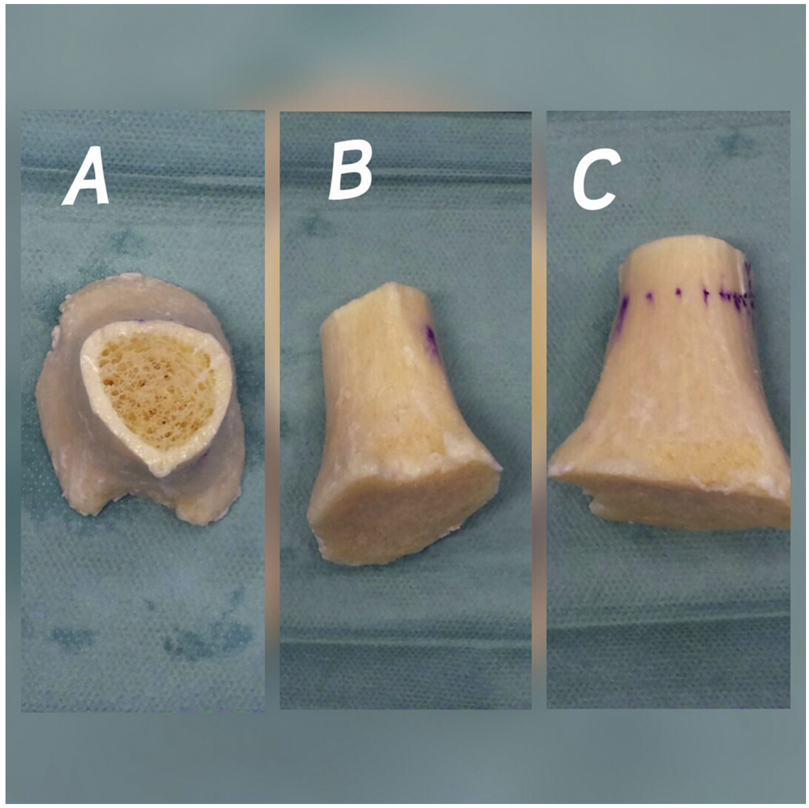

Fig. 1. Freeze-dried distal tibial allograft. Superior (A), lateral (B) and anterior (C) views.

collapse rate of this structural allograft. We hypothesized that our rate would be higher in the nonunion group.

All surgeries were performed by two of the senior authors, with extensive experience in this type of complex procedures, from 2008 to 2016. Inclusion criteria consisted of patients with an allograft bone block TTC arthrodesis using distal tibia, follow-up longer than 12 months, and complete charts and images records. All patients failed nonoperative treatment consisting of non-narcotic pain medication and immobilization in an ankle-foot orthosis designed to limit motion. Patients were excluded if their TTC arthrodesis was performed by any other type of allograft, follow-up was inferior to 12 months or if clinical or radiographic data were unavailable for evaluation. We do not perform allograft bone block TTC arthrodesis in patients with advanced peripheral vascular disease or an ongoing osteomyelitis of the surgical site.

Ten patients met selection criteria for the study. The median age at the time of surgery was 72 (range; 33–81) years. Eight right limbs and two left limbs were reconstructed. There were eight males and two female patients. Median follow-up was 28 (range; 12–87) months. The median body mass index (BMI) was 28 (range; 24–33).

One patient died of other medical condition not related to the surgery. For her, we used the medical records, but we could not obtain a functional evaluation. Indications for TTC arthrodesis using distal tibia structural allograft included failed total ankle arthroplasty (n = 7 patients), prior nonunion of the ankle or subtalar joint (n = 2 patients); one patient had a previously failed TAR conversion to TTC with femoral head structural allograft and the other case a previous TTC fusion without structural allograft in a patient with club foot sequelae. The last case was a gun-shot trauma injury (see Fig. 2). No Charcot neuroarthropathy patients were found in our study. A hindfoot intramedullary arthrodesis nail was used in 5 patients (50%, Fig. 3), with supplemental screws

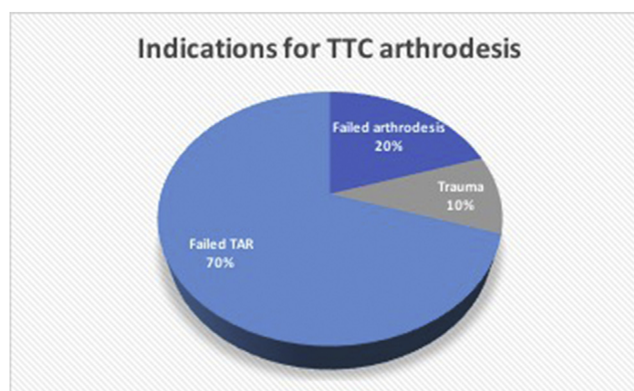

Fig. 2. The graph shows the indications for TTC arthrodesis. The most frequent indication was a failed total ankle replacement.

augmentation in 2 cases. Posterior or lateral plate stabilization was used in 3 cases (30%) and 7.0 mm cannulated screws in 2 patients (20%). Only two patients were smokers, and one developed a nonunion (50%).

Solid arthrodesis was defined by consensus between the two two fellowship-trained foot and ankle investigators after reviewing the surgeon's notes and assessing the radiographs and CT scans. All of our patients had a CT scan to define fusion between 6 months to 1-year postsurgery. Union on the CT scan was defined as bridging trabecular bone on more than 50% of the surface area of the site of arthrodesis. We acknowledge that a successful fusion could be over 25% of the surface area of the fusion as has been proposed recently [16], however we decide to use 50% for comparison with similar studies published [5,6,8].

Fig. 3. A sixty-five years old female who suffered a traumatic ankle arthritis (A and B). She developed a symptomatic TTC non-union (C and D), so revision surgery was performed 18 months later with a R-IMN and a distal tibial allograft. After 1-year follow-up A/P and lateral radiographs (E and F) show a healed and aligned TTC arthrodesis. A CT angiogram shows the pseudoaneurysm and the extensive damage to the right tibialis anterior artery (G). The patient was evaluated and admitted to the operating room for vascular surgery. The tibialis anterior artery was ligated.

2.1. Operative technique

Surgery was performed under spinal anesthesia. The patient was placed in lateral or prone position (depending on the surgical approach). A pneumatic tourniquet was applied to the proximal thigh and inflated. Fluoroscopy was used. In the majority of our patients, we use a lateral trans-fibular approach to the ankle (9/10) taking the distal fibula as an autologous graft in all of our cases. In one patient, we used a posterior approach as described in the literature (see Fig. 4) [5,17,18]. We used a posterior approach given the soft tissue injuries because of the gunshot wound. In most of our cases, the bone stock deficit was due to a failed total ankle replacement (TAR). So, we took out the TAR components, all fibrinous material and necrotic bone were aggressively debrided. Soft tissue samples were taken for culture and histological analysis. The method of preparation of the host bone depended on the condition of host bone. Our goal was to obtain flat saw cuts bleeding cancellous bone in both surfaces. A sample from both surfaces and the allograft were cultured and sent to pathology. Then, we measured the gap between the distal tibia and calcaneus and the distal tibia structural allograft was prepared according to the gap size. The operative procedures differed respect the type of internal fixation according to the surgeon's preference. After the hardware was in place, cancellous bone allograft surrounding the

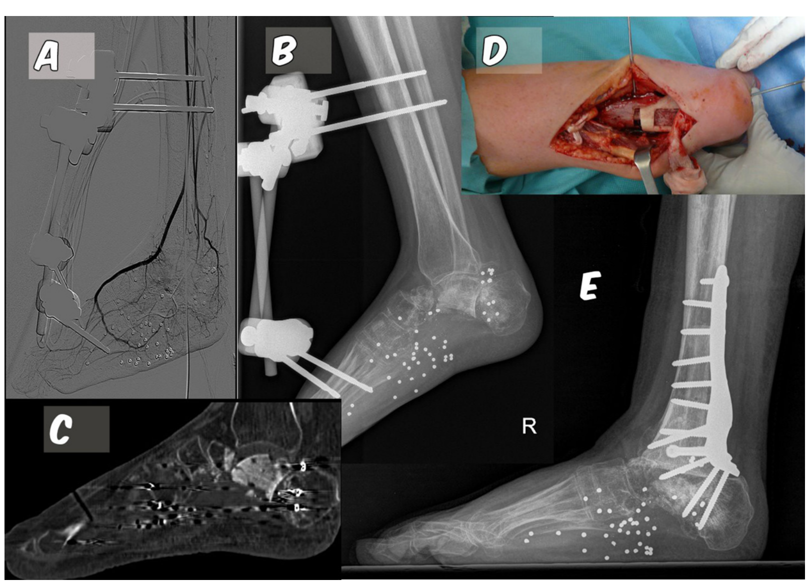

Fig. 4. A thirty-three years old female who suffered a gun shot injury in her right foot. Preoperative images (A and B) reveal a severe bone loss in the hindfoot. CT Scan of the foot that confirms the bone loss and talus damage (C). Intraoperative image that shows the posterior approach and the intimate fit and bony contact of the allograft with the tibia. (E) A 6 months lateral radiograph after TTC fusion with the distal tibial structural allograft.

structural distal tibia allograft was used. We tried to graft fill 50% of the cross-sectional area of the fusion space as suggested by DiGiovanni recently [19]. We did not use any ortho-biologics that potentially could enhance our fusion rate.

Postoperative management included immobilization in a below knee cast for six weeks. Sutures were taken out at three weeks at the clinic. At six weeks, we exchange the cast for a removable boot, but nonweightbearing continue until twelve weeks. After that, a partial weight bearing was allowed

Imagenologic follow-up was done with radiographs. At six months to one year after surgery, we performed a CT scan to ensure that the bone block TTC arthrodesis had successfully fused.

We measured the initial graft height at six weeks post procedure when the first postoperative x-ray was available. The final graft height at one-year post surgery. The measurements were done in the lateral view of the ankle; we measured the height of the graft in the posterior cortex of the tibia and the in the anterior cortex of the tibia. An average of these two distances was considered the graft height.

Patients were revised in the outpatient clinic when we performed a Visual Analog Scale (VAS), AOFAS Hindfoot score, and SF-12 score. We compared our SF-12 scores with age-matched United State population controls given the lack of pre-operative SF-12 scores in our patients. Also, we asked the patients if they would recommend this procedure to a relative or a close person.

Descriptive analysis was first conducted. Median and range are reported for continuous variables, while the frequency is reported for the qualitative variables. To compare between the fusion and the nonunion group non-paired test for medians was used for continuous variables. Fisher exact test was used for dichotomic variables and chi2 for nominal variables. Probability obtained (p) and test used is reported in each table for every comparison. A significance level of 0.05 was established. All analyses were performed using Stata v11.2 (StataCorp LP, College Station, Texas, USA).

2.2. Ethics

The study has been approved by the Relevant Ethical Review Board and was performed according to the declaration of Helsinki. All patients signed an informed consent to participate in this investigation.

3. Results

The union rate was 80% (8/10), with two patients developing a nonunion. Both patients had a clinically stable pseudoarthrosis. One patient was doing his activities of daily living without complaints; another patient was managing reasonably well with an ankle-foot-orthosis (AFO). None of them wanted further surgery. No statistical differences were found between the fusion and nonunion group in relation to age, Diabetes Mellitus, arterial hypertension, BMI > 30, the presence of distal pulses and neuropathy. Results are detailed in Table 1.

The median initial height of the distal tibia allograft used was 19 (range; 14–24) mm. There was no difference between the fusion group and nonunion group regarding initial height of the allograft (see Table 1). In seven cases the allograft did not lose height, all of them from de fusion group. The distribution of graft collapse percentage by group is shown in Fig. 5. Only two cases had a major graft collapse, defined by the authors as a difference between initial and final allograft height superior to 25%. Both were in the nonunion group (Table 2).

Regarding our functional outcomes, the AOFAS Hindfoot Scale median was 69 (range; 31–84). SF-12 health survey was administered to nine out of 10 cases (one deceased case). The physical component was 39 (range; 30–53) and the median mental component was 59 (range; 23–62). The mean SF-12 physical component for the general US population between 40–79 years is 48.762 and 50.8 for the mental component [20]; seven patients were above US population in mental component and two in the physical component. Eight out of nine patients would undergo surgery again if they could choose again and they would recommend this procedure to a close related family member. The visual analog scale (VAS) median was 2 (range; 0–8). The difference between fusion and nonunion group are summarized in Table 3 and Fig. 6.

Table 1
The analysis between fusion and nonunion groups in relation to patient risk factors, surgical approach and fixation type.

	Fusion (n = 8)	Non-union (n = 2)	*P*
Patient factors			
Median age	72 (34–80)	57 (33–81)	0.99[a]
Smoker	1 (13%)	1 (50%)	0.38[b]
Mellitus diabetes	1 (13%)	0	0.80[b]
Neuropathy	0	0	N/A
Present distal pulses	8 (100%)	2 (100%)	N/A
Arterial hypertension	3 (38%)	1 (50%)	0.67[b]
BMI > 30	1 (13%)	2 (100%)	0.07[b]
Approach			
Lateral	7 (87%)	2 (100%)	
Posterior	1 (13%)	0	0.80[b]
Fixation			
Intramedullary nail	3 (38%)	0	
Plate	2 (25%)	1 (50%)	
Screw	1 (13%)	1 (50%)	
Nail + screw	2 (25%)	0	0.44[c]
Graft			
Initial height	19 (16–24)	18 (14–22)	0.79[a]

[a] Non paired test for median difference.
[b] Fisher exact test.
[c] Pearson Chi^2 test.

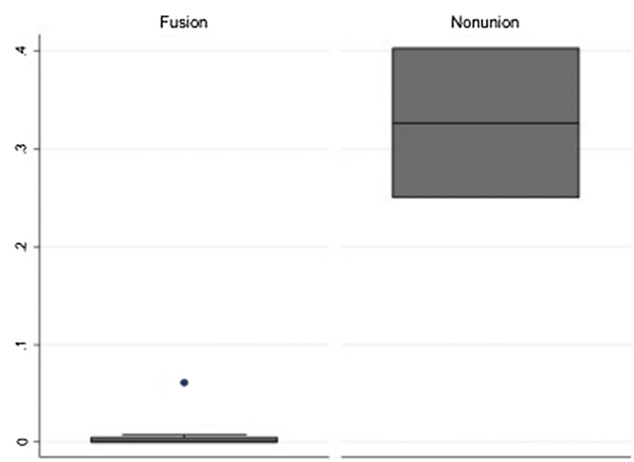

Fig. 5. The graph shows the percentage of graft collapse between two groups. It is calculated ((initial height – final height)/initial height) × 100.

Table 2
The association of allograft height loss regarding the union and nonunion group.

	Union (n = 8)	Nonunion (n = 2)	*P*
No loss height	7 (88%)	0	
Loss height	1 (13%)	2 (100%)	0.07[a]
Significant collapse (>25%)	0	2 (100%)	0.02[a]

[a] Fisher exact test.

Table 3
Functional scores at one-year follow up by group.

Scale	Fusion	Nonunion	*p*
SF12 mental	60 (53–61)	38 (23–62)	0.47[a]
Over US population	4(100%)	1 (33%)	0.14[b]
SF12 physical	38.5 (34–53)	42 (30–51)	0.99[a]
Over US population	1 (25%)	1 (33%)	0.71[b]
AOFAS hindfoot scale	73.5 (63–84)	53 (31–71)	0.16[a]
VAS scale	1 (0–3)	5 (2–8)	0.11[a]

[a] Non paired test for median difference.
[b] Fisher exact test.

3.1. Complications

Only one patient had a wound dehiscence problem that healed with a vacuum assisted closure (VAC) without any signs of osteomyelitis. One patient developed a pseudoaneurysm of the tibialis anterior artery (see Fig. 3). The diagnosis was made at the outpatient clinic two months postsurgery. The patient was evaluated and admitted to the operating room for vascular surgery. The tibialis anterior artery was ligated due to extensive damage. No further problems were observed with this patient. Another patient developed a regional complex syndrome due to damage to the superficial peroneal nerve that was managed with oral drugs and physical therapy with a satisfactory outcome (see Fig. 7).

We did not find any culture or bone biopsy positive in our cases. Also, we did not have any below knee amputation as a complication in any of our patients.

4. Discussion

The use of allograft bone to fill bone defects dates back to the early 1900s [21]. The first long-term follow-up evaluation showed that these grafts were partially replaced and incorporated by the host [22]. Allografts provide the form and matrix of bone tissue, but no viable cells are transplanted. In addition, bone allografts are incorporated into the host more slowly than bone autografts, and they can induce an immune response, which may delay the osteoinductive phase of bone-graft incorporation [23]. The allograft revascularization is very slow, and large, incompletely filled osteons are still present in the graft three years after graft implantation [24]. Large osseous defects in the foot and ankle can be classified as either medullary or segmental [11]. Medullary defects that have a shell of viable cortical bone can be filled with graft. Segmental defects have substantial loss of cortical and cancellous bone, so they do not contain nonstructural graft material [11]. These defects are a challenging problem because the surgeon must decide whether to shorten the defective limb or restore the limb to a more anatomic length using structural grafts.

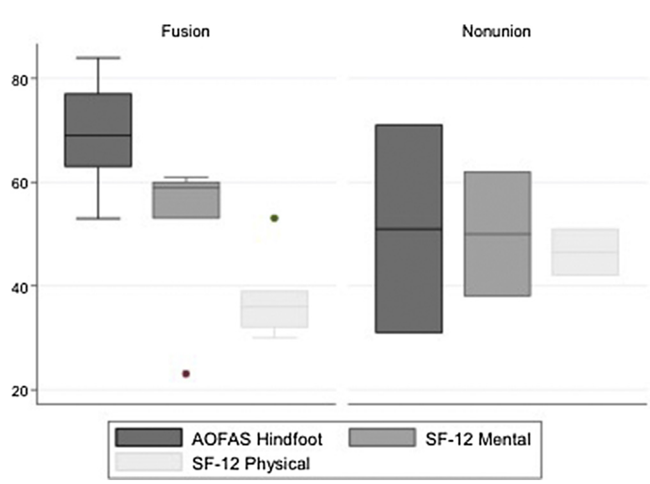

Fig. 6. The graph shows the distribution of three functional outcomes between fusion and nonunion group.

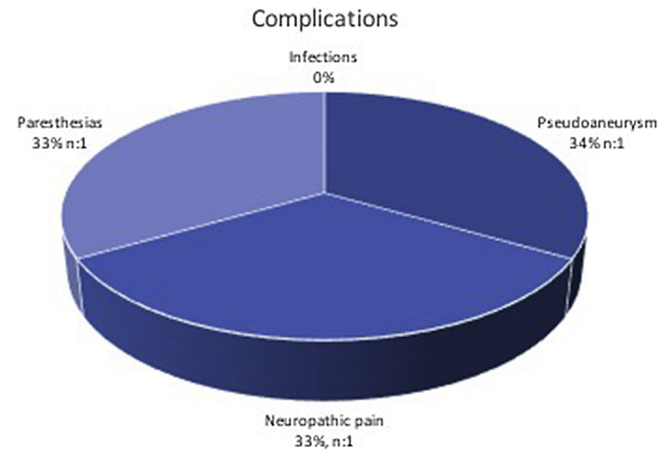

Fig. 7. The graph shows the surgical complications after TTC arthrodesis. It is important to notice that no infection is reported in this case series.

TTC and the use of structural allografts as salvage attempt in the lower extremity has been described [4,6,8,11,22,25–28]. Bussewitz et al. [7] described the use of femoral head allograft and a retrograde intramedullary nail (R-IMN) to treat large deficits in complex combined hindfoot and ankle reconstruction. The fusion rate in 25 patients was 48% with a 16% of major amputations. Jeng et al. [6] reported a 50% fusion rate in 32 patients treated with bone block TTC arthrodesis using femoral head allograft and fixation with R-IMN, plates or external fixation. All diabetic patients did not heal and six below knee amputations (BKA) were reported. Schill [14] reported on a series of 15 infected total ankle replacements that were revised to a TTC interposition arthrodesis using tricortical iliac crest or fibula graft with an intramedullary nail with a 93% successful fusion rate. Thomason and Eyres [10] described a technique using femoral head allograft and an intramedullary nail to treat failed total ankle replacements in three patients. Giza et al. [15] published a case report of a single patient with a failed ankle fusion revised to a bone block TTC arthrodesis with femoral head allograft. Hopgood et al. [12] presented a mixed group of 23 failed total ankle replacements treated with either isolated tibiotalar arthrodesis with screws, TTC arthrodesis with screws, or TTC arthrodesis with a rod. All patients were fused by acutely shortening the limb with direct apposition of the bone ends. No bulk allograft was used in any patient. Fusions rate in the TTC groups (15 patients) was 60% (see Table 4).

To our knowledge, only Berkowitz reports the use of distal tibial allograft as a bulk structural allograft for TTC arthrodesis [8,9]. Berkowitz described 12 patients with failed ankle replacements treated by TTC arthrodesis using femoral head or distal tibial allograft with a 58% fusion rate and good functional scores according to AOFAS-Ankle/Hindfoot score and Maryland Foot Score. Berkowitz used only two fresh frozen distal tibia allograft in his publication.

We present ten cases treated with a savage TTC using distal tibial allograft. This report has the largest number of patients using this technique in the literature. Berkowitz et al. [9] described the use of distal tibial allograft. In his opinion, this allograft has the potential for intimate fit and bony contact and may decrease the need for additional bone grafting and minimize the risk of nonunion. However, he states, significant time and attention are necessary to achieve this intimate fit and this graft may also require special procurement, because it is not routinely available in

Table 4
Rate of fusion among the different studies in the literature.

Papers	Year	N	Distal tibia	Structural graft used	Fixation method	Union rate
Escudero	2018	10	Yes	Distal tibia allograft, autologous fibula	Plates, R-IMN, screws	80%
Pellegrini	2016	15	NO	Femoral head allograft	Plates, R-IMN, screws	80%
Bussewitz	2014	15	No	Femoral head allograft	R-IMN	48%
Jeng	2011	32	No	Femoral head allograft	Plates, R-IMN, external fixation	50%
Berkowitz	2011	12	Yes[a]	Femoral head, distal tibia allograft	Plates, R-IMN, screws	58%
Giza	2010	1	No	Femoral head allograft	R-IMN	100%
Thomason	2008	3	No	Femoral head allograft	R-IMN	100%
Schill	2007	15	No	Autologous iliac crest, autologous fibula	R-IMN (femoral)	93%
Hopgood	2006	15	No	No	10 R-IMN, 5 screws	60%

[a] Only 2 cases.

most hospitals in United States [9]. We agree that a distal tibial structural allograft provides an intimate fit and bony contact compared to a femoral head allograft. Additionally, its conical structural shape gives intrinsic stability to the construct, so allograft collapse and fracture rate are lower (Fig. 8). To our knowledge, only Jeng et al. [6] measure the allograft difference between initial height and final height in the group of patients with an established fusion. The authors did not explain their method to measure the allograft height in their publication [6]. Our loss of allograft height in the fusion group is lower than Jeng study [6] (0.8 vs 3.6 mm). Another important topic regarding allografts choice is that they are weak during revascularization, and the mechanical properties of the bone graft may be affected by preservation techniques [29,30]. We believe that an allograft that has more structural bone and provides a better fit, it is biomechanically stronger than a mostly cancellous bone allograft like the femoral head. We only find two major collapsed grafts during the follow-up period of our study. In both cases, a nonunion of both surfaces of the allograft occurred. For us, contrary to Berkowitz, the procurement of distal tibial allograft is realized routinely. Also, it is cheaper and has a higher availability than femoral head allograft in our province bone bank.

Our fusion rate (80%) is in accordance (or even higher) to the fusion rates reported in the literature [1–6,8–10]. Our fusion rate could be enhanced because we only had one diabetic and none Charcot-neuroarthropathic patient. Jeng et al. [6] and Bussewitz et al. [31] report a higher number of patients with diabetes or Charcot-neuroarthropathy. In Jeng et al. [6] study, the only factor that significantly correlated with the outcome was the presence of diabetes. None of the nine patients with a diagnosis of diabetes mellitus fused radiographically in their report [6]. However, another factor that could decrease our fusion rate is that we didn't use any ortho-biologics in our cases.

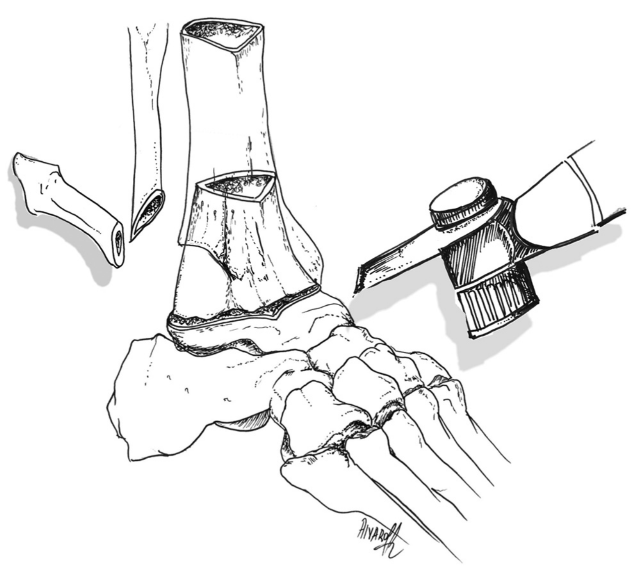

Fig. 8. A diagram that shows how the distal tibial structural allograft provides an intimate fit and bony contact with the host bones. Its conical structural shape gives intrinsic stability to the construct and a lower collapse rate.

Another concern with the use of structural allografts, although rare, is the transmission of infection. An audit of an English bone bank [32], showed an 18% contamination rate of allografts. In their study, one out of nine large allografts that were implanted was complicated by a clinical infection [33]. Sommerville et al. [34] reports a 22% contamination rate in femoral head allografts. James et al. [35] published a 9% positive cultures in 4045 femoral head allografts. The most common organism cultured was a coagulase-negative staphylococcus in both studies. James et al. [35], at a minimum follow-up of one year, concluded that there was no statistically significant difference in the rate of complications of age-matched patients whose femoral heads had a positive culture compared with those whose femoral heads were sterile. We take at least two tissue samples for culture and one for bone biopsy from all our allografts as routine, following the specific protocols in our hospital and Tissue Bank of our country. We did not find any contamination in our 10 cases. We think the use of allografts is a safe option given the low rate of contamination and deep infection reported in our cases and other studies [35,36].

Regarding the type of fixation in our TTC fusions, we mostly used a retrograde nail with or without additional "miss-a-nail" screws. We performed mostly a lateral approach using the fibula as an autologous graft. Two patients developed a nonunion of the ankle and subtalar joints. We did not find any differences regarding the type of fixation or surgical approach as has been suggested in recent studies (see Table 1) [25]. However, our small cohort of cases does not allow us to draw a definite conclusion. We acknowledge that biomechanical stability, maintenance of alignment, and reproducible and meticulous operative techniques should enhance outcomes of TTC fusion. O'Neill et al. [37] demonstrated in a cadaver study that the addition of 1 supplemental screw to a TTC arthrodesis performed with an intramedullary nail significantly increases stiffness and load to failure of the construct when compared to intramedullary nailing alone. Also, some biomechanical studies have highlighted the superiority of plates constructs to intramedullary fixation without an augmentation screw for TTC arthrodesis [38,39]. Therefore, we are now favoring using plates or a retrograde IMN, both with a TTC supplemental screw, as an important step in our surgical technique.

Regarding our complications, we had one superficial infection (10%) and no deep infection. Our wound and dehiscence complications are comparable with what has been reported in the literature for TTC arthrodesis (5–17%) [5,40–42]. We did not have any BKA probably because of the low rate of infection. This outcome could be influenced by the presence of only one diabetic patient and one traumatic case in our cohort of patients. We did have a rare complication as a pseudoaneurysm of the tibialis anterior artery (Fig. 3). There is scarce of literature regarding the incidence of this complication, and it is mostly related to ankle arthroscopy and Lisfranc injuries [43–45]. This complication occurred in one patient that already have a previous surgery on her ankle with a large quantity of cicatricial tissue in the soft tissue envelope around the ankle. After its diagnosis, vascular surgery managed this complication. Interestingly, the clinical and imageneological outcomes of this patient were not affected by this complication.

The SF-12 physical scores for the patients were lower than US age-matched norms except for two patients. This is not surprising considering the clinical outcomes found in other TTC arthrodesis studies that report complaints of limb shortening, pain, limp, and difficulty with walking on uneven terrain [3,5,6,8,26,28,46,47]. Interestingly, one of the patients above the US matched norms had a stable pseudoarthrosis; this may indicate that a nonunion of an allograft TTC arthrodesis may not result in a complete clinical failure as has been suggested by some authors [6,9,31]. Seven patients (70%) had a SF-12 mental component score higher than US age matched norms. This trend is the same found by Jeng et al. [6] and is probably related to the fact that all except-one of the patients stated that they were better off than before the surgery.

Finally, seventy percent of our cases (7/10) are TAR failure. This percentage is not rare given the TAR resurgence due to better and successful outcomes in the last decades [48–52]. When a TAR failure occurs, the decision between revision TAR or salvage arthrodesis (SA) is not clear in the literature. There is no accepted algorithm on how to choose [3]. A recent review of the Swedish Ankle Registry of TAR revision showed low prosthesis survival and patient satisfaction rates [53]. The same authors compared SA against revision TAR in TAR failure cases of the Swedish Ankle Registry; the only statistically significant differences between both groups were the higher age, lower incidence of post traumatic arthritis and the lower reoperation rate of SA compared to revision TAR. Based on their data, Kamrad et al. [3] favor the SA for TAR failure. Given our results, the use of distal tibia allograft is a viable option for SA (tibiotalar or TTC fusion) with large segmental bone defects in a TAR failure case.

Our study has several limitations. First, it is retrospective, lacks a comparative group, and fixation technique was exclusively dependent on surgeon's preference. Also, it involved a small number of patients given the relative infrequency of these conditions. A prospective and well controlled study is difficult because of the limited number of patients requiring this type of intervention. We were unable to identify preoperative patient reported functional outcomes, which hindered any functional comparison. However, postoperative functional outcomes were acceptable and comparable to the current literature available and US matched-age population. Regarding the strengths of our publication, the fusion rate was determined by CT-Scans in all of our cases. CT-Scan is more reliable than radiographs to determine hindfoot arthrodesis [16,54]. Also, this is the largest study regarding the use of distal tibial allograft as an alternative for TTC fusions with large bone defects. Lastly, according to our findings, the distal tibial allograft has a lower bone collapse than femoral head allograft with rates of union and complications at least comparable to the reported in the literature.

5. Conclusions

TTC fusion with the use of distal tibial allograft as a one stage procedure is a reliable treatment option for patients with an extensive bone defect in the ankle due to failed ankle replacement, avascular necrosis, prior infection severe trauma and probably to Charcot-neuroarthropathy. The freeze dried distal tibial allograft shows a lower rate of collapse than other structural grafts and provides an intimate fit and bony contact that enhance the construct stability.

Conflict of interest

The authors declare no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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