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Review

Unipolar allograft reconstruction for post-traumatic avascular necrosis of the distal tibia: A review of the literature, technique, and case series

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ABSTRACT

Background: Avascular necrosis of the distal tibial plafond following ankle trauma is an underreported and potentially devastating phenomenon. Beyond conservative treatment options, surgical intervention has been limited to ankle arthrodesis, which sacrifices motion and may have longterm sequellae for adjacent hindfoot joints. Total ankle replacement has been historically contraindicated. Unipolar allograft reconstruction provides an option for joint salvage. We present a literature overview, implantation technique, and two cases utilizing matched unipolar distal tibial allograft.
Methods: Two younger patients underwent distal tibia allograft reconstruction for tibial plafond collapse due to post-traumatic avascular necrosis. They were followed to assess for clinical improvement and radiographic graft subsidence.
Results: Both patients returned to work and activity. One patient had no graft subsidence at four years, but the other patient became symptomatic with graft subsidence at one year.
Conclusions: Distal tibia allograft reconstruction can be utilized as a joint salvage surgery for post-traumatic avascular necrosis with collapse of the tibial plafond in younger patients that prefer an alternative to arthrodesis. Results may be mixed and necessitate an engaged, activated patient.
Level of evidence: IV.

Contents

1. Introduction

Avascular necrosis of the distal tibia is a known phenomenon following severe trauma to the ankle. It has been associated with higher energy injuries and Weber C fractures, but its true incidence

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is likely severely underreported [1–4]. This diagnosis may be missed entirely by treating physicians or incorrectly labelled as post-traumatic osteoarthritis. The etiology of this condition is not clear and is unknown why it occurs with some injury patterns and not in others. It is theorized that avascular necrosis in the distal tibia may occur secondary to a vascular insult from the initial injury and a subsequent increase in intraosseous pressures. If the area of bony necrosis is large enough and located close enough to the joint surface, the distal tibial plafond can subsequently collapse and devastating destruction of the tibiotalar joint can result. The associated morbidity can be severe and result in chronic pain, dysfunction, and inability to rejoin the work force. The diagnosis carries a poor prognosis and often necessitates intensive reconstructive surgery [5].

If avascular necrosis develops and collapse occurs, the ankle's normal alignment can be disrupted and lead to inappropriate force distribution throughout the joint. This necessitates surgical reconstruction to reestablish the weightbearing anatomy of the lower extremity and decrease patient morbidity. Treatment for an avascular, collapsed tibial plafond has been generally limited to ankle arthrodesis. Historically, avascular necrosis has been a relative contraindication for total ankle arthroplasty due to its reliance on bony ingrowth into porous implants and these patients are often young and active and not ideal for an ankle replacement [6]. Arthrodesis provides reliable outcomes for endstage tibiotalar arthritis. It is frequently recommended for young laborers due to the longevity of the operation and its reliable results [7,8]. No literature exists for this specific diagnosis, but it is reasonable to generalize these expectations. Despite this, many patients are hesitant to proceed with an ankle fusion for misconceptions of the functional limitations of a fusion. This is often misguided as Brodsky et al. recently demonstrated significant improvement in gait following ankle arthrodesis and even an increase in overall sagittal motion at one year [9]. Accordingly, we believe that arthrodesis remains an excellent option; however, ankle arthrodesis in a relatively young patient is not without consequence.

Ankle arthrodesis has been shown to have a correlation with adjacent arthrosis of the hindfoot [7,10,]. New total ankle replacement implants and techniques show promise and may have functional benefit over fusion, but replacement is currently not an ideal option for isolated avascular necrosis of the tibia as it relies on bony ingrowth of healthy vascularized bone [11]. A potential option for this condition is allograft reconstruction with a matched distal tibia osteochondral allograft. The authors present an overview of utilization of distal tibial osteochondral for tibial plafond collapse secondary to avascular necrosis including techniques and a case series of two patients treated with allograft at our institution.

2. Materials and methods

2.1. Distal tibial allograft reconstruction

2.1.1. Patient selection

Distal tibial allograft monopolar reconstruction is indicated only in a select patient population. In a young patient with subacute post-traumatic avascular necrosis of the tibial plafond that has gone on to collapse, this procedure theoretically allows preservation of ankle motion and can restore the anatomy of the tibiotalar joint and its threatened avascular bone stock. Thorough radiographic evaluation of a patient is mandatory for accurately confirming this diagnosis. After routine weightbearing radiographs, both CT and MRI scans our helpful in identifying this diagnosis. MRI is necessary for making the diagnosis. Pathopneumonic MRI findings for avascular necrosis include diffuse edema of the tibia, focal serpentine lines with an outer dark sclerotic appearance with central inner bright signal (on T2), and osteochondral fragmentation. Other etiologies for persistent pain after fracture are imperative to rule out, including malreduction of the fracture, missed injury (i.e. anterolateral impaction injury), infection, or more standard post-traumatic arthritis.

Unipolar allograft transplant is a technically demanding operation that requires thoughtful planning and requires a patient that understands the graft matching process and expectations for outcome. The patient must be engaged and understand this will likely not be the last operation on their ankle joint. Despite lack of published evidence, it should be advised they may require further surgery at a later date including possible conversion to a replacement or arthrodesis. The long-term results of such a procedure remain unknown. If the patient is willing to sacrifice ankle motion and prefers the most reliable definitive treatment in a single surgery, then ankle arthrodesis may be a better option.

Relative contraindications for this procedure would include older, sedentary patients that could not tolerate a prolonged period of immobilization and non-weightbearing. Remote infection, extensive medical comorbidities including diabetes and peripheral vascular disease would also be a deterrent for this operation. An acute infection would be an absolute contraindication for such a procedure, nor should this procedure be performed in the setting of an acute injury or with a poor soft tissue envelope. It should not be performed in a patient with substantial talar disease. The degree of pre-existing talar disease that could lead to a poor outcome has not been elucidated. Because the results of bipolar allograft reconstruction are not encouraging, we recommend ankle arthrodesis (or possible replacement in older patients) if bipolar disease is present [12–14].

2.1.2. Planning for allograft transplantation

Planning for a matched tibial allograft reconstruction requires extensive preoperative discussions over the risks and benefits. The authors recommend repeat discussions to accurately outline expectations and ensure all of the patient's questions can be answered and for the surgeon to verify their understanding. If the patient elects to proceed with this joint salvage operation, adequate anterior–posterior, mortise, and lateral ankle radiographs are imperative. If significant malalignment is present, full-length standing anteroposterior radiographs can be considered. In the setting of post-traumatic avascular necrosis, computed tomography (CT) is required of bilateral lower extremities for evaluation of the extent of avascular necrosis, bony union of the fractures, presence of bony cysts and to assess the status of the talus. The contralateral ankle study is necessary for anatomical matching of the distal tibial allograft.

Once a match is identified, the surgeon is notified and the reconstructive surgery must be performed within a reasonable time period considering graft shelf life (typically within one week). The surgeon must decide which approach to the necrotic segment of distal tibia to utilize. Often removal of pre-existing hardware is required. Prior operative reports and implant records should be obtained prior to surgery. This can also impact the surgical approach required. If necessary, a staged removal is not unreasonable to consider. This can be especially helpful if there is any suspicion of subclinical infection. Cultures can be sent from deep tissue and confirm absence of any infection prior to an allograft implantation.

Prior to surgery, the preoperative CT scan should be reviewed thoroughly to outline the size and location of the defect. This is vital for planning an approach that allows exposure of the entire articular surface and access to perform the reconstruction. Thorough review of the patient's length and alignment are critical. In the setting of malunited ankle fractures, the fibula may be short

or there may be a tibial nonunion. These issues may need to be addressed simultaneously.

2.1.3. Allograft details

The allograft matching process is performed commercially utilizing tissue banks that analyze CT measurements of the length and width of the patient's contralateral tibia matched to the allograft. A graft from tissue banks is typically considered "fresh" if it is harvested and aseptically processed from the donor within 24 h of procurement and is often implanted within 1 week [15–18]. Osteochondral allograft success is enhanced by maintaining biologically viable cartilage which can be dependent on storage techniques [19]. Many studies have shown chondrocyte viability is best preserved when stored at 4 °C and in the correct nutrients. Chondrocyte survival is relatively stable up until 14 days and decreases overtime with another noticeable decrease at 28 days in some studies [19–22]. Pearsall et al. reported osteochondral allograft chondrocyte viability of 67% at 44 days [18]. Mickevicius et al. noted allograft cartilage samples stored at 4 °C to have higher chondrocyte viability and proteoglycan distribution, lower apoptosis, and nearly normal electromechanical properties up until a threshold of 28 days [20]. The authors recommend the standard implantation within 1 week or less.

2.1.4. Allograft implantation technique

Following the receipt of a matched donor, the patient is scheduled promptly for surgical reconstruction. Prior to induction of anesthesia, the surgeon should confirm directly with the commercial representative that the sterilized, matched allograft is present in the hospital and ready for implantation.

The patient should be positioned on the operative table as needed for the desired approach. Typically, this would be in the supine position with an adequate bump under the ipsilateral hip. If a direct lateral approach is to be used, a bean bag can be used to position the patient in the lateral decubitus position. The authors strongly recommend having the preoperative CT scan available in the operative room for reference. A nonsterile tourniquet is applied to the thigh and the patient prepped and draped in a standard sterile fashion. After a timeout to confirm the correct patient, extremity, and procedure, the leg is exsanguinated the tourniquet inflated.

The approach decided upon preoperatively is utilized. The authors employed a standard anterior approach between the tibialis anterior and extensor hallucis longus tendons in Patient A and a direct lateral approach with a fibular osteotomy was performed in Patient B (detailed below). Removal of any deep implants is performed as necessary. Once this is performed, exposure of the tibiotalar joint is performed methodically to allow complete visualization of the entire joint surface. The talar side of the joint should be thoroughly evaluated for any focal articular defects. Preoperative imaging can usually identify significant lesions, but significant disease is a contraindication for a unipolar allograft. Neither patient in this series had a focal, full thickness cartilaginous lesion on the talus despite subacute articular disease. The avascular segment of tibia is identified and confirmed fluoroscopically. This segment is excised with a combination of an oscillating saw and osteotomes. The surrounding, remaining bone can be perforated with a drill to encourage vascularization.

The excised tibia can be used as a guide to make a cut on the matched allograft (Fig. 1). Because some subsidence of the graft can be anticipated, slightly upsizing the graft is recommended. The joint can be overstuffed if the graft is made too large. Therefore the surgeon must make this intraoperative decision to balance oversizing and the possibility of graft subsidence. We recommend slightly oversizing the graft to avoid problems with anticipated subsidence. The graft is then impacted into place. Length, alignment and anatomic joint congruence is confirmed clinically and fluoroscopically. Kirschner wires are helpful for temporary fixation until final position is acceptable. Once the surgeon is satisfied with graft position, permanent fixation is placed to rigidly secure the graft. Any temporary wires should be removed. Final confirmation of alignment and position of the graft and hardware are performed.

Adjunctive procedures can be considered to aid graft incorporation. Supplemental external fixation can help maintain length and increase stability. However, this technique carries the risk of pin site infection and external fixators are typically not tolerated well by the patient. Pins should be carefully placed adequately distant from the incision and the joint to prevent contamination and infection risk. This technique provides the added benefit of holding the ankle joint in neutral with the use of pins in the foot. Another adjunctive procedure to help maintain length is a formal fusion of the syndesmosis. This can be performed to maintain length and act as a rigid strut for the tibiotalar joint. The joint surfaces should be prepared with a curette and/or osteotomes and any cartilage should be denuded to bleeding bony surfaces. Fixation across the syndesmosis is dictated on a patient specific basis depending on the location of the defect, but should include multiple points of fixation and quadricortical purchase.

2.1.5. Postoperative protocol

Postoperatively patients should be non-weightbearing in a splint or external fixator with suture removal once the incisions are healed. The authors recommend continued immobilization for a total of six weeks in a cast or external fixator to allow incorporation of the graft and protection of any accidental weightbearing. At this point, gentle range of motion is recommended to prevent ankle stiffness. Weight-bearing status is slowly progressed around twelve weeks, with careful monitoring for consolidation of the graft and pain improvement. Once fully weightbearing, formal physical therapy should be initiated to specifically work on gait, strengthening, and range of motion. If there is any concern of grafting healing due to pain or swelling then the ankle should be re-immobilized. Graft incorporation with creeping substitution can be monitored on radiographs or with CT scan per surgeon discretion.

2.2. Case series

2.2.1. Patient A

A 20 year old female suffered a left pilon fracture in a motor vehicle collision and was treated with an open reduction and internal fixation by an outside surgeon two months prior to presentation in our clinic. She complained of continued pain, swelling, and inability to bear weight. She had taken leave from school and was out of work secondary to this disability.

Her medical history included polycystic ovary disease and depression, for which she took metformin and escitalopram. She reported occasional alcohol use, but denied tobacco products. At the time, she was a fulltime student in the process of applying for formal training in physical therapy.

On physical exam, the patient was unable to bear weight on her operative extremity. She had noticeable edema about the ankle without any erythema, fluctuance, or drainage. Her previous surgical incision on the posterolateral ankle was well-healed. There was varus malalignment of the ankle joint. She had pain with passive dorsiflexion of the tibiotalar joint. Radiographs at that time showed a malaligned ankle joint with no evidence of healing of a comminuted distal tibial pilon fracture (Fig. 2-I).

Given her age and relative acuity of the fracture, revision fixation was performed to attempt to better align the joint. Her immediate post-operative course was unremarkable; however,

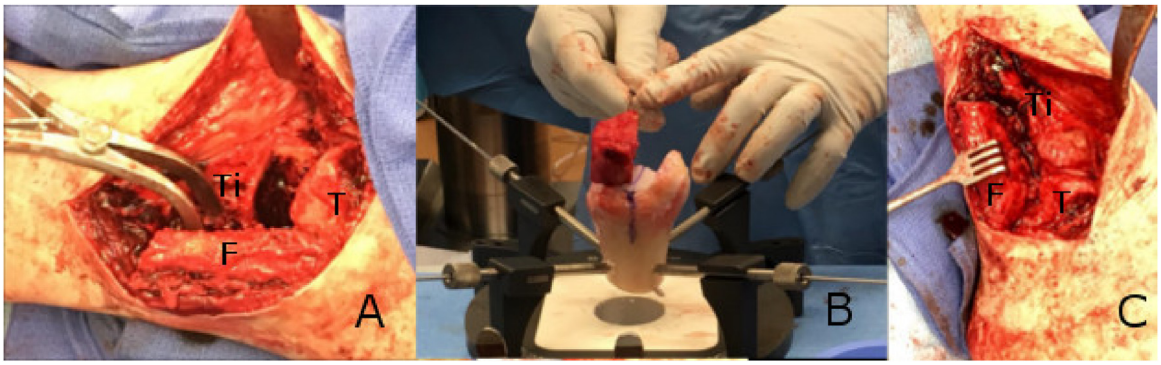

Fig. 1. Intraoperative photographs of the ankle for Patient B revealing the tibia (Ti), talus (T), and fibula (F) after fibular osteotomy and removal of the necrotic distal tibia segment (A). Photograph B shows the excised distal tibia segment with measurement of the matched distal tibial allograft. Photograph C shows the allograft inserted between the tibia and talus prior to fixation.

Fig. 2. AP (IA), mortise (IB), and lateral (IC) ankle radiographs of a 20 year old female who presented with persistent pain and deformity after surgical intervention with another surgeon with little consolidation at the fracture site. AP (IIA), mortise (IIB), and lateral ankle radiographs (IIC) after revision open reduction internal fixation with collapse and avascular necrosis of the distal tibia.

fixation failed and her ankle collapsed into varus as the medial distal tibial plafond developed avascular necrosis (Fig. 2-II). With collapse of her medial plafond and a poorly aligned ankle, further reconstruction surgery was discussed. Due to her age, a total ankle arthroplasty was not a reasonable option. Because the talar side of the joint was currently spared, matched distal tibial allograft reconstruction was considered. Accordingly, we had a lengthy discussion about ankle arthrodesis versus matched distal tibial allograft reconstruction. Ultimately, the patient agreed to pursue matched distal tibia allograft reconstruction in the hopes of restoring alignment and bone stock to her ankle joint. It was stressed that this may require further reconstruction, but carried the potential benefit of maintained motion and the option of future joint replacement remains.

Supplemental external fixation was employed in Patient A, as demonstrated in the 2 week post-operative films (Fig. 3).

2.2.2. Patient B

A 41 year old male sustained a Maisonneuve-type ankle fracture dislocation while dancing. He underwent open reduction and internal fixation by an outside surgeon. Following rehabilitation, he continued to have lateral ankle pain, stiffness, and difficulty weightbearing. He presented for consultation at our clinic nearly one year after injury.

He had no prior medical history, reported occasional alcohol use and denied use of tobacco products. He worked as a commercial real estate manager and enjoyed hiking.

On physical exam, he had diffuse edema about the ankle with tenderness on the lateral aspect of his ankle. His ankle range of motion was from neutral to forty degrees of plantarflexion. He had a well-healed lateral incision without fluctuance, erythema, or drainage. His presenting radiographs are shown in Fig. 4-I. These demonstrate inadequate failed fixation with malreduction of the ankle mortise and sclerosis of the distal tibial plafond. It was decided to proceed with revision fixation. Postoperatively, the patient had a slow recovery and had difficulty progressing with weightbearing. At 6 months post-operatively, he noted worsening anterolateral pain. Radiographs revealed failure of fixation, valgus collapse, and avascular necrosis of his anterolateral tibial plafond (Fig. 4-II).

At this point, the patient's tibiotalar joint was incongruent and survival of the ankle joint was threatened. After failing conservative optimization, reconstructive surgery was discussed. Due to poor healthy bone stock, young age, and a relatively localized degenerative process, total ankle replacement was not recommended. The patient elected to proceed with allograft reconstruction to restore alignment and attempt to regenerate bone stock. If successful, total ankle replacement could become a more viable option in his future.

In this patient, we elected for an adjunctive syndesmotic arthrodesis to act as a strut to maintain length. Syndesmotic fixation was utilized with multiple points of fixation and quadricortical purchase as referenced previously in this patient (Fig. 5).

3. Results

Functionally, Patient A continued to improve with time and physical therapy. At 10 months, she was able to ride a bicycle and had 5° of active dorsiflexion and 30° of plantarflexion. At 4 years she had lost some dorsiflexion (slightly below neutral) due to anterior spurring at the tibiotalar joint and a chronic Achilles contracture. She had a hard block to dorsiflexion that did not improve with knee flexion. She elected to undergo an open debridement of anterior tibial spurs and an open posterior capsular release and Achilles lengthening greater than four years out from

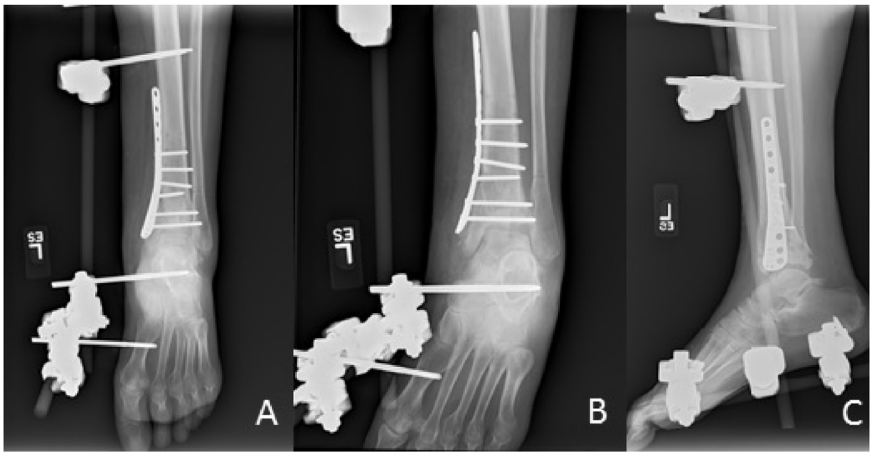

Fig. 3. Postoperative AP (A), mortise (B), and lateral (C) ankle radiographs at two weeks after allograft fixation and external fixation for Patient A.

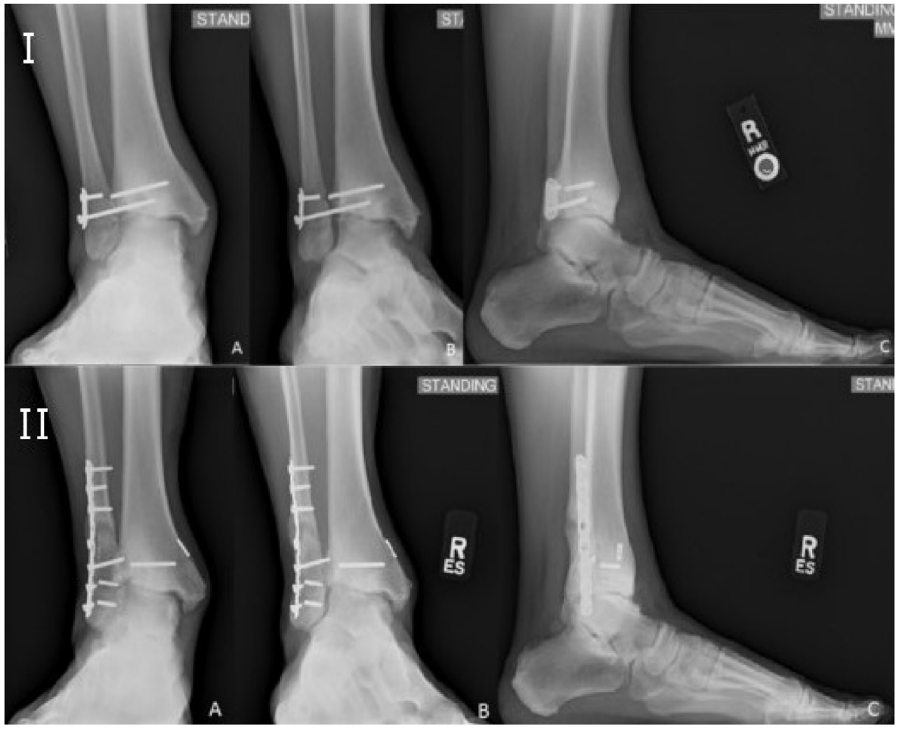

Fig. 4. Presenting radiographs of a 41 year old male who underwent open reduction and internal fixation of a Maisonneuve ankle fracture at an outside institution with AP (IA), mortise (IB), and lateral (IC) ankle views. Also, AP (IIA), mortise (IIB), and lateral (IIC) ankle radiographs following revision open reduction internal fixation and subsequent collapse of the tibial plafond secondary to avascular necrosis.

Fig. 5. Intraoperative radiographs for Patient B demonstrating distal fixation of the allograft and restoration of the articular surface (A), more proximal fibular osteotomy with fixation (B) and a lateral view of the ankle (C).

her original grafting procedure. Following this procedure, the patient maintained a 20° arc of motion at the tibiotalar joint six months after debridement. She completed her physical therapy education program and had begun work as a physical therapist. Immediate postoperative and follow-up radiographs (10 months and 4 years) are shown in Fig. 6.

The syndesmosis fused well for Patient B, but as weightbearing progressed, some settling of the graft was observed (Fig. 7). Despite this, the patient tolerated weightbearing and he continued to improve functionally. He was able to return to work and was playing golf at six months. However, as he increased his activity, he began to have some diffuse ankle pain and stiffness. He did opt for a corticosteroid injection at his one year visit with intermittent as needed non-steroidal anti-inflammatories. His radiographs (Fig. 8) reveal subsidence of the graft compared to previous follow-up. This subsidence could likely represent failure to fully incorporate the graft. Ultimately, the authors started to have discussions regarding total ankle replacement and arthrodesis with the patient which he currently does not desire due to high activity level that would prevent him from adhering to a strict post-operative protocol. Despite his progressive collapse of the graft, the patient maintained a 30° arc of motion at the ankle in the sagittal plane at his sixteen month follow-up visit.

4. Discussion

Avascular necrosis of the distal tibia following trauma can be a devastating phenomenon for a young, active patient. It can lead to tibiotalar collapse and premature arthritis and pain. Use of a matched distal tibial allograft for this condition is a technically challenging operation that can be offered to a young, relatively active patient that is adamant against an arthrodesis. Our results in this case series are not excellent, but these patients have managed to return to work and attempt to get back to activities they enjoy.

This series of two patients demonstrates what we believe are realistic expectations for this condition. An ankle arthrodesis clearly presents a more definitive treatment and will likely give a more reliable result. The authors believe that this surgery requires an engaged patient that can voice full understanding of the risks and expectations of the procedure which we believed these two patients illustrated.

The literature regarding allograft transplantation to the ankle is limited because this procedure has narrow indications. Most of the literature arises from a single institution. Kim et al. reported a 42% failure rate in 7 patients treated with bipolar allograft reconstruction for post-traumatic ankle arthritis [13]. In 2003, Tontz et al. reported promising results of allograft reconstruction for ankle arthritis, though only one of the 11 patients had a unipolar tibial allograft [23]. After a technique adjustment, Meehan et al. reported 5/11 failures in total ankle allograft replacement at 33 months [14]. In a follow-up study, Bugbee et al. reported on the results of 88 bipolar fresh osteochondral allografts in patients with tibiotalar arthritis. Despite a 29% rate of "clinical failure", reported patient satisfaction was high (92%) [12]. All of these series were published from the same institution and were mostly bipolar allografts for endstage arthritis, not specifically post-traumatic avascular necrosis with collapse of the tibial plafond.

There are minimal series of allograft reconstruction performed outside of that institution. Jeng et al. reported 51.7% survivorship of bipolar allograft replacement at two years for ankle arthritis [24]. Similar to the aforementioned studies, the average patient age was 41 and the etiology of their endstage arthritis. The authors of this series concluded that this procedure be strictly limited to very young patients and those that refused arthrodesis.

It is difficult to compare these reports to our case series. It is possible that bipolar transplant could have better articular congruity and could perhaps be better than a unipolar allograft. However, it would be difficult to justify performing a bipolar allograft on a patient with only unipolar disease. Unipolar allograft

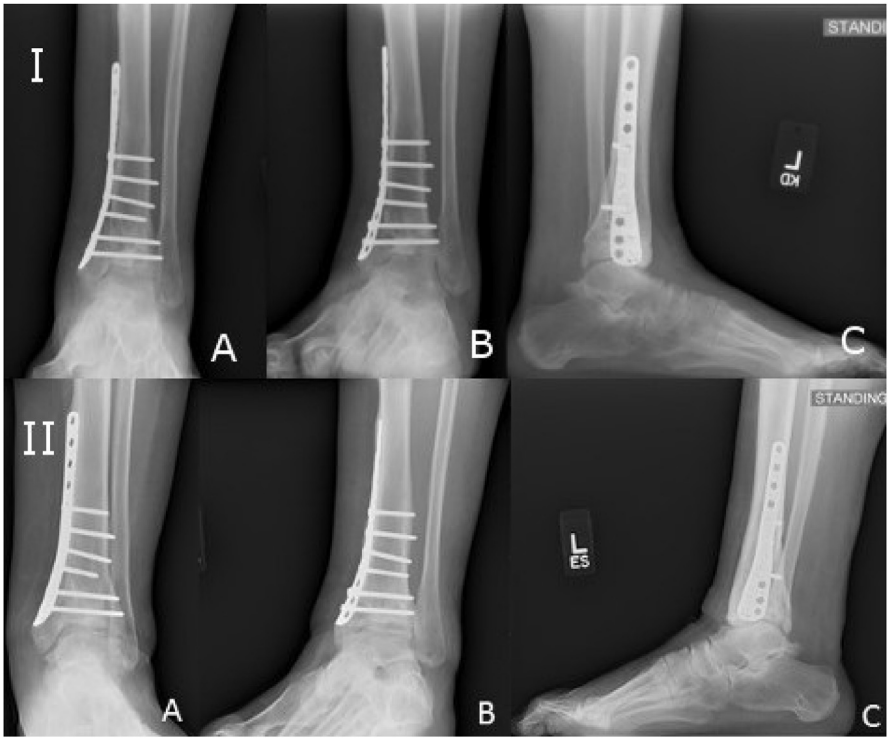

Fig. 6. AP (IA), mortise (IB), and lateral (IC) ankle radiographs of Patient A at 10 months post-operative showing incorporation of the allograft, and AP (IIA), mortise (IIB), and lateral (IIC) ankle radiographs at 4 years post-operative. There is joint space narrowing but no evidence of graft subsidence.

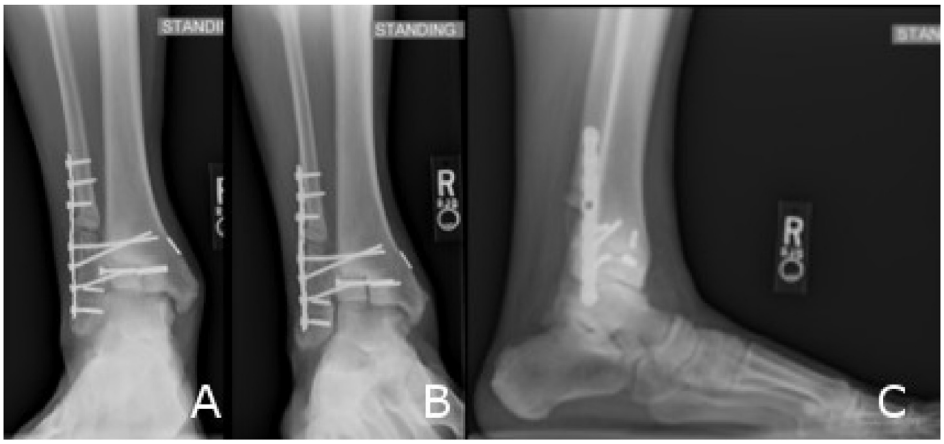

Fig. 7. AP (A), mortise (B), and lateral (C) ankle radiographs of Patient B at 5 month postoperative. Note the successful arthrodesis of the syndesmosis and stable settling of the tibial allograft.

Fig. 8. AP (A), mortise (B), and lateral (C) ankle radiographs of Patient B at 1 year postoperative with subsidence of the graft.

reconstruction requires a significant dependence on accurate matching based on preoperative CT scans to find a near perfect match the native talus. It also requires meticulous technique to contour and fixate the graft to have a congruent surface.

Avascular necrosis in the ankle more commonly impacts the talus and spares the tibial plafond [25]. Reports of unipolar talus allograft reconstruction have generally been favorable with survivorship reported between 66 and 100% [26–30]. Patients with osteochondral lesions (OCLs) have been treated with osteochondral allografts with inconsistent results [31]. Haene et al. report midterm outcomes treating large talar lesions with osteochondral allografts with good/excellent results in 10/16 patients [32]. Gross et al. reported 9 patients treated with osteochondral allograft, and 6 grafts remained in situ with a mean survival of 11 years, and 3 required fusion due to failure of the graft [28]. Another study of 12 patients treated with allograft for talar OCLs showed 3 grafts with radiolucencies, four with edema, one with failure of incorporation, and none with subsidence [33].

In addition to osteoarthritis and osteochondral lesions, the use of allograft reconstruction has also been employed for other distal tibial pathology involving young patients with distal leg tumors [34–36]. However, there are no specific reports on the use of distal tibial plafond fresh allograft osteochondral reconstruction for post-traumatic avascular necrosis.

A common concern for patients (and physicians as well) when undergoing this procedure is the risk for an immune response to the graft. We did experience subsidence of our graft in one patient, which possibly is related to failure of the bone to incorporate. A possible etiology for failure of graft incorporation would be an immune response to the foreign graft. Interestingly, a histologic evaluation of failed osteochondral allografts did not demonstrate any evidence of graft rejection. The histologic review revealed that transplanted cartilage can survive up to seven years and there were various degrees of host bone incorporation and bony necrosis [37]. There are no reports in the literature of a true immune rejection to an allograft or late sequalae due to a graft rejection immune response. As such, the authors do not recommend any use of immunosuppressive therapy.

Another concern when performing bony allograft transplant procedures is the risk of the development of rhesus immunization. In the literature, there are case reports of the development of rhesus antibodies following allograft procedures. In these cases, rhesus negative patients seroconverted to rhesus positivity following allograft transfer [38–41]. With a myriad of bone graft procedures performed routinely, this occurrence has been limited to case reports, but surgeons should be aware of this possibility. Rhesus immunization carries potential risk for future pregnancies or blood product transfusions. Accordingly, attempts should be made to match rhesus compatibility when performing allograft transplantation. Female patients of child-bearing age that undergo allograft transplantation should mention this to their obstetrician as part of their routine patient intake history if they become pregnant. Rhesus immunization screening is routine and

complications from this rare issue can be avoided with appropriate precautions.

Patient selection is crucial for utilization of a matched distal tibial allograft for treatment of post-traumatic avascular necrosis of the distal tibia. One aspect of this selection process involves patient engagement and inviting the patient to be an active, informed participant in the decision making process. Empowering patients through patient activation – having knowledge, skills, and confidence to manage one's health – has been shown to improve a broad range of health related outcomes [42].

Another consideration is the price for an allograft in an increasingly cost-conscious healthcare model, especially since an arthrodesis may be an eventual outcome regardless of treatment with the allograft. The cost may be worth it for desired functionality or to delay surgery, such as a total ankle replacement, for a few more years.

A potential benefit of a matched tibial allograft is the future ability to more safely perform a total ankle arthroplasty. Avascular necrosis has been a historic contraindication for arthroplasty due to relying on healthy vascular bone to grow into the prostheses. When performing this allograft procedure, the devitalized bone is excised. Even without complete graft incorporation, the bony anatomy can potentially be restored with the hope of new, healthy vascularized bone that could tolerate future total ankle replacement. It would be the surgeon's hope that the allograft would incorporate and provide years of functional relief, but it is our expectation that the joint will ultimately fail and require further reconstruction. Although Patient B in our case series experienced continued pain, stiffness, and subsidence of the graft, he still has arthrodesis and now total ankle replacement as alternate treatment plans. Regardless of the timing of failure of this procedure, the procedure can allow for restoration of the bone stock and alignment of the joint.

No literature exists regarding the conversion of distal tibia allograft to total ankle arthroplasty. There are case reports of talar avascular necrosis treated primarily with total ankle arthroplasty. Lee et al. reported good ankle function in two patients with end stage ankle arthritis and talar avascular necrosis treated with total ankle arthroplasty following revascularization of the talus [43]. Also, de Sousa et al. presented a case of post-traumatic avascular necrosis of the talus treated with hybrid ankle prosthesis with good clinical results [44]. A benefit of the distal tibia allograft transplantation may be excision of the necrotic bone to allow for improved revascularization prior to total ankle arthroplasty. We hope more viable bone is present than necrotic bone after the reparative phase of the allograft, which heals by creeping substitution [45]. After transplantation, future imaging can be performed to assess the vascularity of the graft and the possibility of conversion to total ankle arthroplasty.

There are obvious limitations of our case series as it is difficult to gather any definitive conclusions from two patients with limited follow-up. Further follow-up of our patients is needed to evaluate for continued survivorship of the graft and tibiotalar joint function. In addition, a potential goal of this procedure is motion preservation. We did see osteophyte formation and decreased motion with time in one of our patients that necessitated surgical intervention. More formal gait analysis could be performed on patients in the future to accurately quantify tibiotalar motion before and after such a procedure. More studies with monopolar osteochondral allografts for the distal tibia are needed to evaluate for long-term outcomes of this method. Further epidemiologic review of the true incidence of distal tibial avascular necrosis following ankle trauma is warranted in order to increase awareness of its occurrence and potentially lead to early recognition and possible prevention of collapse.

5. Conclusion

Distal tibia allograft reconstruction can be utilized as a joint salvage surgery for post-traumatic avascular necrosis with collapse of the tibial plafond in younger patients that prefer an alternative to arthrodesis. Results may be mixed and not reliable, but the surgery may provide the ability for future conversion to total ankle replacement if some revascularization can occur. The authors urge caution and thorough discussions with patients about expectations and goals of this procedure. Patient selection and involvement are important considerations to optimize patient outcomes.

Conflict of interest

The authors have no conflicts of interest.

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