Particulated Juvenile Articular Cartilage Allograft Transplantation With Bone Marrow Aspirate Concentrate for Treatment of Talus Osteochondral Defects

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Abstract: Osteochondral defects (OCDs) of the talus are potential sequelae of traumatic ankle injury and chronic ankle instability. Conservative treatment may fail thus requiring surgical intervention. Primary surgical intervention has classically entailed bone marrow stimulation, which may include drilling, microfracture, and/or abrasion arthroplasty, filling in the defect with fibrocartilage. Clinical data has revealed good short-term success but the long-term effects and follow-up have been questioned. Newer techniques, such as osteochondral autograft transfer, fresh osteochondral allograft transfer, and autologous chondrocyte implantation, have shown initial promise in restoring physiological hyaline cartilage but each procedure carries increased morbidity as arthrotomy, osteotomy, or a second procedure are often necessary. Juvenile articular cartilage allograft transplantation has shown initial promising results in treating smaller sized OCDs and restoring physiological hyaline cartilage without the increased morbidity of osteotomy or 2-step procedures. Augmentation with biological adjuncts has been shown to further aid in healing and regeneration of physiological articular cartilage. The purpose of this article is to describe a novel surgical all-arthroscopic technique for transplantation of juvenile articular cartilage allograft augmented with bone marrow aspirate concentrate for the treatment of OCDs.

Level of Evidence: Diagnostic Level 4. See Instructions for Authors for a complete description of levels of evidence.

Key Words: osteochondral defect, BMAC, DeNovo cartilage, arthroscopic repair

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HISTORICAL PERSPECTIVE

Osteochondral defects (OCDs) of the talus are frequent sequelae of traumatic ankle injury and chronic ankle instability. Ankle sprains in the general population are common with approximately 2,000,000 injuries occurring every year in the United States.[1,2] A total of 10% to 30% of all acute ankle sprains may have persistent disability and possible OCDs.[3] Damage to the articular cartilage of the talus may also occur in cases of chronic lateral ankle instability, distal fibular fracture, and deltoid ligament tear.[4–6]

Conservative treatment options, such as rest, physical therapy, ankle bracing, and glucocorticoid injections, should be utilized initially as some patients may experience temporary symptomatic relief. But, these injuries create a difficult clinical problem for orthopedic surgeons because the poor blood supply and limited healing potential of articular cartilage makes conservative treatment options frequently ineffective.[7–9] Used techniques include bone marrow stimulation, osteochondral autograft transfer, fresh osteochondral allograft transfer, and matrix-induced autologous chondrocyte implantation.

Primary surgical treatment has classically involved bone marrow stimulation techniques, including microfracture, drilling, and abrasion arthroplasty, which attempt to fill in the OCD with fibrocartilage by promoting an inflammatory response and formation of a fibrin clot within the defect. Although this technique is low-cost, technically undemanding, and minimally invasive, the resulting fibrocartilage scar may degenerate with time because the intrinsic characteristics of the repair tissue are more akin to disorganized type-I cartilage as opposed to the type-II cartilage composing articular cartilage.[10,11]

Tissue transplantation techniques, both osteochondral autograft transfer and allograft transfer, are amenable options when primary bone marrow stimulation fails for treating larger lesions. Unfortunately, these procedures carry a high risk of associated morbidity as malleolar osteotomy may be necessary to access the surgical site and transplant the graft. Both procedures also demand a high level of skill to properly size and position the graft to restore congruency to the articular surface. Osteochondral autograft transfer requires harvesting one or more osteochondral plugs, often from the knee, which can result in donor-site morbidity.[12] Allograft transfer carries its own unique disadvantages including high-cost, limited availability, and a theoretical risk of disease transmission. Although these techniques replace the defect with hyaline cartilage, the associated morbidities are significant.

Matrix-induced autologous chondrocyte implantation is an attractive option because it allows the transplantation of cultured chondrocytes to restore normal hyaline cartilage to the damaged articular surface. However, a 2-stage procedure is required to harvest the chondrocytes, grow them in culture, and implant them to repair the OCD. There is also a potential for overgrowth of the chondrocytes at the site of implantation.

New techniques and technologies have emerged that avoid the morbidities of current surgical approaches.[13–16] The DeNovo NT Graft (Zimmer Inc., Warsaw, IN) is an off-the-shelf, prepackaged allograft of particulated juvenile articular cartilage from the patella of donors below 13 years old, more often below 2 years old. The juvenile chondrocytes in the implant demonstrate a higher metabolic activity level, a higher cellular density, and a greater potential to regenerate hyaline-like cartilage.[9,17–20] Each package is marketed to repair an OCD up to 2.5 cm^2 in size. In practice, this technique is not routinely used for treating lesions larger than 1.5 cm^2. This method of repair is a single-step procedure that may eliminate the need for osteotomy because the particulated nature of the allograft allows the entire procedure to be performed arthroscopically.

Furthermore, recent literature has begun to expound the beneficial effects of biological adjuncts used in conjunction with surgical repair for OCDs.[21] Bone marrow aspirate

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concentrate (BMAC) obtained from centrifugation of bone marrow aspiration contains high concentrations of platelets, growth factors, and mesenchymal stem cells.[22] In vivo models have demonstrated that BMAC combined with surgical repair of OCDs results in better healing of cartilage injuries than surgery alone.[23,24] Also, the repair tissue is composed primarily of type-II cartilage that more closely resembles the natural physiological articular cartilage.[23]

The purpose of this article is to describe a novel surgical technique using an entirely arthroscopic approach for treating OCDs with juvenile particulated articular cartilage allograft augmented with BMAC. This is the first published article detailing an all-arthroscopic technique using both juvenile particulated articular cartilage allograft and BMAC to treat an OCD of the talus.

INDICATIONS AND CONTRAINDICATIONS

The indications for surgical treatment of patients with an OCD are expanding as technologies and techniques continue to improve. A patient diagnosed both clinically and radiographically with a symptomatic OCD that has failed conservative treatments is an ideal candidate. Furthermore, patients that have failed surgical treatment with bone marrow stimulation techniques are also good candidates for surgery. The shelf-life of the DeNovo NT graft is 49 days from the start of processing. Should the intraoperative assessment of the OCD be contrary to the preoperative assessment and dictate that juvenile particulated articular cartilage allograft implantation is not warranted then the product can be stored and utilized for another patient so long as the packaging is not disturbed.

Arthroscopic treatment with particulated juvenile allograft transplantation augmented with BMAC is contraindicated in patients with diffuse osteoarthritic changes of the ankle that render the ankle inaccessible by arthroscopy. Cystic bony components underlying the articular cartilage are not an absolute contraindication as bone grafting from the calcaneus or iliac crest are possible options for intervention. Transchondral talus fractures with talar impaction or depression, kissing lesions, global osteoarthritis, and active infection are all contraindications for this surgery. No specific guidelines for the maximum size of an OCD that can be treated with this technique have been established. Bone marrow stimulation techniques have shown poor clinical outcomes for lesions >1.5 cm^2 but the DeNovo NT graft is marketed to treat lesions up to 2.5 cm^2 per package.[25]

PREOPERATIVE PLANNING

Patients are evaluated clinically with a history and physical examination before pursuing imaging studies. The temporal nature of the injury must be established to segregate acute from chronic injuries. Mechanical symptoms, such as clicking, locking, or experiences where the ankle "gives out" should be documented. Ligamentous laxity based on the anterior-drawer test and talar-tilt test must be compared with the contralateral ankle. A diagnostic and therapeutic intra-articular injection of anesthetic and corticosteroid can also be helpful in delineating the injury.

Imaging techniques include plain radiographic films, anteroposterior and lateral stress x-ray with the Telos Stress Device (METAX, Hungen, Germany), computed tomography (CT), and magnetic resonance imaging (MRI). Plain radiographic mortise, anteroposterior, and lateral views of the ankle help to establish initial staging of the lesion and define general ankle morphology, alignment, and diffuse arthritic changes. Lateral and anteroposterior stress x-ray images provide baseline objective data categorizing ligamentous stability of the ankle and help decipher if further surgical intervention is necessary to restore the lateral soft tissue integrity of the ankle. Surface cartilage lesions are best identified with MRI (Figs. 1, 2). Coinciding soft tissue injuries are also easily assessed with MRI. Cystic bony lesions underlying the articular cartilage are best evaluated with CT imaging. The dimensions of cystic bony components are better established with CT imaging as MRI can often overestimate the size of the lesions due to enhancement of surrounding bony edema.[26]

TECHNIQUE

The patient is placed on the operating table in a supine position with a pneumatic tourniquet applied to the proximal thigh. After induction of general anesthesia and nerve block, the patient is prepped for bone marrow aspiration, identifying the anterior superior iliac spine as the anatomic landmark. Approximately 60 mL of blood is aspirated through the anterior superior iliac spines using a bone marrow needle. Redirecting of the needle is encouraged to prevent withdrawal of the entire venous blood. The bone marrow aspirate is then prepped and concentrated in the Magellan Autologous Platelet Separator (Arteriocyte Medical Systems, Cleveland, OH) to yield approximately 3 mL of BMAC.

At this point, depending on the preoperative identification of any bony defects in the talus below the articular cartilage, bone graft harvest of the iliac crest or calcaneus is performed. The decision to harvest bone graft from the iliac crest or calcaneus is based on the size of the bony defect and the degree of cystic change in the talus. For smaller defects measuring <1 cm in depth, bone graft is taken through the Jamshidi Bone

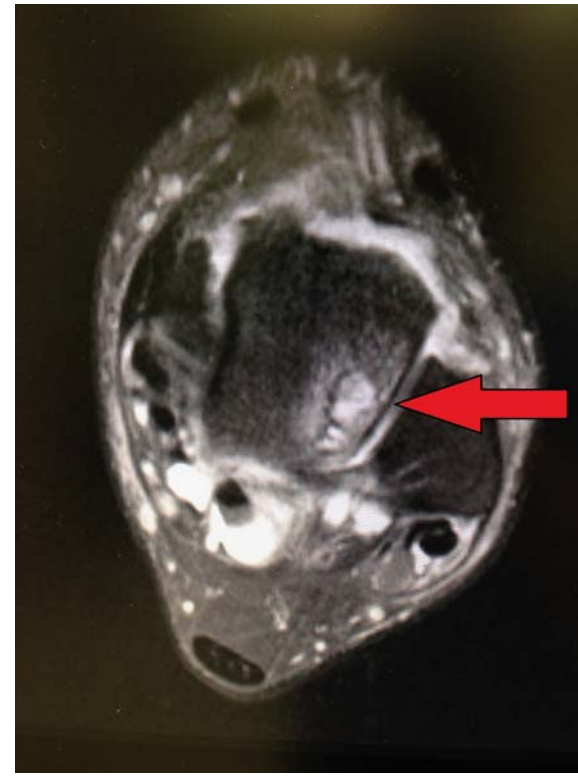

FIGURE 1. T2 axial magnetic resonance imaging of the ankle with osteochondral defect (arrow) identified.

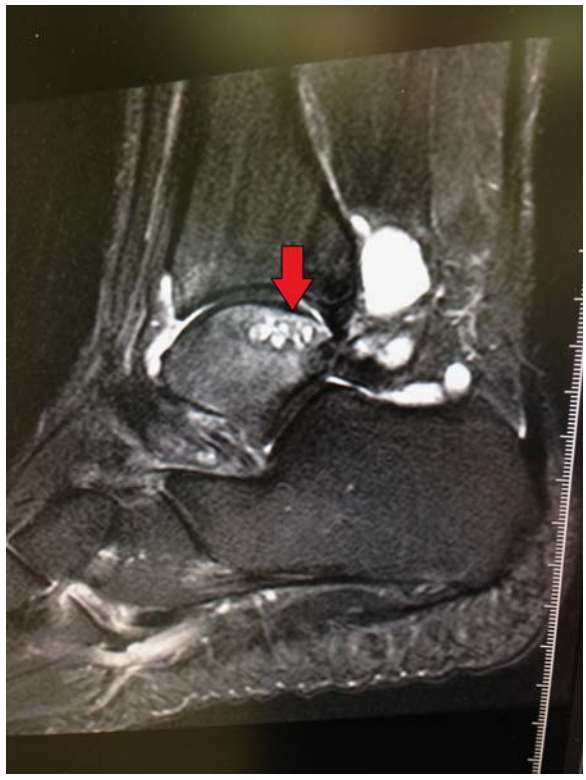

FIGURE 2. T2 sagittal magnetic resonance imaging of the ankle with osteochondral defect (arrow) identified.

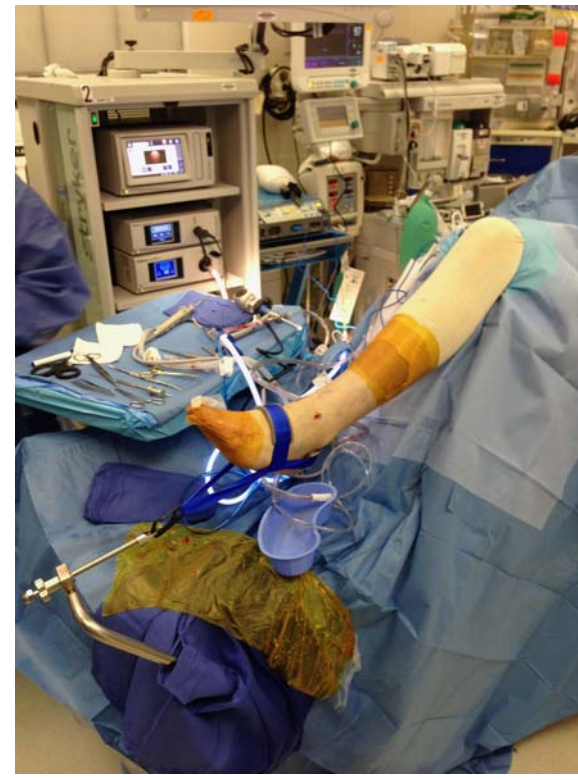

FIGURE 3. Patient positioning for ankle arthroscopy with the hip and knee flexed at 60 and 70 degrees, respectively.

Marrow Needle (Carefusion, San Diego, CA) in the iliac crest after aspiration of the bone marrow. Defects larger than 1.5 cm^2 require a cancellous bone graft harvest with a curette from the calcaneus accessed through a small lateral incision.

The patient and the operative leg are draped and prepped in the usual sterile manner with the leg elevated and placed in a positioner with the hip and knee flexed at 60 and 70 degrees, respectively (Fig. 3). Blood is drained from the operative leg with an Esmarch's bandage and the tourniquet inflated to 250 mm Hg. The operative foot is placed in a noninvasive ankle distractor and the ankle joint accessed arthroscopically through standard anteromedial and anterolateral portals.

Using a mechanical shaver, debridement of scar tissue, osteophytes, and loose cartilaginous fragments within the ankle joint is performed in its entirety along with arthroscopic evaluation of the osteochondral lesion. Using a microfracture kit and curette, all bony cysts and loosely adhered articular cartilage are debrided down to fresh subchondral bone creating sharply demarcated borders of viable articular hyaline cartilage surrounding the defect (Figs. 4, 5).

The ankle is then drained of all fluid utilizing an epidural spinal needle connected to vacuum suction placed through either of the anterior portals. Occasionally, a posterior outflow tract is used. The remainder of the procedure is performed "dry." While the ankle is being drained and all minor bleeds allowed to clot, the DeNovo NT graft is prepared (Fig. 6). First, the package is drained of all packaging fluid using a 25-G needle and syringe (Fig. 7). The juvenile articular cartilage fragments are manually loaded into the distal end of an arthroscopy cannula and packed down in the cannula with a trochar (Fig. 8). The graft is then set aside until transplantation. After the ankle has completely dried and all minor bleeds have ceased, the bone graft is transplanted and packed down into the bony defect with a freer elevator (Fig. 9). Evicel (Ethicon, Rockville, MD), a fibrin glue sealant, is layered over the bone graft. The juvenile particulated articular cartilage graft is then gently transplanted through the arthroscopic cannula with the trochar and positioned lightly with a freer elevator to cover the defect uniformly, making an effort to contain the graft only within the defect. Evicel is again applied over the cartilage

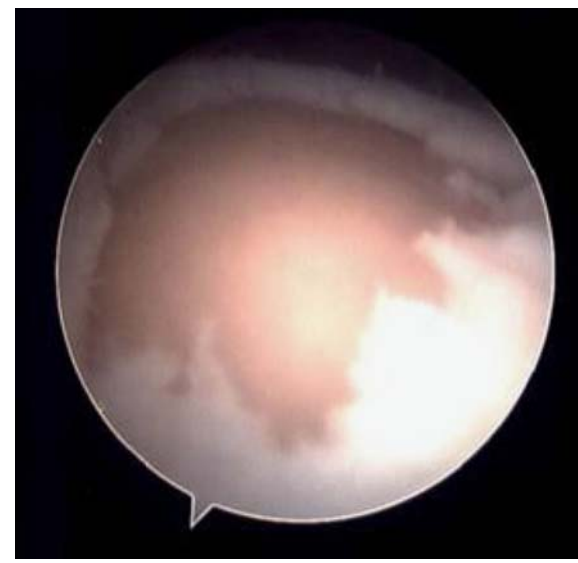

FIGURE 4. Arthroscopic view of the osteochondral defect of the talus with no bony involvement.

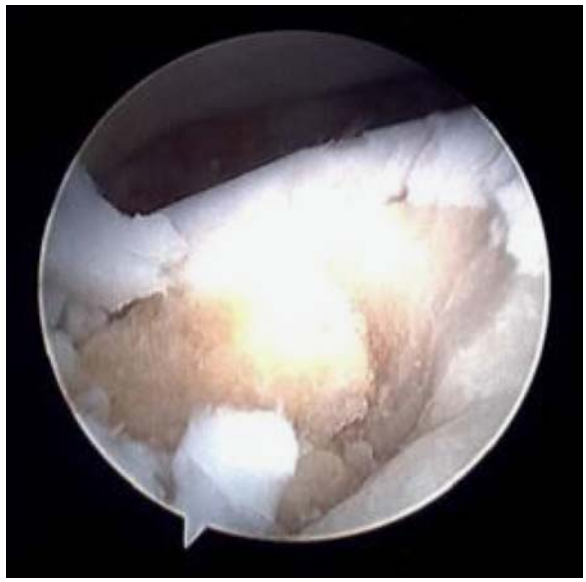

FIGURE 5. Arthroscopic view of the osteochondral defect of the talus with an underlying bony cystic component.

graft for additional fixation. While the fibrin glue is still wet, the BMAC is dripped over the graft through the arthroscopic portals to completely cover the new graft. The fibrin glue is then allowed to dry for 5 to 10 minutes. A final arthroscopic visualization of the graft confirms that the graft was properly placed and sufficient time has passed to allow the glue to affix the graft in place (Fig. 10). The anterior portals are closed in the standard manner and any remaining BMAC is injected percutaneously into the ankle joint.

COMPLICATIONS

The theoretical risk of disease transmission with allograft transplantation is present but, to date, there have been no reported incidences. Most complications related to arthroscopic ankle surgery are secondary to nerve injury while establishing the arthroscopic portals. Transient neuritis was reported in 2% of cases in a systematic review of 1305 ankle arthroscopies by Zengerink and van Dijk.[27] Transient dysesthesia, hypesthesia, or hyperesthesia can develop as scar tissue forms within the incisions. The pitfalls of this technique are that it is done "dry" that can complicate visualization of the OCD. The defect may also be larger than anticipated during preoperative planning and may need to be converted to an open procedure with malleolar osteotomy or plafondplasty. As with any surgical procedure, there is a risk of infection with the incision but this risk remains minimal in arthroscopic procedures due to the minimally invasive nature of the surgery.

We have used this technique to treat 50 patients diagnosed with an OCD to date. Overall the patients have responded well with results similar to microfracture at 1- and 2-year follow-up (Fig. 11). Despite similar results at 2-year follow-up, the prospect of higher long-term success rates at 5- and 10-year follow-up is hopeful as the particulated juvenile articular cartilage allograft transplantation allows for restoration of physiological articular cartilage composed of type-II cartilage. There have been no postoperative infections or allograft rejections recorded. The main complication is failure where the juvenile particulated articular cartilage allograft does not completely incorporate or starts to fibrillate over time.

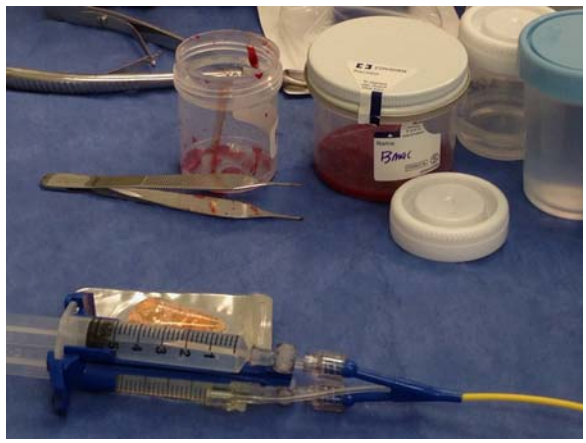

FIGURE 6. Preparation of the DeNovo NT allograft. Clockwise from top left, calcaneus bone graft, bone marrow aspirate concentrate (BMAC), Evicel application device, DeNovo NT allograft.

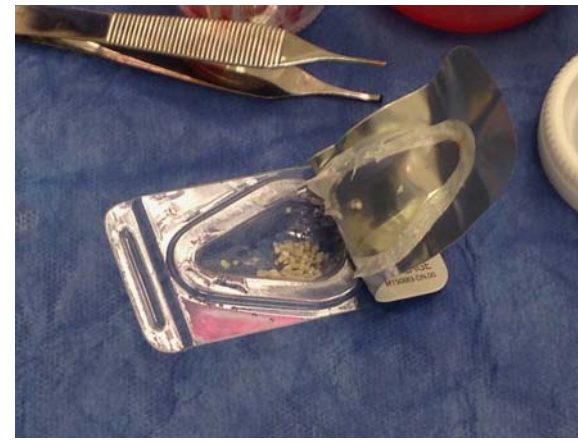

FIGURE 7. DeNovo NT allograft with preservation fluid drained from packaging.

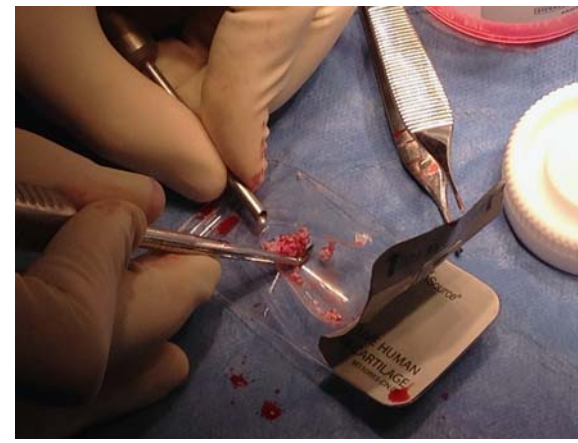

FIGURE 8. Loading the DeNovo NT allograft into the trochar for arthroscopic application.

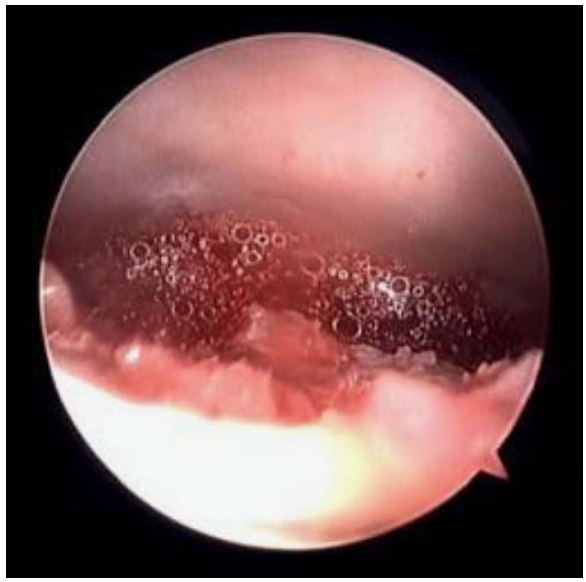

FIGURE 9. Arthroscopic view after the calcaneus bone graft has been smoothed down within the osteochondral defect.

POSTOPERATIVE MANAGEMENT

Postoperatively, the patient is placed in a plaster backsplint for 2 weeks and kept non–weight-bearing for 6 weeks. At the first follow-up visit at 2 weeks the patient is transitioned to a CAM walker boot given that the incisions have fully healed and physical therapy is started. Gentle active and passive range-of-motion exercises and elastic band strengthening exercises are encouraged during initial physical therapy sessions to encourage cartilage healing and avoid postoperative adhesions and loss of motion. After 6 weeks the patient is graduated to partial weight-bearing status in the boot with incremental progression to full weight-bearing as guided by the physical therapist over the course of the following 2 to 6 weeks. At that point, increased strengthening exercises to achieve preoperative levels of function are prescribed. Typically patients are able to transition to a regular shoe at 3 months and permitted to reinitiate high impact activities such as running, jumping, and sporting activities at 5 to 6 months.

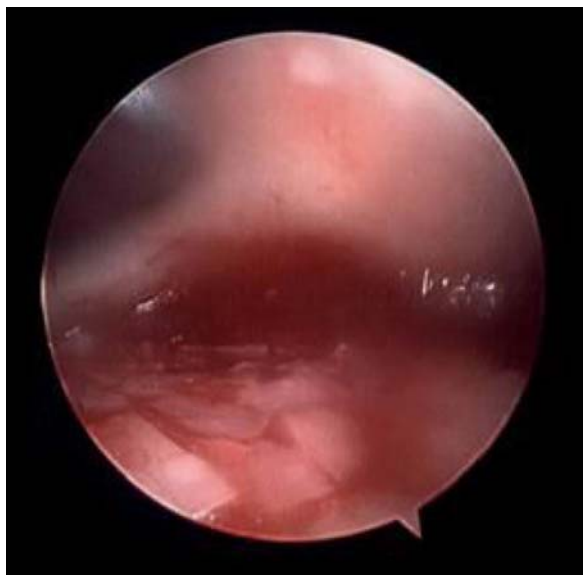

FIGURE 10. Final arthroscopic view of the DeNovo NT allograft.

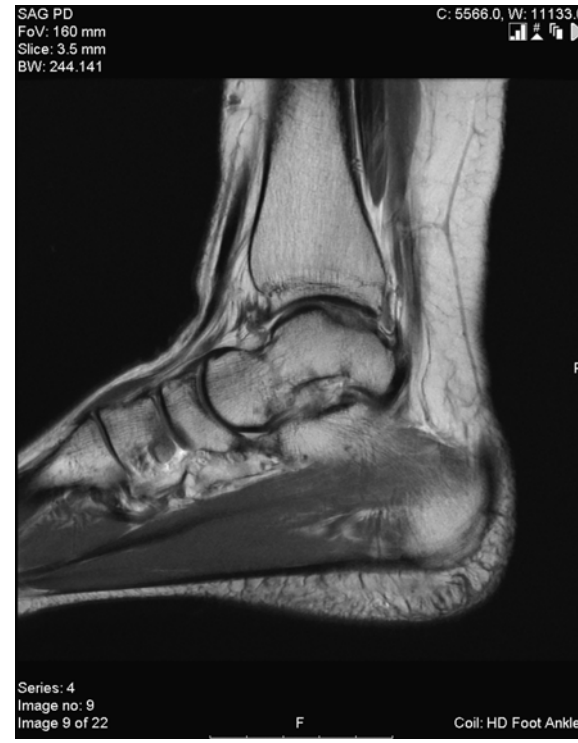

FIGURE 11. Follow-up magnetic resonance imaging at 1-year follow-up.

FUTURE OF THE TECHNIQUE

Surgical intervention for the treatment of OCD of the talus is a continually evolving field. Arthroscopic particulated juvenile allograft transfer augmented with BMAC is a promising development as it obviates many of the disadvantages of previous surgical techniques such as the development of fibrocartilage as opposed to physiological hyaline articular cartilage, the need for malleolar osteotomy or arthrotomy, technical difficulty, harvest donor-site morbidity, the theoretical risk of disease transmission, and the need for a 2-step procedure.[2,10–12,20] Long-term clinical outcome data are not available at this time because this technique is still in its infancy. Prospective clinical trials are currently underway to gather outcome data of a large series of patients treated with this technique. Data collected from these clinical trials will work to determine the clinical outcomes and help identify specific criteria for ideal candidates.

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