Osteochondral dessicans of the talus, also referred to as osteochondral lesions or osteochondral defects (OCDs), was first described by Monro in the 18th century after removal of a loose fragment from the ankle.1, 2 After discovering a loose body in the knee in 1888, Konig described a theory of spontaneous necrosis, or osteochondritis dessicans.2-4 In 1959, Berndt and Hardy5 were the first to classify the lesion as a result of a traumatic injury with a specific mechanism of action in the ankle and presented a staging system based on the amount of displacement of the osteochondral fragment, which since has become the most widely accepted classification of OCDs.

Osteochondral lesions of the talus compose 0.09% of all fractures and 0.1% of talar fractures.6-8 The condition typically affects patients 20 to 40 years of age, and it occurs in males twice as frequently as in females.6, 8 Approximately 98% of patients with lateral dome lesions and 70% with medial dome lesions have a history of trauma.6, 8-10 Symptoms of osteochondral lesions include swelling, pain, and stiffness of the ankle joint.3, 9, 10 These lesions also may be associated with chronic ankle sprains, ankle functional instability, and decreased range of motion with synovial effusion.3, 9, 10 Owing to nerve absence in cartilage, isolated chondral or osteochondral lesions may be asymptomatic. A high level of suspicion is warranted in patients with a history of chronic ankle instability or isolated ankle trauma because it is believed that osteochondral lesions rapidly progress to deeper lesions, resulting in diffuse degenerative changes to the joint.10

Background: Management of osteochondral defects of the talus remains a challenge, and many lesions do not respond to traditional treatments. The use of fresh allografts is a promising alternative.

Methods: A freehand inlay surgical technique for reconstructing osteochondral defects of the talus with fresh osteochondral allografts fixated with bioreabsorbable chondral darts is described. A retrospective review of a consecutive series of 15 patients (eight males and seven females; mean age, 42.2 years) with stage IV osteochondral defects who underwent this procedure is presented. Seven patients reported a history of trauma. The mean lesion diameter was 1.7 cm.

Results: Mean follow-up was 1.6 years. The Foot and Ankle Outcome Score subscale mean scores obtained at the most recent follow-up were as follows: 66.0 (pain), 64.8 (other symptoms), 71.2 (activities of daily living), 50.7 (sport and recreation function), and 42.1 (quality of life). Nine lesions had no evidence of lucency, and six demonstrated mild lucency, indicating that no allograft had been absorbed. Most patients exhibited no step-off deformity or arthrosis. No graft-related complications occurred. No subsequent surgical procedures were required.

Conclusions: Early results suggest that this technique is a viable option for treating large osteochondral defects of the talus, as evidenced by the favorable patient assessment and radiographic outcomes and the lack of postoperative complications and subsequent procedures. Unlike previous allograft techniques, hardware complications did not occur. Based on these results, this technique will continue to be used. (J Am Podiatr Med Assoc 100(1): 25-34, 2010)
Treatment of talar defects remains a challenge owing to the poor intrinsic healing properties of cartilage. Because cartilage has no lymphatic or nerve supply and is avascular, it grows and repairs more slowly compared with other connective tissues. In addition to nonoperative modalities, several surgical treatments have been described, including fragment excision, subchondral drilling, abrasion arthroplasty and debridement, autologous chondrocyte transplantation, mosaicplasty, and osteochondral graft transplantation with either an autograft or an allograft. The use of a fresh osteochondral allograft may be particularly beneficial for large lesions with more extensive disease or as a salvage procedure for failed autografting or subchondral perforation. Transplantation of an osteochondral allograft involves filling the defect with viable chondrocytes and an intact hyaline cartilage organ structure. Although minimal, disadvantages of allografts include risk of disease transmission, slower biological remodeling, and an immune response. Advantages, on the other hand, consist of decreased patient morbidity, tissue flexibility, and the ability to resurface large lesions.

Previous studies involving fresh allografts for the treatment of OCDs of the talus are limited and involve various methods of graft fixation. The purpose of this study is to introduce a novel freehand inlay technique for reconstructing stage IV OCDs of the talus using fresh talar transplant allografts fixated with bioresorbable chondral darts. The transplanted nonfrozen articular (hyaline) cartilage is a composite of living cartilage with a layer of underlying subchondral bone that serves as a mature matrix with viable chondrocytes and that provides a surface for fixation and integration with the host. The bioresorbable chondral darts are used to secure the fresh allograft and are indicated for use in the fixation of small bone fragments such as apical fragments, osteochondral fragments, and cancellous fragments in the knee. It was hypothesized that use of this allograft would provide sufficient stability and maintenance of joint alignment, resulting in good early functional outcomes. A retrospective review of a consecutive series of cases was performed to assess the early results of this technique.

Materials and Methods

Study Population

A retrospective review with approval by the institutional review board affiliated with Grant Medical Center was conducted on the first consecutive series of patients with stage IV OCD of the talus who underwent reconstruction with this freehand inlay technique using fresh talar transplant allografts. All of the procedures were performed by the senior author (L.J.) using the standardized technique described herein. During 15 months, 15 patients (15 OCDs) underwent this specific type of treatment. Previous conservative therapy had failed in all of the patients. Clinical symptoms included pain and difficulty in walking and shoe activity limitations. Patients younger than 14 years and those with active infection or malignancy were excluded.

The population comprised eight males (53.3%) and seven females (46.7%), with a mean (SD) age of 42.2 (16.0) years (median, 48.0 years; range, 14.7–64.0 years). The mean (SD) body mass index (calculated as weight in pounds multiplied by 703 and divided by the square of the height in inches) was 28.9 (5.5) (median, 30.5; range, 16.5–37.8), indicating that most patients were overweight or obese. Three patients (20.0%) were current smokers. Two patients (13.3%) were diabetic. Twelve osteochondral lesions (80.0%) involved the right ankle and three (20.0%) the left ankle. Seven patients (46.7%) reported a history of trauma. One patient (6.7%) failed previous surgical treatment with another type of allograft. Most osteochondral lesions involved the lateral talus (n = 8, 53.3%), followed by the central talus (n = 5, 33.3%) and the medial talus (n = 2, 13.3%). The mean (SD) lesion diameter was 1.7 (0.62) cm (median, 1.8 cm; range, 0.70–3.0 cm); only one lesion was less than 1 cm in diameter. Concomitant surgical procedures performed in conjunction with the OCD reconstruction are summarized in Table 1. Mean (SD) follow-up for the 15 osteochondral lesions was 1.6 (0.39) years (median, 1.5 years; range, 0.80–2.1 years).

Preoperative Magnetic Resonance Imaging Measurements

Digital magnetic resonance imaging was used to measure all of the osteochondral lesions preoper-

### Table 1. Concomitant Surgical Procedures in 15 Patients with Stage IV Osteochondral Defects Undergoing a Novel Freehand Inlay Technique

<table>
<thead>
<tr>
<th>Additional Procedure</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral ankle stabilization</td>
<td>12</td>
</tr>
<tr>
<td>Arthroscopy</td>
<td>8</td>
</tr>
<tr>
<td>Excision/resection of the os trigonum</td>
<td>2</td>
</tr>
<tr>
<td>Neurectomy</td>
<td>2</td>
</tr>
<tr>
<td>Posterior tibial tendon reconstruction</td>
<td>2</td>
</tr>
<tr>
<td>Achilles tendon repair</td>
<td>1</td>
</tr>
<tr>
<td>Arthrodesis, 1-4 digits</td>
<td>1</td>
</tr>
<tr>
<td>Peroneus longus tendon repair</td>
<td>1</td>
</tr>
<tr>
<td>Removal of a loose body</td>
<td>1</td>
</tr>
</tbody>
</table>
tively. The measurements were based on either the core of chondral damage or the overlying subchondral damage areas (Fig. 1). If the two zones were demarcated on magnetic resonance images, then the smaller measurement, the core of chondral damage, was used. However, if there was no demarcation, as often is the case in early or questionable lesions, then the overall maximum dimension was measured.

**Allograft Procurement**

Consent for osteochondral tissue donation was similar to that for other vital organ donation and followed the provisions established by the American Association of Tissue Banks for procuring, processing, and testing donor tissue. Donor blood tests were conducted, and the results must be negative for human immunodeficiency virus type 1 and 2 antibodies, hepatitis B surface antigen and core antibody, hepatitis C antibody, human T-lymphotropic virus types 1 and 2, and syphilis before distribution of the graft. The allografts were obtained from one of five tissue banks. Donors and recipients were matched according to comparable size of the ankle joint and the side (left or right) of the involved talus bone.

After graft procurement, the fresh grafts were packaged in three pouches, of which the two inner pouches were sterile. In the innermost sterile pouch, the graft was enclosed in Dulbecco’s modified Eagle’s medium tissue solution and chondroitin sulfate. To ensure chondrocyte viability, the grafts were implanted within 7 to 29 days of procurement. Because exposure to room air for as little as 30 min may cause degeneration of the surface cells, manipulation of the graft was performed on a separate sterile field to ensure that the articular cartilage remained moist in cold to room temperature sterile isotonic solution (lactated Ringer’s).

**Surgical Technique and Postoperative Rehabilitation Protocol**

Patients were prepared and draped in a standard sterile manner, with placement of a mid-thigh tourniquet and elevation of the lower extremity. The surgical approach was determined by OCD location. For medial talar defects, a medial malleolar osteotomy was performed to ensure adequate exposure of the medial aspect of the talus. The malleolus was predrilled with two 4.0-mm cannulated cancellous screw guide pins before the osteotomy. The proximal cortex was then overdrilled, and the guide pins subsequently were removed. An oblique medial malleolar osteotomy was performed to retract the medial malleolus with the deltoid ligaments still attached to expose the medial shoulder of the talar dome. Lateral talar defects required a fibular osteotomy or transection of the lateral collateral ligaments to achieve proper exposure. Centrally located talar defects necessitated the use of an anterior approach, with dissection between the extensor hallucis longus and tibialis anterior tendons.

Once adequate exposure and appropriate ankle joint distraction was achieved, the OCD was inspected (Fig. 2). The margins of the lesion were probed,

![Figure 1. Magnetic resonance imaging of the anteroposterior (A) and lateral (B) views demonstrating preoperative measurements of the osteochondral defect.](image-url)
as an inlay with subsequent bioresorbable chondral dart fixation.

The location of the lesion and the dimensions of the excavated osteochondral bone were used to match the exact orthotopic site of the donor allograft (Fig. 5). The allograft was prepared by outlining the dimensions of the lesion on the donor talus and isolating the desired section with a power sagittal saw (Fig. 6). The allograft then was transferred and inserted into the recipient's matching void (Fig. 7). In some cases, additional contouring of the graft may be necessary to provide the best alignment. Each graft must be configured to match the particular anatomy of the host talus by mitering the graft edges or surfaces to ensure a proper fit.

After proper graft alignment, platelet-rich gel was

Figure 2. Intraoperative photograph demonstrating visualization of the osteochondral defect after medial malleolar osteotomy was performed.

Figure 3. Intraoperative photograph depicting measurement of an osteochondral defect.

Figure 4. Intraoperative photograph obtained after a freehand osteotomy and excision of the defect were performed to prepare for graft insertion.

Figure 5. Comparison of size and morphological structure between the extracted osteochondral bone and the donor allograft.
applied to the contact surfaces of the graft to promote cartilage and bone regrowth. The graft was secured with a minimum of two chondral darts composed of biodegradable poly-L-lactic acid and designed with a double-reversed barb for compression and fixation (Arthrex Inc, Naples, Florida) (Fig. 8). The darts were placed through the graft to acquire compression and to prevent axial rotation. If a medial osteotomy was performed, it was reduced and fixated with two malleolar screws. In addition, because the success of talar allograft transplantation is enhanced if alignment and stability of the joint also are addressed, additional surgical procedures, such as arthroscopy and ankle stabilization, were performed at the discretion of the senior author (L.J.). After layered closure, a posterior splint was used, followed by application of an external bone stimulator to assist in graft integration and healing of the osteotomy site.

Postoperative rehabilitation was identical for all of the patients and consisted of 6 to 8 weeks of non-weightbearing ambulation. Physical therapy was initiated 8 weeks postoperatively, followed by 3 weeks of progressive weightbearing ambulation in a removable short-leg walker.

Study Design

The Foot and Ankle Outcome Score was used to assess pain, function, and quality of life postoperatively. The patient-administered Foot and Ankle Outcome Score is based on the Knee Injury and Osteoarthritis Outcome Score, has been validated in patients with lateral ankle instability, and comprises five subscales: pain, other symptoms, activities of daily living, sport and recreation function, and foot- and ankle-related quality of life. A normalized score was calculated for each subscale, with 100 indicating no symptoms and 0 indicating extreme symptoms. A medical record review also was performed to document complications, subsequent surgical procedures, and failures.

An author (W.T.D.) who did not perform the procedures conducted a blinded review of the immediate postoperative and most recent follow-up radiographs to measure lucency, step-off, and arthrosis. Degree of lucency, defined as absorption of the graft, and step-off were graded as none, less than 1 mm, or greater than or equal to 1 mm. Arthrosis was categorized as none, mild, moderate, or severe.
Results

The Foot and Ankle Outcome Score subscale scores obtained at the most recent follow-up are summarized in Table 2. No graft-related complications occurred, and no subsequent surgical procedures were required (Fig. 9). There has been no evidence of delamination. Of the 15 OCD lesions, nine (60.0%) had no evidence of lucency and six (40.0%) revealed mild lucency, indicating that allograft absorption did not occur. Nine OCD lesions (60.0%) did not have a step-off deformity, whereas four (26.7%) had a step-off of less than 1 mm and two (13.3%) had a step-off of 1 mm or greater. Arthrosis was absent in nine patients (60.0%). The remaining six patients (40.0%) developed either mild (n = 4, 26.7%) or severe (n = 2, 13.3%) arthrosis. No radiographic evidence of graft rejection was apparent.

Discussion

Management of OCDs of the talus is challenging.\textsuperscript{11, 12} Because conservative treatment of stage IV talar osteochondral lesions has produced poor outcomes, with success rates of less than 50%, most surgeons recommend operative treatment.\textsuperscript{2, 6, 7, 10} Traditional surgical techniques include subchondral drilling, abrasion arthroplasty, and debridement.\textsuperscript{3, 6, 7, 17, 27, 29} Satisfactory short-term results have been reported with these techniques, but the fibrocartilage healing that occurs has been shown to deteriorate over time and is associated with late arthrosis.\textsuperscript{7, 17} The primary reason for failure is the inability of fibrocartilage to resist compression, which is essential in withstanding long-term cyclic loading and shearing forces.\textsuperscript{20, 22}

Ideally, OCDs should be replaced with hyaline cartilage to replicate natural anatomical and physiologic features. Current techniques for hyaline cartilage transplantation include mosaicplasty and osteochondral graft transplantation with either an autograft or an allograft to replace the diseased hyaline cartilage.\textsuperscript{2, 7, 16, 18, 20–26, 28} Both procedures typically involve cylindrical autogenous grafts from the knee.\textsuperscript{7, 22–26} The unique morphological features of the talus do not lend themselves to autograft or allograft transplantation using cylindrical punch techniques, and access is difficult with cylindrical

<table>
<thead>
<tr>
<th>Table 2. Foot and Ankle Outcome Score Subscale Scores in the 15 Study Participants at the Most Recent Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subscale Scores</strong></td>
</tr>
<tr>
<td>Pain</td>
</tr>
<tr>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Median</td>
</tr>
<tr>
<td>Range</td>
</tr>
</tbody>
</table>

Figure 8. A. The double-reversed barb of the bioresorbable poly-L-lactic acid chondral dart used for compression and fixation of the allograft. B. Intraoperative photograph demonstrating placement of the chondral darts to secure the allograft to the host bone. A minimum of two darts is recommended to achieve adequate fixation.
Figure 9. A and B, Preoperative radiographs of a 29-year-old man with a lateral osteochondral defect (OCD) measuring 1.5 cm in diameter. In addition to surgical treatment of the OCD, a lateral ankle stabilization procedure also was performed. C and D, Immediate postoperative radiographs demonstrate excellent placement of the allograft. E and F, Most recent follow-up radiographs at 2 years demonstrate no radiolucency or arthrosis, with mild step-off of less than 1 mm. The patient was satisfied with the outcomes of the procedure and exhibited Foot and Ankle Outcome Score subscale scores of 89.7 for pain and 91.7 for activities of daily living.
punch instrumentation. With this harvesting method, donor-site morbidity may occur in upwards of 15% or 16% of cases in a previously asymptomatic joint.7, 26, 30 Considering this relatively high incidence of donor-site morbidity and the large amount of bone harvesting required to repair medium and large OCDs, these treatment options are not recommended for larger defects.7, 8, 10, 12, 25, 30 In addition, the irregular shape of OCDs represents a technical challenge of symmetry because cylindrical autogenous grafts are used to fill irregularly shaped defects.7, 22, 26 As a result, the remaining space between the circular grafts and the portion of unfilled lesions will heal as fibrocartilage.17, 20, 24 Similarly, an additional drawback regarding mosaicplasty involves the extensive fibrocartilage ingrowth between multiple grafts.7, 22, 26 With both methods, interruption of the articular surface integrity significantly alters ankle joint contact characteristics, leading to the development of arthritis.7, 22 Finally, because most osteochondral lesions involve the medial and lateral shoulders, access is difficult with mosaicplasty instrumentation, further necessitating a freehand inlay technique for anatomical talor allograft transplantation.24, 26, 34

Fresh osteochondral allografts address the shortcomings of the aforementioned techniques and have been used to successfully repair OCDs of the knee and, more recently, the ankle.11, 25, 28, 35-37 First, allograft use eliminates the need for a donor site and the associated harvest-site morbilities.7, 12, 25 Second, allografts may be prepared in any size, enabling surgeons to create anatomically appropriate grafts to restore complex articular geometry, which is crucial when dealing with defects of irregular morphological structure.7, 12, 25 Third, the composite nature of fresh allografts offers a mechanism to restore the associated subchondral bone deficiencies commonly seen in OCDs by providing mature hyaline cartilage with normal architecture to serve as a matrix and as a source of viable chondrocytes.7, 12, 25, 30 The use of transplanted tissue thus avoids the inherent difficulties associated with cartilage repair and regeneration and, instead, enables healing through the well-understood mechanism of allograft bone incorporation.12

Results of using fresh allografts for the treatment of OCDs of the talus are scarce.25, 28 Meehan et al.28 used fresh allografts to replace diseased articular cartilage in 11 ankles with a variety of conditions, including traumatic arthritis, osteoarthritis, and OCDs. Of the two cases with OCDs in which allografts were used, one allograft was considered successful at mean follow-up of 32.5 months, and the other failed.28 A repeated allograft procedure was performed for the latter case, with a successful result reported 12 months postoperatively.28

Gross et al.25 used fresh allografts secured with cancellous screws to treat nine patients with stage IV OCD lesions that were a minimum of 1 cm in diameter. At mean follow-up of 12 years (range, 4–20 years), four of the nine cases required hardware removal 5 to 24 months after surgery. Ankle arthrodesis was performed in three cases because of resorption and fragmentation of the graft, rather than arthritic deterioration, 36 to 83 months postoperatively. Six patients had grafts that remained in situ, with mean survival of 11 years (range, 4–19 years). The average overall survival of the nine grafts was 9 years (range, 3–19 years). The six patients with grafts in situ described functional range of motion, reported no or mild pain, and were satisfied with the procedure. Four of the six grafts exhibited no radiologic evidence of resorption, fragmentation, or degenerative change. However, two of these grafts appeared to be raised 1 mm above the host articular surface. One graft was 50% resorbed, with no evidence of osteoarthritis, whereas the other exhibited an area of fragmentation that involved less than one-third of the graft. No evidence of gross or microscopic rejection was found.

Herein we presented the largest known study using fresh osteochondral allografts for the treatment of OCDs of the talus. At mean follow-up of 1.6 years, all of the patients functioned well, as indicated by the Foot and Ankle Outcome Score subscores. In addition, all 15 grafts remained intact, with no evidence of fragmentation, absorption, or graft rejection. Furthermore, no postoperative graft-related complications were reported, and no patients have required a subsequent procedure such as total ankle arthroplasty or arthrodesis. The technique described in this study is similar to that by Gross et al.25 except for the fixation method used to adhere the fresh allograft to the host bone. Gross et al.25 secured the allograft to the host bone using one or two small mini-fragment cancellous screws countersunk into the extra-articular bony portion of the graft. Conversely, the technique described in the present study uses bioresorbable chondral darts that offer compression and fixation properties to secure the fresh allograft. The bioresorbable poly-L-lactic acid darts provide secure fixation under the hyaline cartilage, eliminating contact with articulating surfaces. The incidence of immune responses from the use of poly-L-lactic acid has been relatively low in animal and human models.36 Furthermore, an immune response in this particular application is unlikely because cartilage is avascular and has no lymphatic supply. Because the darts are resorbable, po-
tential complications associated with hardware, such as prominent hardware, pain, and possible breakage, all of which may necessitate hardware removal, are not relevant. Four of the nine patients in the study by Gross et al.25 required hardware removal 5 to 24 months after the osteochondral repair procedure. Conversely, the chondral dart is made of poly-L-lactic acid and is designed to maintain sufficient strength during healing and then to degrade and be replaced by host tissue. The by-product of chondral dart degradation is lactic acid, which enters the Krebs cycle and is converted to carbon dioxide and water.

Many of the weaknesses of the present study are related to the inherent biases of retrospective studies and include lack of randomization or a control group. In the future, larger prospective randomized studies that directly compare this freehand inlay technique with fresh allografts with other surgical options may assist in determining the optimal method for managing OCDs of the talus. Studies with longer follow-up also are needed to assess the long-term efficacy of this technique. We believe that the potential benefits of this technique outweigh the limited early follow-up. Because an identical allograft was used and given the technique similarities in the present study and in that by Gross et al.25 comparable graft survival rates should be expected. However, the key advantage of this technique is that it avoids the significant hardware complication rates seen in the study by Gross et al.25 Surgeon experience also plays a role in the outcomes of this technique because proper allograft preparation and contouring improves with experience and enhances graft alignment. In addition, the development of standardized instrumentation to assist in contouring is problematic because the anatomical composition of every host talus is unique.

Conclusions

The freehand inlay technique using fresh talar transplant allografts presented in this study seems to be a viable option for the treatment of large OCDs of the talus, as evidenced by the favorable early patient assessment and radiographic outcomes and the lack of postoperative complications and subsequent procedures. Advantages of the technique include allograft use, which may be prepared in any size and avoids harvest-site morbidities; a freehand inlay technique that allows close contouring of bone and results in minimal bone removal; and fixation with bioresorbable darts that achieves compression and fixation while eliminating hardware-related complications. This technique replaces the OCD but preserves more bone compared with more aggressive alternatives such as arthrodesis and total ankle arthroplasty. Based on these promising results, this technique will continue to be used and patients will continue to be monitored to assess intermediate results.

Financial Disclosure: An unrestricted grant from Arthrex Inc was used to fund this study.

Conflict of Interest: None reported.

References