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Osteochondral Allograft Transplantation for Osteochondral Lesions of the Talus: Midterm Follow-up

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Abstract

Background: Fresh osteochondral allograft (OCA) transplantation represents a biologic restoration technique as an alternative treatment option for larger osteochondral lesions of the talus (OLT). The purpose of this study was to evaluate midterm outcomes after OCA transplantation for the treatment of OLT.

Methods: Nineteen patients (20 ankles) received partial unipolar OCA transplant for symptomatic OLT between January 1998 and October 2014. The mean age was 34.7 years, and 53% were male. The average graft size was 3.8 cm^2. All patients had a minimum follow-up of 2 years. Outcomes included the American Academy of Orthopaedic Surgeons Foot and Ankle Module (AAOS-FAM), the Olerud-Molander Ankle Score (OMAS), and pain and satisfaction questionnaires. Failure of OCA was defined as conversion to arthrodesis or revision OCA transplantation.

Results: Five of 20 ankles (25%) required further surgery, of which 3 (5%) were considered OCA failures (2 arthrodesis and 1 OCA revision). The mean time to failure was 3.5 (range, 0.9 to 6.7) years. Survivorship was 88.7% at 5 years and 81.3% at 10 years. The median follow-up of the 17 patients with grafts in situ was 9.7 years. The mean OMAS improved significantly from 40 points preoperatively to 71 points postoperatively ($P < .05$; range, 5 to 55). The mean postoperative AAOS-FAM core score was 81.5 ± 15 (range, 40.5 to 96.6). Fifteen of 17 patients responded to follow-up questions regarding their ankle; 14 patients reported less pain and better function, and 13 patients were satisfied with the results of the procedure.

Conclusion: Our study of midterm results after OCA transplantations showed that this procedure was a reasonable treatment option for large OLT.

Level of Evidence: Level IV, case series.

Keywords: ankle, articular cartilage, osteochondral allograft transplantation, osteochondral lesions of the talus

Osteochondral lesions of the talus (OLT) occur in up to 73% of all ankle fractures, in 50% of ankle sprains, and in 41% of ankles with lateral instability.[32,33,40,42] These lesions most often occur without a specific history of trauma, and their management is difficult and challenging to orthopedic surgeons worldwide, because they frequently affect young and active patients. Marrow stimulation techniques have been shown to have better outcomes in lesions that are smaller than 10 to 15 mm in diameter.[6,17,25,35] Common treatments for larger lesions are autologous chondrocyte implantation (ACI) and osteochondral autograft transfer (OAT). Both have been reported to have satisfactory mid- and long-term results. The downside is that ACI requires 2 operative procedures and intact subchondral bone integrity and OAT is limited by donor site morbidity.[12,16,29,44]

Fresh osteochondral allograft (OCA) transplantation represents a biologic restoration technique that has been used in a wide variety of indications and different joints. The advantage of OCA is that large lesions can be treated in a one-stage procedure with a single, highly viable osteochondral graft without having the issue of donor site morbidity. OCA transplantation of the talus is used

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Table 1. Demographic and Outcome Data.

Ankle	Sex	Age	Side	Talar Portion	Percent Grafted	Graft Size (cm²)	Latest Follow-Up (y)	Standardized AAOS-FAM Score[a]	Normative AAOS-FAM Score[a]	OMAS Preop	OMAS[a]	Further Surgeries (no.)
1	Male	35.3	Left	Lateral	20	1.8	18.5	82.60	41.44	N/A	55	No
2	Male	38.5	Right	Lateral	50	5.4	10.7	40.46	7.26	40	65	Yes (1)
3	Female	29.0	Right	Medial	65	6	6.7[b]					Yes (1)
4	Male	27.0	Left	Lateral	25	2.2	3.0[b]					Yes (2)
5	Male	42.9	Left	Medial	50	3.75	10.9	81.26	40.36	15	70	No
6	Male	42.9	Right	Medial	50	3.5	10.9	81.26	40.36	15	70	No
7	Female	28.8	Left	Medial	N/A	N/A	9.7	N/A	N/A	N/A	N/A	No
8	Male	57.7	Left	Lateral	30	3	5.6	N/A	N/A	N/A	5	No
9	Female	41.8	Right	Lateral	40	4.5	0.9[b]					Yes (1)
10	Male	35.3	Left	Medial	50	3.25	10.8	82.06	41.01	50	55	No
11	Male	26.7	Left	Lateral	30	4.5	10.4	96.60	52.80	45	95	No
12	Female	26.9	Right	Medial	35	1.7	11.2	67.46	29.16	25	50	Yes (3)
13	Female	20.5	Right	Lateral	30	2.8	2.7	N/A	N/A	5	N/A	No
14	Female	37.3	Right	Medial	40	3	4.5	83.73	42.36	35	N/A	No
15	Male	35.8	Left	Medial	60	6.4	2.1	92.60	49.55	45	90	No
16	Female	40.5	Left	Lateral	40	4.2	2.2	N/A	N/A	55	60	No
17	Male	34.5	Left	Medial	30	4.2	2.6	91.00	48.25	50	75	No
18	Female	34.2	Right	Medial	40	4.68	7.0	N/A	N/A	40	N/A	No
19	Male	33.6	Right	Lateral	30	2.1	11.7	89.54	47.07	N/A	N/A	No
20	Female	24.7	Left	Medial	35	4.2	8.8	89.00	46.63	60	80	No

Abbreviations: AAOS-FAM, American Academy of Orthopaedic Surgeons Foot and Ankle Module; N/A, not available; OMAS, Olerud-Molander Ankle Score. Failed unipolar partial talus OCA procedures are highlighted in gray.
[a]Time of the latest follow-up.
[b]Time to failure.

as a salvage procedure after failed conservative treatment or prior operative procedures (eg, debridement, OAT, or ACI), but may also be considered a primary procedure in patients with large or cystic lesions, which are not suitable for other techniques.[5] If compared with the abundant clinical data on the knee joint, OCA transplantations of the ankle are less frequent. The general clinical outcome data of OCA transplantations of the talus are limited to a few case series. The purpose of this study was to report on midterm outcomes of OCA transplantations for the treatment of OLT. We hypothesized that partial talus OCA transplantation would provide a durable treatment option for OLT at midterm follow-up.

Methods

Based on our institutional review board–approved OCA database, we identified 19 patients (20 ankles) who received a partial unipolar OCA transplantation for a symptomatic OLT between January 1998 and October 2014 by a single surgeon. All patients gave informed consent to participate in the OCA database. Patients had a minimum follow-up of 2 years (Table 1). All patients showed radiographic evidence of OLT with good ankle range of motion and a history of injury and/or instability. In our cohort, the mean age at the time of surgery was 34.7 ± 8.4 (range, 20.5 to 57.5) years, the mean body mass index (BMI) was 27.9 (range, 23 to 34.4), and 10 patients (53%) were male. Of the 20 ankles, surgery was done on the left in 11 cases (55%) and on the right in 9 cases (including 1 bilateral). The medial portion of the talar dome was affected in 11 ankles (55%) and the lateral portion in 9 ankles. The average graft size was 3.8 (range, 1.7 to 6.4) cm^2. The average grafted area of the talar dome was 39.5% (range, 20% to 65%). These measurements were done by the surgeon intraoperatively. The majority of the allografts were fixated using absorbable pins (15 of 20, 75%), followed by metal screws (4 of 20, 20%) or a combination of pins and screws (1 of 20, 5%). One patient received the OCA transplantation as the first-line surgical treatment because of the large necrotic nature of the lesion, cystic components, and over 10 years of history with extensive conservative treatment. All other patients had previous failed operative interventions, with a mean of 1.7 (range, 1 to 5) previous surgeries (Table 2). Five ankles underwent concomitant surgeries at the time of the OCA transplantation, which included hardware removal (2 ankles), anterior tibial osteophyte removal (2 ankles), and ligament reconstruction (1 ankle).

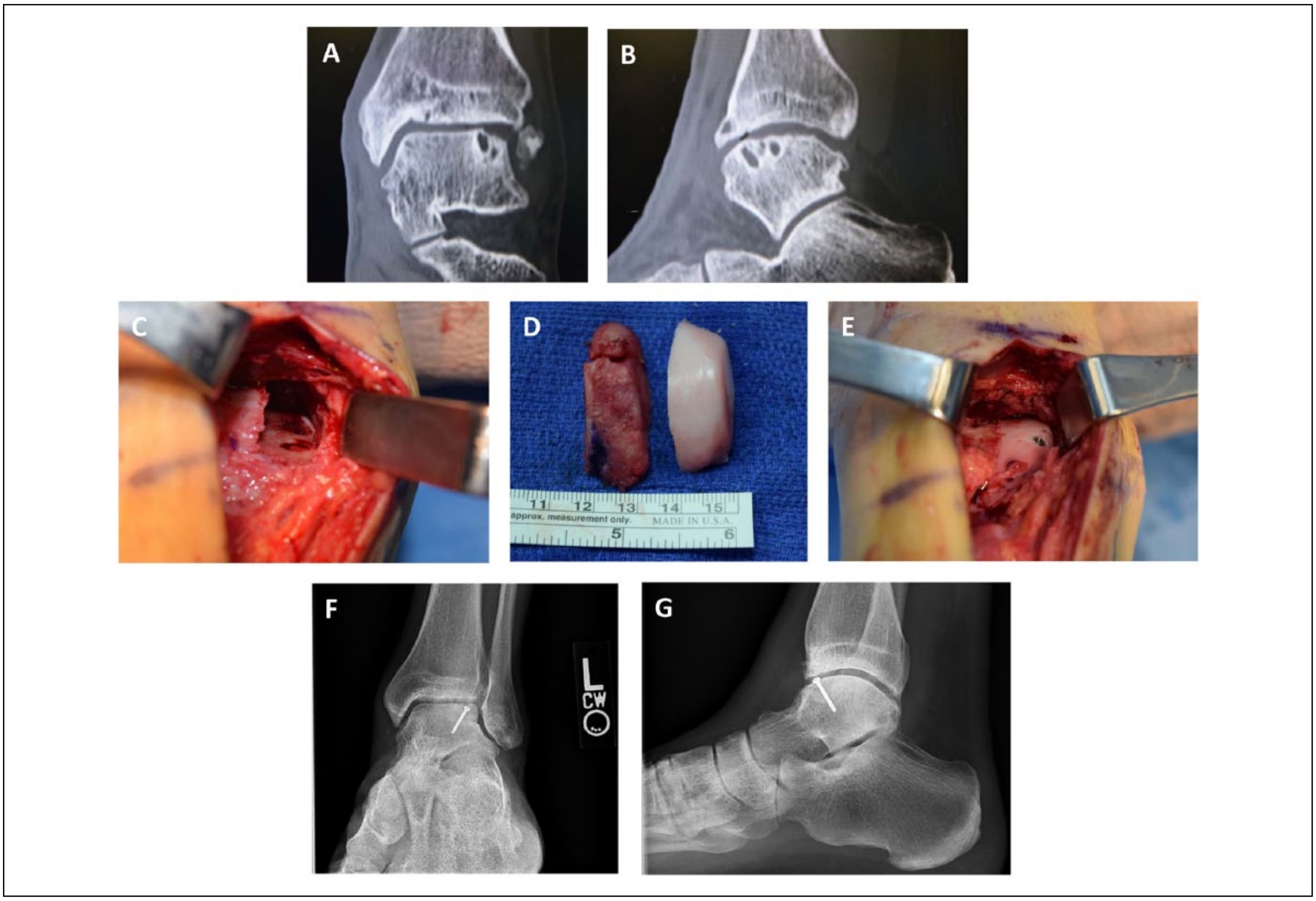

Figure 1. Osteochondral allograft transplantation in the ankle of a 26-year-old male with an osteochondral lesion of the talus. (A) Anteroposterior and (B) lateral preoperative computed tomography images of the talus. (C) Intraoperative image of the talus after resection of the lesion. (D) Resected lesion (left) and allograft (right). (E) Intraoperative image of the allograft after implantation and fixation. (F) Anteroposterior and (G) lateral 2-year postoperative radiographs show a healed talus allograft.

For follow-up clinical evaluation, all patients were contacted via phone or mail and asked to complete a questionnaire evaluating if further surgery was needed on the operative ankle following the OCA transplantation. OCA failure was defined as a conversion to arthrodesis or revision OCA transplantation. Patients were also asked for their current level of pain, function, and satisfaction with the results of the OCA transplantation. Additionally, patients were asked to complete the American Academy of Orthopaedic Surgeons Foot and Ankle Module (AAOS-FAM) postoperatively.[26] The Olerud-Molander Ankle Score (OMAS)[37] was collected preoperatively and postoperatively. The AAOS-FAM score is a patient-reported assessment outcome tool and consists of 5 subscales: pain (9 questions), function (6 questions), stiffness and swelling (2 questions), giving way (3 questions), and shoe comfort (5 questions). In our study, we only used the core scale, which excluded the shoe comfort scale. The final standardized score ranged from 0 to 100 points, with the lower the score, the greater the disability. Based on a general reference population of the United States, the AAOS normative scores were calculated from the standardized values using the online available worksheet provided by the AAOS (www.aaos.org/research/outcomes/Foot_AnkleScoring.xls). If a patient scored above 50 points, he or she was above the general, healthy population's average (and vice versa).

Surgical Procedure

All fresh OCAs were obtained from a tissue bank that was certified by the American Association of Tissue-Banks. Prior to implantation, no human leukocyte antigen (HLA) matching was performed. The graft was recovered within 1 day after donor death, was never frozen, and was stored at 4°C until transplantation, within 28 days of graft harvesting.

All patients were operated on under temporary distraction using a direct anterior approach through the interval between the extensor hallucis longus and the tibialis anterior tendons (Figure 1).[18] After assessing the tibiotalar joint, the affected area of the talar dome was marked and resected using a small oscillating saw. As much native bone stock as possible was preserved to minimize the amount of transplanted allograft bone. In case of the presence of cystic lesions extending beyond the depth of a resection level, curettage and autologous bone grafting were performed. Autograft was obtained from the excised portion of the talus that did not contain the lesion, usually anterior for medial lesions and posterior for lateral lesions. Sclerotic bone was drilled to enhance integration of the graft. Based on measurements of the resected portion of the talar dome, the allograft was prepared using a freehand technique with an oscillating saw. Prior to implantation, the graft underwent pulse lavage with normal saline to remove debris and marrow elements. The correct position of the graft and the exact restoration of the talar dome were confirmed fluoroscopically in both planes. Before removing the external distractor, the graft was fixated with absorbable pins, a cannulated screw, or a combination of both.

Postoperative Care and Rehabilitation

All operated ankles were protected in a splint until removal of the sutures at 2 weeks, followed by transition to a controlled ankle motion (CAM) walker to permit early ankle motion exercises. Patients were strictly non–weight-bearing for 6 to 8 weeks and then progressed to partial weight-bearing (25% to 50% of body weight) in the CAM walker, with functional rehabilitation for a period of at least 6 weeks. A gradual return to full weight-bearing was permitted once graft incorporation was confirmed radiographically, usually at 12 weeks.

Statistical Analysis

All statistical analyses were performed using SPSS version 13.0 (SPSS Inc., Chicago, IL). Means and frequencies were calculated to summarize patient characteristics (age, sex, BMI, and number of previous surgeries on operated ankle), allograft details, and data regarding number and type of further surgeries following the OCA transplantation. The Kaplan-Meier method was used to compute survivorship with failure of the OCA (further surgery that involved removal of the allograft) as the endpoint. Among patients whose grafts remained in situ at latest follow-up, means and frequencies were used to summarize follow-up data (pain, function, satisfaction, and radiographic data, and AAOS-FAM scores). Wilcoxon signed-ranks tests were used to assess score changes from preoperatively to latest follow-up on the OMAS.

Table 2. Previous Surgeries.

Ankle No.	No. of Previous Surgeries	Type of Previous Surgery
1	1	Arthroscopic drilling
2	1	Arthroscopic drilling
3	5	Arthroscopic drilling (2×), arthrotomy and debridement, ACI
4	1	Arthroscopic drilling
5	1	Arthroscopic drilling
6	1	Arthroscopic drilling
7	2	Arthroscopic drilling (2×)
8	1	Diagnostic arthroscopy
9	4	Drilling and Brostrom procedure, OAT and Brostrom procedure, sural nerve resection
10	2	Diagnostic arthroscopy, debridement
11	1	Arthroscopic drilling and Brostrom procedure
12	2	OAT with malleolar osteotomy, arthroscopic drilling
13	1	Arthroscopy with microfracture
14	3	N/A
15	1	Diagnostic arthroscopy
16	1	N/A
17	0	None
18	3	Osteotomy, OAT
19	1	Arthroscopy with debridement/ synovectomy, removal of 2 loose bodies, chondroplasty
20	1	Diagnostic arthroscopy

Abbreviations: ACI, autologous chondrocyte implantation; N/A, not available; OAT, osteochondral autograft transplantation.

Table 3. Further Surgeries.

Procedure[a]	**No.**
Debridement[b]	3
Diagnostic arthroscopy	3
Achilles tendon lengthening	2
OCA failure	3
Arthrodesis	2
OCA revision	1

Abbreviations: OCA, osteochondral allograft.
[a]Some patients had more than one further surgery or multiple procedures at the same time.
[b]Debridement included an open arthrotomy with removal of osteophytes on the anterior tibia/talus, removal of any loose cartilage, and synovectomy when necessary. No lysis of adhesions was performed.

Results

Further surgery was required in 5 of 20 ankles (25%) (Tables 1 and 3). Two of the 5 ankles (10% of the entire cohort) underwent a total of 4 further surgeries that did not involve graft removal. Three of the 5 ankles (15% of

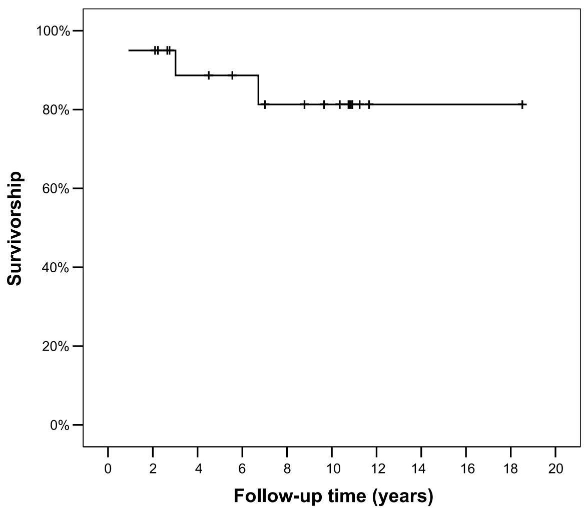

Figure 2. Survivorship of the unipolar partial talus osteochondral allograft transplantation was 88.7% at 5 years and 81.3% at 10 years.

entire cohort) were classified as OCA failures. The OCA failures included conversion to arthrodesis (2 ankles) and OCA revision (1 ankle). The mean time to failure was 3.5 (range, 0.9 to 6.7) years. Survivorship of the allograft was 88.7% at 5 years (95% CI, 0.65, 0.98) and 81.3% at 10 years (95% CI, 0.57, 0.94) (Figure 2).

The median follow-up of the 17 nonfailed ankles (in regard to subjective outcome measures of pain, function, satisfaction, AAOS-FAM, and OMAS) was 9.7 (range, 2.1 to 18.5) years. Of the 15 patients who answered the questions regarding their level of pain, function, and satisfaction, the majority reported to have less pain (14 of 15) and better function (14 of 15) compared with prior surgery, and 13 of 15 were satisfied with the procedure. All patients (15 of 15) stated that they would have the surgery again. The majority of patients (13 of 15) described their overall condition as improved at the time of the latest follow-up.

The mean OMAS improved significantly from 40 points preoperatively to 71 points postoperatively ($P <$ .05; range, 5 to 55). One patient reported an excellent outcome (OMAS: 100 to 91 points), 6 patients reported a good outcome (OMAS: 90 to 61 points), and 4 patients reported a fair outcome (OMAS: 60 to 31 points). Only 1 patient reported a poor outcome (OMAS: 30 to 0 points), but this patient reported being extremely satisfied with the procedure. The mean postoperative AAOS-FAM core standardized score was 81.5 ± 15 (range, 40.5 to 96.6), and the mean postoperative AAOS-FAM core normative score was 40.5 ± 12 (range, 7.3 to 52.8).

Table 4. Radiographic Findings.

Findings[a]	No.
Joint space narrowing	4
Graft interface visible	1
Subchondral cysts	4
Sclerosis	1
Graft radiodensity in comparison with host tissue	
Equal	8
Decreased	2
Increased	1

[a]Eleven of 17 nonfailed ankles were available for radiographic evaluation at a mean of 4.1 years after surgery.

Radiographic Evaluation

At a mean of 4.1 years (range, 1 to 9.7 years) after the OCA transplantation, 11 of 17 nonfailed ankles had radiographic follow-up (Table 4). There was evidence of joint space narrowing in 4 of 11 patients and subchondral cysts in 3 of 11. We found no signs of graft collapse or radiographic evidence of graft failure. Only 1 patient showed subchondral sclerosis. The graft interface was not visible in 10 patients, and the radiodensity of the graft was equal to that in the host tissue in 8 patients.

Discussion

The management of larger, symptomatic OLT still remains a challenge. The most common procedure for lesions smaller than 15 mm in diameter is marrow stimulation, which shows good clinical results in early to midterm follow-up with success rates up to 89%.[7,31,46] Despite this, there are reports that indicate that the repair tissue that initially contained a good collagen II content turns into fibrocartilaginous scar tissue after 1 year, with predominantly collagen I content and low mechanical properties.[3,14,23,41] Besides the many encouraging reports in the short to midterm, Ferkel et al[11] showed that the overall results deteriorate in 35% of the patients over a time course of 5 years. For salvage procedures and lesions that are larger than 15 mm in diameter, ACI and OAT have been described as suitable treatment options. Aurich et al[2] reviewed 18 patients who underwent arthroscopic matrix-associated ACI (MACI) for OLT with an average lesion size of 1.5 cm^2. Fifty-eight percent of all patients had prior operative procedures. After a mean follow-up of 2 years, all clinical scores significantly improved, including American Orthopaedic Foot & Ankle Society (AOFAS) (80.4 points postoperatively) and AAOS (postoperative standardized AAOS, 83.5). Encouraging results for ACI/MACI of the talus have also been reported in the mid- and long term, with failure rates up to 6.7%, postoperative AOFAS hindfoot scores up to 92 points, and good to excellent results in up to 85% of the treated patients.[16,28,29] However, the main downside of this procedure is that ACI/MACI is very cost-intensive and requires 2 separate operative interventions as well as an intact osseous bed. The repair tissue often results in fibrocartilaginous tissue.[16] OATs allow larger lesions to be addressed using single or multiple osteochondral plugs, especially if subchondral cysts are present and the osseous bed is not intact. Haleem et al[21] showed that the use of double osteochondral plugs has noninferior results to the use of single plugs. OAT show up to 93% good to excellent clinical results in the midterm, but long-term studies are missing.[15,46] One downside of this procedure is the donor morbidity, with knee pain in up to 50% of the patients.[22,27,43,46] Another problem is a possible increase of the joint contact pressure if the graft is placed in an elevated or incongruent position or if there are differences in the surface curvature between the graft and host tissue.[10,30] Recent studies show different results regarding the question of whether previous microfracture or concomitant procedures have an influence on the outcome after OAT.[13,39,45]

Another option for large and even more complex lesions of the talus is OCA transplantation, which we report in this study. Despite the high reoperation rate of 25% (5 patients), including 3 OCA failures (required removal of the graft) (15%), we showed promising midterm results. After a median follow-up of 9.7 years, 93% of our patients with grafts remaining in situ had less pain and better function and 87% were satisfied with the procedure and described their overall condition after the procedure as improved. All patients reported that they would have the surgery again. Regarding the functional outcome scores, the OMAS improved significantly from 40 points preoperatively to 71 points postoperatively, with nearly 60% of the patients reporting good to excellent results and a mean standardized AAOS-FAM core score of 81.5. To our knowledge, there are no other midterm studies of OCA transplantation for the treatment of OLT available to compare our results with, but they are in line with the currently available shorter-term results.

In the latest study, Haene et al[19] reported a prospective series of 16 patients (17 ankles) who received a bulk OCA for a large symptomatic OLT at a mean follow-up of 4 years. The mean lesion volume was 3408 mm^3, the mean patient age 35.8 years, and the mean BMI was 30. Half of the patients were female. Of the 17 ankles, 16 underwent previous operative procedures that were mainly arthroscopic debridement (14 ankles). The authors reported a failure rate of 29% (5 ankles) and a reoperation rate of 24% (4 ankles), including 2 conversions to arthrodesis. At the latest follow-up, 10 patients reported good to excellent results with ongoing symptoms in 6 of them and a mean AOFAS hindfoot scale of 79.3. Furthermore, the AAOS-FAM core score improved significantly from 52.3 points preoperatively to 69.9 points postoperatively ($P = .02$). In the largest study to date, El-Rashidy et al[9] evaluated the outcomes of 38 patients after bulk OCA transplantation of the talus. The mean age of the cohort was 44.2 years, 58% of the patients were male, the mean lesion size was 1.5 cm^2, and all patients had a mean of 1 previous operative procedure (range, 0 to 4). After a mean follow-up of 37.7 months, the authors reported that 8 patients (21%) required further operations and the procedures of 4 patients (11%) were considered failures, of which 2 patients received an ankle replacement, 1 patient received an arthrodesis, and 1 patient received a bipolar OCA. The mean AOFAS scale was 78.8 points at the latest follow-up and improved significantly by 26.5 points from pre- to postoperative ($P < .001$). The majority (74%) of the patients reported good to excellent results, and all but 2 patients (95%) would have the surgery again. MRI scans of 15 of the 38 patients at an average of 33 months after surgery revealed only 1 graft collapse. Berlet et al[4] assessed 12 patients after allograft transplantation for the treatment of OLT. In this prospective study, the mean follow-up period was 3.3 years and half of the patients were female, with a mean age of 39.9 years. The mean lesion size was 1.5 cm^2. Before implantation, the allografts were soaked in autologous platelet-rich plasma to improve graft integration and reduce immunogenic reactions. The authors reported no complications, failures, or revisions among the 12 patients. However, 1 patient who was initially enrolled in the study was excluded from the final cohort because of an allograft collapse that required a revision procedure 2.7 years after the initial OCA transplantation. The mean AOFAS scale at the latest follow-up was 79 points, with an average pre- to postoperative improvement of 18 points. Adams et al[1] conducted a small retrospective case series involving 8 patients after OCA transplantation for osteochondral lesions of the talar shoulder that failed initial conservative treatment. The mean age of the patients was 31 years, 62% were female, and the mean lesion volume was 2089 mm^3. After a mean follow-up of 48 months, the authors reported a significant decrease in pain scores, from a mean of 6 points pre- to 1 point postoperatively ($P < .05$), and the mean AOFAS hindfoot scale was 84 points. Even though radiographic lucencies were seen in 5 patients, only 1 of them was symptomatic, and no patient had to undergo subsequent arthrodesis or arthroplasty. Half of the patients required further operative procedures (including hardware removal, arthroscopic debridement, revision open reduction and internal fixation of the malleolar osteotomy, and osteotomy for malalignment of the ankle). Only 1 clinical failure occurred due to a partial graft delamination. Hahn et al[20] evaluated 13 patients who underwent fresh bulk allograft transplantation of the talus. In this cohort, the mean age was 30 years, with 61% being female. The mean lesion size was 2.7 cm^2. After a mean follow-up of 48 months, all patients were satisfied with the procedure and all would have the procedure again. The mean AOFAS score was 81 points with a significant pre- to postoperative improvement. Eleven patients (85%) were able to return to high-impact sport again. Even though 5 patients (39%) had complications and required further operative interventions (4 for hardware removal and 1 for arthroscopic debridement), the authors reported no failed allografts. These results are in line with the data we have shown in our study.

Our study has several limitations, including the small patient population and that the patients were not available for clinical and radiographic examination at the latest follow-up. Another limitation is that the functional outcome data (measured by the AAOS-FAM score and the OMAS) used in this study are difficult to compare with the existing literature. No collection of the AAOS-FAM was done preoperatively. In a recent review, Hunt and Hurwit[24] showed that most of the existing ankle-related outcome studies used the AOFAS scales. However, in an outcome measure instrument validation study, the authors concluded that the AOFAS score may not be sufficient to truly compare or quantify patient outcomes because of its objective components.[34] There is still a need for a more consistent use of valid and reliable outcome measure instruments in foot and ankle–related research.[24,36] We chose the self-administered AAOS-FAM score because it was one of the few foot and ankle scores that has internal and external reliability measures,[38] it met 3 of the 4 validity criteria (with the exception of responsiveness),[24] it was easy to fill out,[8] and it did not require a follow-up clinical examination, for which our patients were not available.

Conclusion

At a median follow-up of nearly 10 years, we observed an improvement of pain and function in 93% of patients, a satisfaction rate of 87%, and a graft survivorship of more than 80% following OCA transplantation of the ankle for OLT. Our study adds promising midterm results to the existing studies with shorter follow-up duration that reported positive outcomes after OCA transplantations of the ankle. However, the high failure and reoperation rates indicate that proper patient selection and education is required prior to the procedure. Considering the treatment alternatives, this procedure was a reasonable treatment option for large OLT after primary failed operative intervention. OCA transplantation may possibly delay further procedures like arthrodesis or arthroplasty, which could be important for the young adult.

Declaration of Conflicting Interests

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Supplemental Material

A supplemental video for this article is available online.

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