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A Comparison of Outcomes of Revision Surgical Options for the Treatment of Failed Bulk Talar Allograft Transfer: A Systematic Review

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ABSTRACT

Talar bulk osteochondral allograft transplantation is a useful treatment strategy for large, uncontained osteochondral lesions of talus. Complications and high revision rates from osteochondral talar allograft transfer can be common. Talar graft failure is a devastating complication that results from failure of allograft incorporation within the host bone and subsequent resorption and sometimes subsidence can occur. Treatment options and outcomes for graft failure have rarely been reported. The purpose of this study is to evaluate treatment options and their outcomes for treating talar allograft failure. A systematic review was completed to find all reports of salvage treatments for talar graft failure and outcomes of these reports were analyzed. Eleven studies involving a total of 522 ankles, in 520 patients, met the inclusion criteria. The allograft failure rate was 11.5% in these studies with a reoperation rate of 18.9%. With limited reports, satisfactory outcomes for treatment of graft failure with ankle arthrodesis were 77.3%, 50% for revision allograft procedures, and 50% for total ankle arthroplasty. Considering the large failure rate and reoperation rate for bulk talar allograft transplantations, superior revision, and salvage options are needed. More prospective cohort studies focusing on consistent and standard outcome measures are needed to further assess revision options for failed talar allograft procedures.

Osteochondral lesions of the talus (OLT) are defects of the articular cartilage of the talus and underlying subchondral bone (1-4). These lesions have poor ability to heal without surgical intervention partially due to the delicate vascular supply to the talus. Most OLTs can be treated arthroscopically with debridement or marrow stimulation techniques (5,6). Large osteochondral defects, as well as uncontained lesions that involve the talar shoulder, can present a treatment challenge. Routine bone marrow stimulation and subchondral drilling techniques have been shown to have poor outcomes in lesions larger than 15 mm (7,8). Fresh osteochondral allograft transplantation is a viable alternative and may be suitable for these lesions. The rationale for allograft transplantation is to implant a viable osteochondral segment, capable of surviving the transplantation, and be fully integrated by the host (9). Osteochondral allograft transplantation fills the defect with mature hyaline cartilage structure while addressing the underlying bone deficiency (10,11). Osteochondral allografts may be created to match any size defect and eliminate the need for donor site morbidity. Thus, this technique is advantageous for large, deep, or uncontained OLTs (12).

Despite successful clinical outcomes, the re-operation rate has been reported as 25% in a systematic review, with failure rates up to 35% (13-15). Complications may include graft failure (failure of graft incorporation with subsequent necrosis and/or subsidence), graft delamination, arthrofibrosis, nonunion, and malunion of malleolar osteotomies (13,14,16-18). One of the most devastating complications is lack of bony ingrowth and subsequent failure of the allograft. Several articles have published case series outcomes and failure rates for osteochondral allograft transplantation of the talus (13,14,16,17,19,20). However, the treatment for these failures has not thoroughly been discussed, and limited outcome studies have been published. The purpose of this study is to present a systematic review of the literature regarding surgical options and outcomes following revision of failed fresh bulk osteochondral allograft transplantation. We hypothesize that ankle arthrodesis will have the best subjective and objective outcomes, but all options,

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including ankle arthroplasty and revision allograft transplantation will have poor results.

Materials and Methods

A systematic review of the literature was conducted to identify all publications related to the treatment of failed talar allograft transplantation. An extensive literature search was performed using an Internet-based search through PubMed Database (https://pubmed.ncbi.nlm.nih.gov/) between January 1, 1990 and April 1, 2019. We performed the systematic review last accessed in April 2019. Six search terms were used, including: (1) "Talar osteochondral allograft," (2) "Treatment talar allograft failure," (3) "Allograft osteochondral defects of the talus," (4) "Talar allograft complications," (5) "Revision talar allograft," (6) "Fresh osteochondral allografting." Three investigators (C.J., E.S., and C.S.) independently performed the electronic searches and assessed by consensus the methodology and quality of each study.

Included were English language studies that reported: (1) the use of fresh or frozen talar allograft, (2) at least 1 outcome measure, and (3) revisional cases, published between January 1, 1990 and April 1, 2019. A published article was excluded if it was a review or techniques report.

The data extracted from the included studies were considered in accordance with the guidelines described in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (21). PRISMA is a 27-item checklist that is intended to improve review quality (21). Appraisal of the included studies was performed using the Coleman Score (22), wherein a score of 100 indicates the highest quality study with no confounding factors or other biases.

Statistical analysis of the pooled data included the weighted mean. The data were weighted as follows: for each sample size, the numeric results were summed and then divided by the total sample size for all included studies (i.e., the weighted mean age was determined by taking the mean for all patients in one study and multiplying it by the number of patients in the study and then repeating this for each included study, after which the total number was divided by the total number of patients and results). To evaluate heterogeneity among the included studies each individual meta-analysis was to be evaluated using the I^2 statistic, which is the percentage of the total variation between studies that cannot be attributed to chance. A statistical description of the pooled data was then compiled and provided in this report.

Results

The search for potentially eligible studies for inclusion yielded a total of 402 items. After considering all of the potentially eligible items, 11 (2.7%) met our inclusion criteria (Figure). A total of 522 ankles (allografts) in 520 patients were included in the current systematic review (Table 1). The weighted mean age was 30.3 years and weighted mean follow-up was 41.2 months. The weighted mean time to revision surgery was 53.3 months. The weighted mean duration of follow-up after revision surgery was 45.3 months. There were 93 (17.82%) reported cases of failed allograft transfer, and 84 (90.3%) of these (16.1% of all allograft procedures) required a revision procedure. Of the 84 reported revision cases, 30 (35.7%) were converted to a revision allograft, 20 (23.8%) were converted to total ankle arthroplasty, and 34 (40.5%) were converted to ankle arthrodesis (Table 2). One of the 5 studies reported on 20 of the 30 revision allograft cases and reported a 5-year survivorship of 84% and 65% at 10 years (23). Of the 14 patients that retained their graft, a mean AAOS-FAM Core score of 70.5 was reported at an average follow-up of 10.3 years (23). Out of the 30 revision allograft cases, 22 reported patient satisfaction which resulted in a 50% satisfactory outcome (n = 11/22), and 30.0% were reported to have a poor result or required additional surgery (n = 9/30) (16,23-27). Only 2 of the 5 studies from the total ankle arthroplasty group reported objective outcomes that were unable to be correlated (23-25). Nine of 11 patients from the Gaul et al study had mean AAOS-FAM score of 82 at average follow-up of 3.8 years (24). Only 4 of the 20 total ankle arthroplasty cases reported patient satisfaction; 2 patients were "extremely satisfied" or had a "satisfactory outcome," and 2 patients had a "poor result" or were "somewhat dissatisfied" (16,24,25). Of the 8 studies that performed revision ankle arthrodesis, only 1 reported AOFAS scores, and another study reported an average AAOS-FAM score of 83 (Table 2) (24,28). Out of the 34 ankle arthrodesis cases, 22 outcomes were reported. Of these, 18.2% were reported to have a poor outcome (n = 4/22), and 77.3% were reported to have a satisfactory outcome (n = 17/22) (16,19,24,26-30).

The overall reoperation rate was 18.9% (n = 99/522). Reported reoperation procedures included hardware removal, revision procedures, arthroscopic debridement and malunion open reduction and internal fixation. The overall incidence of graft failure was 11.5% (n = 60/522) (Table 3). The methodological quality of the included studies was poor. One (9.1%) study was a prospective cohort trial, 2 (18.2%) studies were prospective case series, and 8 (72.7%) were retrospective case series (16,19,23-31). The mean Coleman Score was 54.3 (range 34-67; Table 4) (22). Of the 11 included studies, none warranted a Coleman Score above 70 (22). Due to inconsistent reporting of outcome measures there was insufficient data to perform additional analysis of heterogeneity; hence, we did not implement computations to derive I^2.

Discussion

The purpose of the present systematic review was to evaluate the surgical options and outcomes following revision of failed fresh bulk osteochondral allograft transplantation. Only 11 studies were identified that met the inclusion criteria (16,19,23-31). The most commonly reported revision technique was ankle arthrodesis (34 cases), followed by revision allograft (30 cases), and total ankle arthroplasty (20 cases). Eight studies were retrospective case series, which are prone to selection bias. There was significant inconsistency in reported subjective and objective outcomes. Thus, the reported results in the current study should be interpreted with caution.

Complication rates from osteochondral allograft transplantation are relatively high, as graft failure, disease transmission, immunogenic response, delayed union of a malleolar osteotomy, as well as hardware irritation and infection can all negatively affect the outcome (9,13). Graft survival has varied from 66% to 100% (14,16,18-20,27) and according to a recent systematic review the reoperation rate is 25% for talar allograft transplantation (13). This study found improved results from the included reports, with a total reoperation rate of 18.9%, and graft failure rate of 11.5%. However, there were inconsistencies in the thoroughness of the reported reoperation rate in the included studies, and this percentage may even be higher. With such a high risk for complication, it is important to understand the revision options and outcomes when these complications occur. A common reason for revisions is fragmentation and resorption of the graft that subsequently leads to collapse (14,18,19,27). Graft failure is consistently associated preoperatively with the presence of subchondral cystic lesions, prior operation, as well as large lesions (7,12,16). Understanding these risk factors may aid in preventing a poor outcome, and pointing the surgeon down a different treatment route.

Disease transmission and graft versus host immunogenicity are 2 other potential risks that can be detrimental to a patient receiving an osteochondral allograft transplant. Allograft-associated infection is rare but may potentially be fatal. Clostridium contamination risk increases with the length of time between donor death and procurement (32,33). According to the report by Mroz et al (34), there have been 3 reported cases of HIV transmission, 2 cases of hepatitis C virus transmission, and 1 case of hepatitis B virus transmission through allograft tissue (34). Although advances in serologic testing and pathogen prevention have improved for allografts, it is important to always inform patients of this risk.

It is unknown how big a role the immune response is to osteochondral allograft transplantation. It has previously been suggested that articular cartilage is relatively immunoprivileged, as the surrounding matrix around the chondrocytes protects against the host's immune cells, whereas bone marrow components of the allograft may not (35-37). Although animal studies have shown less immunologic reaction in cross matched donor allografts, unmatched allografts have not yet been

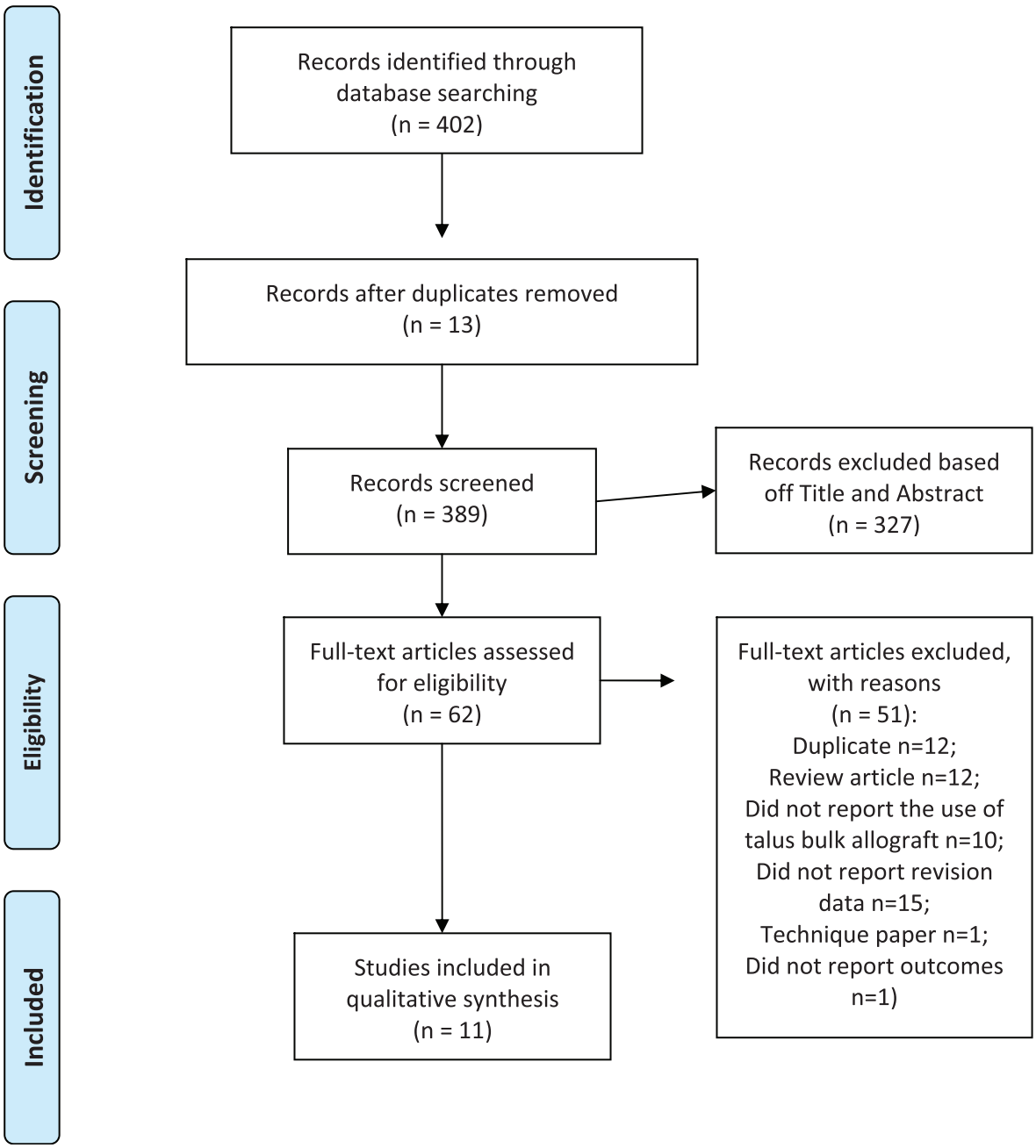

Figure. A flowchart showing the results of the published data search using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis 2009 Guidelines (21).

shown to have a significant decline in clinical outcomes (36,38). In a study by Meehan (25), 10 out of 11 patients tested positive for serum HLA cytotoxic antibody post operatively after receiving fresh osteochondral allografting for the ankle joint (25). The one case that did not test positive was on an immunosuppressant medication for a kidney transplant, and this patient's radiographic and clinical outcome scores proved to be the most successful in the cohort. Further understanding of the graft versus host response may be beneficial in decreasing graft failure rates.

Total ankle replacement, ankle arthrodesis, and revisional talar allograft replacement have all been described in the literature for the treatment of graft failure (Table 2) (14,19,23-25,30,39). Ankle arthrodesis has been reported the most as a revision option with 34 cases, 22 of which were found to report outcomes (16,19,23-31). There was a reported 18.2% poor outcome rate, with a 77.3% (17/22 patients) satisfactory outcome rate for ankle arthrodesis as the revision method (16,19,23-31). Satisfactory outcome rate for revision allograft procedures was 50% (11/22 patients), and 50% (2/4 patients) for total ankle arthroplasty (16,23-27). These results are limited due to such a small patient population and low quality of studies, especially for the total ankle arthroplasty cohort. Although ankle arthrodesis is one of the most reported revision options, it remains a challenge in young patients, as arthrodesis can provide predictable pain relief, but at the risk of functional limitations and the development of adjacent joint arthritis. Adjacent hindfoot arthritis is inevitable following ankle arthrodesis, with an occurrence reported as approximately 50% at 8 years and nearly 100% at 20 years (40-43).

Table 1
Demographic data included in the systematic review

Author	Level of evidence	N (ankles)	N (patients)	Mean age (y)	Follow-up (mo)	Graft failure (N)	Revision procedure	Follow-up at time of revision surgery (mo)	Follow-up after revision (mo)
Meehan et al 2005 (25)	IV	11	11	43	33	5	3 bipolar allografts, 1 TAA, 1 no further surgery	26.8	12.5
El-Rashidy et al 2011 (16)	IV	38	38	44.2	37.7	4	2/4 TAA, 1/4 ankle arthrodesis, 1/4 bipolar allograft	NA	NA
Raikin et al 2004 (28)	IV	6	6	36	23.1	1	Ankle arthrodesis	17	NA
Jeng et al 2008 (26)	IV	29	29	41	24	20	14 (5 repeat allograft transplantation, 3 TAA, 5 ankle arthrodesis	N/A	N/A
Raikin et al 2009 (19)	IV	15	15	41.9	54	2	Ankle arthrodesis	54	NA
Gortz et al 2010 (27)	IV	12	11	35.5	38	2	1 revision allograft, 1 arthrodesis	23.5	86
Giannini et al 2014 (29)	III	57	57	35.5	47.3	9	Arthrodesis	22.7	N/A
Adams et al 2018 (31)	IV	14	14	40	55	2	Total ankle arthroplasty	NA	N/A
Haene et al 2012 (30)	IV	17	16	35.8	49	4	2 ankle arthrodesis	NA	
Gaul et al 2018 (23)	IV	175	175	NA	123.6	20	20 Revision allograft	80.4	NA
Gaul et al 2019	IV	148	148	NA	AA 88.8; TAR 45.6	24	13 Ankle arthrodesis, 11 Total ankle arthroplasty	AA 40.8; TAR 73.2	NA
Total		522	520	30.3	41.2	93	84	53.3	45.3

Abbreviation: TAA, total ankle arthroplasty.

Table 2
Reported outcomes by revision procedure

	Pre-AOFAS	Post-AOFAS	Post-FFI	Post-SMFA	Post-AAOS-FAM core score	Other
Revision allograft						
Failure 1 (Meehan 2005) (25)	61	87	2.4	9.5	NA	Patient satisfied
Failure 2 (Meehan 2005) (25)	53	41	5.3	24.6	NA	Patient satisfied
Failure 3 (Meehan 2005) (25)	56	70	2.3	6.1	NA	Patient satisfied
Failure 4 (El-Rashidy 2011) (16)	NA	NA	NA	NA	NA	Poor result and/or incomplete chart
Failure 5-9 (Jeng 2008) (26)	NA	NA	NA	NA	NA	2 satisfactory radiographs with no clinical complaints, 1 joint space narrowing with slight improvement, 2 required additional surgeries: 1 TAA, 1 bone block ankle arthrodesis
Failure 10 (Gortz 2010) (27)	NA	NA	NA	NA	NA	OMAS score of 100, subjective excellent outcome at 86 months post revision
Failure 11-30 (Gaul 2018) (23)	NA	NA	NA	NA	70.5 (SD 17, range 42.3-99)	4 Extremely satisfied, 1 satisfied, 3 Somewhat satisfied, 4 dissatisfied, 4 required salvage arthrodesis, 1 required arthroplasty, 1 BKA
Arthroplasty						
Failure 31 (Meehan 2005) (25)	49	41	7.4	44.3	NA	Patient satisfied
Failure 32-33 (El-Rashidy 2011) (16)	NA	NA	NA	NA	NA	Poor result and/or incomplete chart
Failure 34-37 (Jeng 2008) (26)	NA	NA	NA	NA	NA	N/A
Failure 38-39 (Adams 2018) (31)	NA	NA	NA	NA	NA	n/a
Failure 40-50 (Gaul 2019)	NA	NA	NA	NA	82 (SD 26, range 52-98)	1 extremely satisfied, 1 somewhat dissatisfied
Arthrodesis						
Failure 51 (El-Rashidy 2011) (16)	NA	NA	NA	NA	NA	Poor result and/or incomplete chart
Failure 52 (Raikin 2004) (28)	42	64	NA	NA	NA	1/1 ankle arthrodesis: reported satisfactory outcome, would still have undergone procedure again
Failure 53-57 (Jeng 2008) (26)	NA	NA	NA	NA	NA	N/A
Failure 58-59 (Raikin 2009) (19)	NA	NA	NA	NA	NA	2/2 ankle arthrodesis patients rated their result as poor, but stated they would still undergo the allograft procedure if asked to do it again
Failure 60 (Gortz 2010) (27)	NA	NA	NA	NA	NA	failed arthrodesis due to chronic pain
Failure 61-69 (Giannini 2014) (29)	NA	NA	NA	NA	NA	9 failures at mean 22.7 months, all received ankle arthrodesis, 9/9 achieved satisfactory outcomes
Failure 70-71 (Haene 2012) (30)	NA	NA	NA	NA	NA	2 graft failures converted to ankle arthrodesis, no outcomes reported
Failure 72-84 (Gaul 2019)	NA	NA	NA	NA	83 (SD 13, range 64-100)	4 extremely satisfied, 3 satisfied, 1 somewhat dissatisfied

Abbreviations: AOFAS, American Orthopedic Foot and Ankle Society; FFI, Foot Function Index; SMFA, Short Musculoskeletal Functional Assessment Questionnaires; AAOS-FAM Core Score, American Academy of Orthopaedic Surgeons-Foot and Ankle Module Core Scale.

Total ankle arthroplasty is a second option for treating failed talar allograft implantation. This option is limited to certain cases, as too much osteonecrosis or allograft collapse in the talus can interfere with the talar component and lead to early failure of the implant. In cases where the osteonecrosis and graft failure can be resected with you talar cuts, then ankle arthroplasty becomes a revision option (31). In the prospective case series from Adams et al (31), 2 of 14 patients after having received fresh osteochondral allograft transplantation to the talar shoulder, were considered failures due to cartilage delamination (31). These 2 failures were converted to a total ankle replacement,

Table 3
Number of reoperations, graft failures, and reported complications

Author	Patients requiring reoperation	Graft failure	Nonunion/ delayed healing	Superficial Infection	Deep Infection	DVT/ PE	Wound complication	Disease transmission	Hardware complication	Malunion	Adjacent joint arthritis	Fibular fracture	Immunogenicity	Other
Meehan et al	7	5	NA	1		NA	NA	NA	2	NA	NA	1	Cytotoxic serum HLA-antboids (+) in 10/11 patients	NA
El-Rashidy et al 2011 (16)	8	4	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA
Raikin et al 2004 (28)	1	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Jeng et al 2008 (26)	14	20	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA
Raikin et al 2009 (19)	4	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gortz et al 2010 (27)	3	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Giannini et al 2014 (29)	9	9	NA	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA
Adams et al 2017	5	2	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	2 cartilage delamination
Haene et al 2012 (30)	4	4	NA	NA	NA	NA	NA	NA	NA	1 medial mal malunion	NA	NA	NA	
Gaul et al 2018 (23)	20	6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gaul et al 2019	24	5	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	99	60												
Incidence	18.90%	11.50%												

Abbreviations: DVT, deep venous thrombosis; PE, pulmonary embolism.

Table 4
Coleman scores

		Meehan et al	El-Rashidy et al	Raikin et al	Jeng et al	Raikin et al	Gortz et al	Giannini et al	Adams et al	Haene et al	Gaul et al (2018)	Gaul et al (2019)
Part A	1. Study size	0	0	0	0	0	0	4	0	0	10	10
	2. Mean follow-up	0	3	0	0	3	3	3	3	3	3	5
	3. Percentage follow-up	3	5	5	5	5	5	5	5	5	5	3
	4. Number of interventions	5	5	5	10	10	10	5	10	10	10	10
	5. Type of study	0	0	0	0	10	0	10	10	0	0	0
	6. Diagnostic certainty	0	0	0	0	5	5	5	5	5	5	5
	7. Description of technique	3	5	3	5	5	5	5	5	5	5	5
	8. Description of postop rehab	5	5	0	5	5	5	5	5	5	0	0
Part B	1. Outcome criteria	7	7	5	8	8	10	6	8	10	7	7
	2. Procedure for assessing outcomes	3	6	6	6	6	6	6	6	6	3	3
	3. Description of subject selection process	10	10	10	10	10	10	10	10	10	10	10
Total score		36	46	34	49	67	59	64	67	59	58	58

exemplifying a scenario of how this salvage technique can be utilized for certain patients (31).

The third reported salvage technique is revisional ankle allograft transplantation. Although, a 50% patient satisfaction rate is reported from our review, bipolar ankle osteochondral allografts have been reported having as low as 31% success rates (16,25-27). In El-Rashidy's case series, one reported graft failure was salvaged with repeat grafting utilizing a bipolar allograft (16). Unfortunately, no specific outcomes on this case were reported (16). Jeng et al (26) reported on 2-year outcomes from 29 patients that had received osteochondral ankle allografts, though, all of their grafts were bipolar and only one of these cases was used to treat an osteochondral lesion of the talus (26). They reported the low success rate of 31% (26). Fourteen of the 29 revisions required a repeat ankle transplant, prosthetic total ankle arthroplasty, or bone block arthrodesis (26). Meehan et al (25) reported on 11 patients with end-stage ankle arthritis that were treated with fresh osteochondral allograft procedures, 9 of which were bipolar (25). This study reports 5 failures (45%) in the average 33 months of follow-up (25). Three of which required complete revision of their osteochondral allograft, 1 was converted to a total ankle arthroplasty, while the fifth case had severe graft collapse with no further surgery elected (25). Of the 4 revision cases, subjective satisfaction results were reported after 6 to 12 months from revision surgery, and all 4 patients were reportedly satisfied (25). A total second operation rate of 63.6% occurred in this study (25). Although this study was not specifically addressing failed talar allograft transplantation, it does report a large complication and failure rate of bipolar osteochondral allografts. According to Meehan et al (25), the main advantage to a repeat osteochondral allograft procedure would be that it further preserves the option of arthrodesis and arthroplasty, which can potentially be harder to revise (25). Although revisional talar allograft and bipolar ankle allografts remain a salvage option, case series results have shown high failure rates and limited success with the bipolar ankle allograft technique (16,23,25,26,43).

Of note, 2 recent studies were published by Gaul et al that looked at all 3 of these revision options on their cohort of patients that had failed prior talar or tibiotalar allografting (23,24). These 2 studies did provide a large volume of revision cases to our systematic review (20 revision osteochondral allografting, 13 ankle arthrodesis, and 11 total ankle arthroplasty) (23,24). This inherently provided a larger weight to our mean averages for our systematic review data, increasing the risk of bias to our results. If these Gaul studies were excluded from our data our results would include a 27.6% reoperation rate (55/199) and a 24.6% graft failure rate (49/199) following a talar allograft procedure. And, patient satisfaction for the following revision techniques would be: 60% (6/10 patients) for revision allograft, 50% (1/2 patients) for total ankle arthroplasty, and 71.4% (10/14 patients) for ankle arthrodesis. The patient satisfaction averages are similar with and without the Gaul data being added, but the revision and reoperation rates from the Gaul data were much lower than the other studies and the systematic review by VanTienderen et al (13,23,24). This may explain why our reoperation rate was only 18.9%. The Gaul studies did provide a good comparative group for AAOS-FAM Core scores as they reported a mean average 70.5 for their revision allograft group, 82 for their total ankle arthroplasty group, and 83 for their ankle arthrodesis group (23,24).

There are important limitations to this systematic review. The inclusion criteria allowed articles written only in the English language. Therefore, this may have excluded relevant articles that could have otherwise affected the results and may have given bias favoring research emanating from English-speaking countries. In addition, the current data are reflective only from the published literature, and thus the conclusions must be interpreted in light of publication bias. Due to the paucity of high-level evidence, practical concerns still exist regarding optimal surgical treatment and long-term outcomes. Due to inconsistent reporting of outcome measures, there were insufficient data to perform additional analysis of heterogeneity. Therefore, a subgroup or meta-analysis to compare outcomes between surgical procedures was not possible. Unfortunately, the overt inconsistency in the reported outcomes observed in the reports that we included were, at face, markedly different, indicative of a high degree of heterogeneity. As such, we did not pursue calculation of the I^2 statistic, which further limits the value of our review.

Strengths of the study include unanimous agreement among the authors regarding inclusion and exclusion of all studies. We used an evidence-based database and reporting guidelines to reduce the risk of publication bias and increase transparency (21). The reported outcomes after revision allograft, total ankle arthroplasty, and ankle arthrodesis are of clinical importance. Lastly, there are no previous guidelines or meta-analysis to determine the optimal treatment after failed talus bulk allograft transfer. Thus, the current systematic review serves to address this gap in knowledge.

In conclusion, our pooled results demonstrate that satisfactory outcomes may be achieved with revision allograft transfer, total ankle arthroplasty, and revision ankle arthrodesis as salvage options after failed talus allograft transfer. The evidence in the current literature precludes strong recommendations with regard to superior revision procedures or salvage options. Further research is warranted, including appropriately powered prospective cohort studies focusing on consistent and standard report of objective and subjective outcomes.

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