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Saudi Orthopedic Association

Journal of Musculoskeletal Surgery and Research

Review Article

Allograft use in foot and ankle reconstruction: A narrative review of indications, outcomes, and limitations

Mayar A. Alqarni, MBBS.[1], Khalid M. Alhomayani, MD.[1], Hashem A. Bukhary, MD.[1]

[1]Department of Surgery, Orthopedic Division, College of Medicine, Taif University, Taif, Saudi Arabia.

***Corresponding author:**
Mayar A. Alqarni,
Department of Surgery,
Orthopedic Division, College of Medicine, Taif University, Taif,
Saudi Arabia.

dr.mayaralqarni@outlook.com

Received: 27 June 2025
Accepted: 09 August 2025
Epub ahead of print: 03 October 2025
Published: 01 January 2026

DOI
10.25259/JMSR_300_2025

Quick Response Code:

ABSTRACT

Allografts have emerged as an effective option in foot and ankle reconstruction, offering advantages such as reduced donor site morbidity and shorter operative time compared to autografts. This narrative review examines the clinical efficacy, safety, and applications of biologic allografts, excluding synthetic grafts, in a variety of foot and ankle procedures. A structured literature search was performed using PubMed, Embase, and the Cochrane Library to identify English language studies published from January 2000 to April 2024. The search strategy combined medical subject headings terms and keywords including "allograft," "tissue transplantation," "foot and ankle reconstruction," "osteochondral defects," "Achilles tendon," "lateral ligament," and "ankle arthroplasty." Eligible studies reported on patient-reported outcomes, functional assessments, or complication rates. While autografts remain the standard in many settings, allografts have demonstrated comparable outcomes in selected procedures, particularly when autograft harvest is contraindicated or undesirable. The success of allografts depends on appropriate graft selection, surgical technique, and the specific anatomical site. Future advances in tissue processing and biologic integration may enhance their role in complex reconstructions.

Keywords: Achilles tendon, Allografts, Foot and ankle reconstruction, Osteochondral defects, Tissue transplantation

INTRODUCTION

Allografts play a key role in reconstructive foot and ankle surgery, offering solutions for complex conditions such as bone defects, ligamentous injuries, and cartilage damage. An allograft is defined as tissue transplanted from one individual of the same species but with a different genetic composition to another individual of the same species.[1] These grafts offer structural integrity, stimulate biological healing, and significantly reduce donor-site morbidity associated with autograft harvest, leading to their widespread adoption in orthopedic procedures, specifically in foot and ankle surgeries.[2]

Allografts may be classified based on their tissue composition and intended clinical application into ligamentous or tendinous allografts, structural or cancellous bone allografts, and osteochondral allografts. Each category provides specific advantages tailored to distinct

How to cite this article: Alqarni MA, Alhomayani KM, Bukhary HA. Allograft use in foot and ankle reconstruction: A narrative review of indications, outcomes, and limitations. J Musculoskelet Surg Res. 2026;10:33-9. doi: 10.25259/JMSR_300_2025

surgical scenarios. For instance, structural bone allografts are frequently utilized in subtalar arthrodesis and hindfoot reconstructions to restore anatomical alignment and biomechanical function, while fresh osteochondral allografts effectively address extensive cartilage lesions of the talus.[1,3] Recent advancements have further expanded their clinical applicability by introducing biologically enhanced allografts containing mesenchymal stem cells (MSCs), which demonstrate osteogenic, osteoinductive, and osteoconductive properties, making them especially beneficial in complex revisions and challenging reconstructive procedures.[4]

There are several reasons for the use of allografts in foot and ankle surgery. A significant advantage is the avoidance of donor site morbidity, a notable drawback associated with autograft harvesting.[1] In addition, allografts provide effective solutions for extensive defects where autologous tissue alone proves insufficient.[5] The utilization of pre-prepared allograft tissue also reduces operative time compared to procedures requiring autograft harvesting, enhancing surgical efficiency.[2] Beyond these practical advantages, many advanced allografts possess intrinsic biological properties that facilitate tissue healing. For example, MSC-based grafts actively promote bone regeneration through their osteogenic capabilities.

Nevertheless, the adoption of allografts involves certain challenges. Potential risks such as disease transmission, immunological rejection, and inconsistent rates of graft integration must be carefully considered during graft selection for specific surgical procedures. Advances in tissue preservation, including cryopreservation and sterilization techniques, have significantly mitigated these risks over recent years. Such advancements have improved graft viability and reduced immunogenicity, enhancing both the safety and reliability of allograft use.[1,2]

Clinically, allografts have demonstrated particular value in situations where native tissue is insufficient or unsuitable for reconstruction. For instance, fresh osteochondral allografts have shown promising mid- to long-term outcomes in addressing extensive talar cartilage defects.[5] Structural bone allografts similarly play a crucial role in arthrodesis procedures by providing mechanical stability and promoting fusion.[3] Tendon and ligament allografts are frequently utilized in reconstructive procedures such as chronic lateral ankle instability (CLAI) repair or Achilles tendon reconstruction when autologous tissues are unavailable or inadequate.[2]

The growing body of evidence supporting the efficacy of allograft-based approaches highlights their potential to enhance functional outcomes and reduce surgical complications in foot and ankle reconstruction. Future developments are likely to focus on biologically enhanced grafts and innovations in tissue engineering, potentially revolutionizing clinical practice by optimizing graft integration rates and long-term surgical success.

This narrative review aimed to critically examine the current evidence on the use of allografts in foot and ankle reconstruction, highlighting their clinical indications, reported outcomes, limitations, and emerging advancements.

MATERIALS AND METHODS

This narrative review was conducted using a structured literature search of three major electronic databases: PubMed (MEDLINE), Embase, and the Cochrane Library. The search encompassed studies published from January 2000 to April 2024 and was limited to English-language articles. To maximize the retrieval of relevant literature, a combination of medical subject headings and free-text terms was used with the following Boolean strategy:

("Allograft" OR "Tissue Transplantation") AND ("Foot Surgery" OR "Ankle Surgery" OR "Foot and Ankle Reconstruction") AND ("Osteochondral Defects" OR "Achilles Tendon" OR "Lateral Ligament" OR "Subtalar Arthrodesis" OR "Ankle Arthroplasty").

Studies were eligible for inclusion if they:

- Focused on the clinical application of allografts in foot and/or ankle surgery, and
- Reported outcomes such as patient-reported scores, graft integration, surgical complications, or functional recovery.

Exclusion criteria were as follows:

- Experimental animal studies
- Biomechanical studies without clinical outcomes
- Studies involving synthetic grafts or xenografts.

A total of 40 studies met the inclusion criteria and were included in the final review. Most of the included literature represented Level III or IV evidence, consisting primarily of retrospective case series, observational studies, and narrative reviews. No randomized controlled trials were identified. As this is a narrative review, a formal grading system of evidence was not performed; however, the methodological limitations and heterogeneity of the included studies were considered in the interpretation of findings and mentioned in the limitations section. Data were synthesized to evaluate the role of allografts in various foot and ankle reconstruction procedures, including ligament repair, osteochondral lesion management, arthrodesis, and tumor-related reconstruction.

DISCUSSION

Historical perspectives

In the late 19th and early 20th centuries, pioneers in orthopedic surgery began experimenting with bone transplantation, paving the way for modern allograft utilization. In 1881, William Macewen first documented the use of allografts for skeletal reconstruction, marking an early milestone in bone grafting.[6] However, the initial applications faced significant challenges, such as immunological rejection and infection, due to a limited understanding of tissue compatibility and sterilization techniques.[6] Early large-scale osteochondral allograft transplants conducted by surgeons like Erich Lexer in the early 1900s were primarily experimental, reserved for severe trauma or malignancies requiring limb salvage.[7] Despite these technical and immunological limitations, such pioneering efforts laid crucial foundations for contemporary allograft research and clinical practice.

The prominence of allografts, especially in foot and ankle surgery, increased significantly during the latter half of the 20th century. During the 1960s and 1970s, case series documenting osteochondral allograft transplantation became more frequent, particularly in managing osteoarthritic lesions and malignancies.[8] Gross *et al*. highlighted the widespread adoption of osteochondral allografts in the 1990s for preserving ankle joints in cases of osteochondral lesions and post-traumatic arthritis.[9] Concurrently, research demonstrating favorable biomechanical properties and positive clinical outcomes established allograft tendons as standard options for ligamentous reconstruction, including Achilles tendon repair.[10] These advancements underscore the evolving reliability and preference of allografts over autografts in complex reconstructive surgeries.

Benefits and limitations of allografts

Allografts have become increasingly popular in foot and ankle reconstruction due to their availability and versatility. Key advantages include reduced surgical time, absence of donor-site morbidity, availability of larger graft sizes, and the capacity for pre-shaping and sizing, which enables a precise anatomical fit during surgery.[11] They are particularly valuable in cases requiring extensive reconstruction or when autologous tissue is insufficient. However, the use of allografts also has notable limitations. Despite substantial mitigation through enhanced screening and processing techniques, the risk of disease transmission remains a critical concern.[12]

Table 1: Key advantages and disadvantages of allografts in foot and ankle reconstruction.

Advantages	Disadvantages
No donor site morbidity	Risk of disease transmission
Reduced operative time	Slower graft incorporation than autografts
Availability of larger, pre-shaped grafts	Higher graft failure
Useful in complex or revision cases	Risk of immunogenic reaction
Versatility in different reconstructive contexts	Prolonged recovery in some cases

In addition, allografts may exhibit higher rates of graft failure, slower integration compared to autografts, and potentially extended recovery periods.[13] Immunogenic reactions elicited by allografts can also adversely affect graft integration and long-term outcomes.[14] Thus, while offering notable advantages, allografts present certain risks and limitations that must be carefully weighed. The choice between allografts and autografts should be individualized based on the specific procedure, patient characteristics, and surgical expertise.[12] Recent advancements in tissue engineering and decellularization techniques hold promise for enhancing allograft performance, reducing immunogenicity, and further expanding their role in foot and ankle reconstruction.[14] The key advantages and disadvantages of allografts in foot and ankle reconstruction are summarized in Table 1.

Allografts currently represent 57% of the bone graft market, positioning them as the predominant commercial option.[15] However, the cost and availability of allografts can vary based on factors such as the donor's age, sex, and the type of graft.[16] These variables may influence the selection and availability of specific allograft types. Furthermore, allografts obtained from female donors aged 50 and above have demonstrated significantly higher rates of anterior cruciate ligament (ACL) graft rupture, which may affect their utilization and availability in certain patient populations.[16] Despite their widespread use, allografts continue to face challenges related to disease transmission and limited supply, which can constrain their availability in certain contexts.[15] The financial implications of using allografts extend beyond the initial purchase cost. While they may reduce the morbidity associated with autograft harvesting and provide control over graft size,[16] they can be resource-intensive and encounter supply difficulties.[17] This could lead to increased costs for procurement and processing. Nevertheless, the potential benefits of allografts, such as reduced surgical time and lower donor site morbidity, may help offset some of these costs.

Ligament allografts in foot and ankle surgery

Lateral ankle ligament reconstruction

Lateral ankle ligament reconstruction using allografts is indicated in patients with CLAI refractory to conservative management.[18] CLAI commonly results from inadequately treated acute lateral ligament injuries, requiring surgical intervention when extensive rehabilitation is unsuccessful.[18,19] Reconstruction typically follows an anatomical approach, particularly if damaged ligaments are irreparable. Arthroscopic techniques have also emerged, providing minimally invasive reconstruction alternatives.[20] During the procedure, grafts should be tensioned to approximately 10 N, with careful avoidance of excessive tension, particularly when employing non-absorbable augmentations.[19] Clinical outcomes using allografts for lateral ankle ligament reconstruction have demonstrated significant improvements in patient-reported outcome measures, including the Manchester-Oxford Foot Questionnaire, the American Orthopedic Foot and Ankle Society (AOFAS) score, and the Karlsson score.[20-22] However, reconstructed ligaments may not completely replicate the biomechanical properties of native ligaments.[12] Although complications are uncommon, superficial peroneal nerve injury and mild anteroinferior lateral ankle pain can occur postoperatively.[20,21] Tenodesis techniques are discouraged due to inferior long-term outcomes linked to altered hindfoot biomechanics.[15] Overall, the use of allografts for lateral ankle ligament reconstruction offers favorable clinical outcomes with low complication rates.[18] Overall, allograft use for lateral ankle ligament reconstruction offers favorable clinical outcomes with low complication rates.

Achilles tendon reconstruction

Allograft reconstruction of the Achilles tendon is recommended for chronic ruptures with gaps exceeding 4 cm, making direct repair impractical.[23] Reconstruction methods depend on defect size and residual tissue quality, with Achilles tendon allografts being highly effective for larger defects. The procedure involves bridging the tendon gap using allograft tissue that is securely attached to the native tendon remnants and the calcaneus, aiming to restore tendon continuity and function.[23] While allografts reduce donor-site morbidity and surgical duration, potential risks include disease transmission, delayed integration, and immune reactions.[24] Clinical outcomes have been predominantly positive, with studies reporting significant improvements in AOFAS scores from 68.7 preoperatively to 98.0 postoperatively. Functional recovery was further demonstrated by participants' ability to perform single-heel raises and hops at final follow-up.[23] Nonetheless, wound complications and infections are potential concerns, though not observed in the referenced study.[23]

Deltoid ligament reconstruction

Deltoid ligament reconstruction utilizing allografts is primarily indicated for chronic medial ankle instability, patients with a history of unsuccessful primary repairs, or those with ligamentous laxity.[25,26] Although less common than lateral injuries, deltoid lesions significantly impair ankle stability and function.[27] Importantly, deltoid pathology is frequently underdiagnosed in patients with lateral ankle instability; up to 72% of those undergoing surgery for chronic lateral instability also have deltoid involvement, even in the absence of medial symptoms.[28] This highlights the need for thorough evaluation and potential reconstruction in complex cases. Although detailed techniques for deltoid ligament reconstruction using allografts are limited in the literature, anatomical reconstruction principles apply, aiming to restore the biomechanical integrity of both superficial and deep ligament components.[28] Potential allograft options include anterior tibial tendon grafts, which are placed precisely to mimic the original ligament anatomy and tension.[29] Clinical outcomes specific to deltoid ligament reconstruction using allografts are currently sparse. However, analogous procedures for lateral ligament reconstruction using allografts have shown high patient satisfaction, functional improvements, and low revision rates at 3-year follow-ups,[30] suggesting that similar promising outcomes may be achievable for deltoid ligament reconstructions, pending further research.

Bone allografts in foot and ankle surgery

Hindfoot reconstruction and subtalar arthrodesis

Bone allografts serve as a critical resource for both subtalar arthrodesis and broader hindfoot reconstruction, addressing bone defects, arthritic changes, and complex deformities arising from trauma or tumor excision.[31,32]

In severe cases where conservative treatment is ineffective, surgery may be the only alternative to amputation.[31] Structural allografts, such as hemicylindrical and calcaneal grafts, have demonstrated superior survival rates, with techniques ranging from *in situ* arthrodesis and lateral calcaneal wall decompression to intramedullary nailing.[31,32] Tantalum spacers have also emerged as effective alternatives, showing promising fusion rates and lower complication profiles.[33]

Clinical outcomes associated with both subtalar arthrodesis and hindfoot reconstruction are generally favorable, with reported allograft survival rates of 79% at both 5 and 10 years.[34] Patient satisfaction is typically high, encompassing significant improvements in pain, foot function, and overall mobility.[31] Nevertheless, complications can arise, including infection, non-union, hardware-related issues, stress fractures, and articular failure, particularly with calcaneal and osteoarticular allografts.[34] The complication rate for structural allografts can be as high as 36%, although other studies have documented lower complication rates of approximately 17%, highlighting variability based on graft type and surgical techniques.[35] Thorough pre-operative evaluations remain vital for identifying the true source of pain and ensuring optimal patient selection.[26] Advancements in screening and sterilization methods continue to reduce disease transmission risks, thereby bolstering the reliability and safety of allograft use.[26]

Osteochondral defects of the talus (osteochondral allograft)

Osteochondral allografts are increasingly utilized for significant osteochondral talar defects, particularly those exceeding 1.5 cm in diameter or 150 mm^2 in area, cystic lesions, or revision cases.[36] They effectively address extensive lesions lacking subchondral bone integrity. The procedure typically employs an open surgical approach, in which the defect is prepared and a donor osteochondral allograft is precisely sized and shaped to fit securely, thereby restoring the native hyaline cartilage and subchondral bone structure.[36] Clinical outcomes are generally positive, demonstrating improved pain relief and functional scores. Despite encouraging results, complications such as graft failure, non-union, and infection have been reported.[35,37]

Bone allografts in fracture and tumor-related reconstruction

Bone allografts are essential in the management of foot and ankle fractures, non-union, and defects resulting from trauma or tumor excision.[34,35] In fracture management, particularly for intra-articular calcaneal fractures, bone substitutes such as calcium phosphate and calcium sulfate have demonstrated effectiveness in filling defects, maintaining reduction, and promoting union.[38] Reconstruction in tumor-related cases often involves resection of affected bone segments, followed by stabilization using non-vascularized structural bone allografts combined with autologous bone chips, secured by intramedullary nailing or plating.[39] Clinical outcomes generally reflect allograft survival rates of around 79% at 5 and 10 years. However, notable complication rates of up to 36% have been reported, including non-union, local recurrence, infection, fracture, and articular failure.[34] High-dose irradiation of bone allografts, aimed at reducing infection risk, can increase the incidence of fractures compared to non-irradiated grafts.[40] Therefore, meticulous pre-operative planning, surgical expertise, and careful consideration of potential complications are essential for achieving optimal outcomes in fracture and tumor-related reconstruction using bone allografts.

Limitations

Most included studies were Level III or IV evidence, such as retrospective case series, limiting the strength of conclusions. Study heterogeneity in graft type, surgical technique, and outcome measures further restricts direct comparison. As a narrative review, no formal bias assessment was conducted. These limitations highlight the need for high-quality, prospective research to better define the role of allografts in foot and ankle reconstruction.

CONCLUSION

Allografts play a pivotal role in foot and ankle reconstruction by providing viable solutions for ligamentous repair, managing bone defects, and restoring osteochondral tissue. Their key benefits – reduced morbidity, surgical efficiency, and biological versatility – support their continued adoption in diverse clinical scenarios. Despite these advantages, selecting the appropriate graft, employing meticulous surgical technique, and implementing robust screening and sterilization protocols remain essential to mitigate immunogenic reactions, infection risk, and potential graft failure. Ongoing innovations in tissue engineering and biologically enhanced grafts may further enhance integration rates and long-term outcomes, solidifying the central role of allografts in complex foot and ankle reconstructions.

Recommendations: Allografts should be selectively used in cases involving large defects, revision surgeries, or when autografts are unsuitable. Graft selection must be guided by the defect's size, location, and biomechanical demands. Optimal outcomes rely on precise surgical technique and proper graft handling. Rigorous donor screening and validated processing methods are essential to minimize immunogenic and infectious risks. Biologically enhanced grafts may offer additional benefits in complex reconstructions. Continued outcome monitoring and further research are recommended to refine indications and improve long-term success.

Authors' contributions: HAB: Conceived and designed the study; MAA: Conducted research, provided research materials, and collected and organized the data; MAA and KMA: Wrote the initial and final draft of the article. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

Ethical approval: The Institutional Review Board approval is not required.

Declaration of patient consent: Patient's consent was not required as there are no patients in this study.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation: The author confirms that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

Conflicts of interest: There are no conflicting relationships or activities.

Financial support and sponsorship: This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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