

Reconstructive Strategies for Distal Lower Extremity Defects: A Critical Review of Free Flaps, Propeller Flaps, and Locoregional Options

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ABSTRACT

Reconstruction of distal lower extremity defects represents a significant challenge in plastic and reconstructive surgery due to limited soft tissue coverage, compromised vascularity, and high functional demands. Over the last decades, reconstructive strategies have evolved from free flaps as a universal solution to a more individualized approach incorporating locoregional flaps, perforator-based propeller flaps, and optimized perioperative management. This review critically synthesizes current evidence regarding reconstructive options for distal leg and foot defects, focusing on clinical outcomes, complication profiles, patient selection, vascular assessment, and postoperative rehabilitation. Available data suggest that while free flaps remain indispensable for extensive and complex defects, locoregional and propeller flaps offer comparable short-term functional and aesthetic outcomes in selected cases, with reduced operative burden. However, the presence of osteosynthesis material, vascular comorbidities, and diabetic microangiopathy significantly modifies reconstructive risk. Current evidence is limited by heterogeneity, small sample sizes, and lack of high-quality comparative trials. Future research should focus on strategy-based algorithms, standardized outcome measures, and enhanced recovery protocols tailored to lower extremity reconstruction.

KEYWORDS: Lower extremity reconstruction; Free flaps; Propeller flaps; Locoregional flaps; Diabetic foot; Microvascular surgery.

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I. INTRODUCTION: Reconstruction of distal lower extremity defects remains one of the most demanding areas of reconstructive surgery. The combination of thin soft tissue envelope, frequent exposure of bone or fixation hardware, compromised vascularity, and high biomechanical demands places patients at increased risk of complications and functional impairment. Traditionally, free tissue transfer has been considered the gold standard for complex distal leg defects; however, advances in perforator anatomy, flap design, and perioperative care have expanded the reconstructive armamentarium.

Contemporary reconstructive paradigms emphasize individualized decision-making rather than routine use of

free flaps. Locoregional muscle and fasciocutaneous flaps, as well as perforator-based propeller flaps, have emerged as viable alternatives in selected patients. This review aims to critically analyze current literature addressing reconstructive strategies for distal lower extremity defects, focusing on clinical outcomes, limitations, and future directions.

II. RECONSTRUCTIVE DECISION-MAKING IN DISTAL LOWER EXTREMITY DEFECTS

A. Patient- and Defect-Oriented Reconstruction

Modern reconstructive algorithms stress that successful outcomes depend on appropriate patient selection, defect characteristics, and systemic conditions rather than technical

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execution alone. Factors such as defect size, location, exposure of critical structures, vascular integrity, and patient comorbidities are central to reconstructive planning. Free flaps are indispensable for extensive, composite defects, while smaller defects may be reliably treated with locoregional or perforator-based flaps



Figure 1. Propeller flap on set.

III. FREE FLAPS IN DISTAL LOWER EXTREMITY RECONSTRUCTION

Free tissue transfer provides well-vascularized tissue capable of covering large defects and resisting infection. Reported success rates in high-volume centers exceed 95%, with failures often attributed to systemic factors such as hypotension, hypercoagulability, or venous thrombosis rather than anastomotic technique. However, free flaps entail prolonged operative times, higher physiological stress, and complex postoperative monitoring.

In diabetic patients, particularly those requiring prior revascularization, free flap failure rates are significantly higher. Chronic kidney disease and peripheral arterial disease further increase reconstructive risk, underscoring the need for meticulous vascular evaluation and risk stratification.

IV. PROPELLER FLAPS VERSUS FREE FLAPS

Randomized and comparative studies have demonstrated that perforator-based propeller flaps can achieve functional and aesthetic outcomes comparable to free flaps in selected distal leg defects. Advantages include reduced operative time, earlier mobilization, and lower donor-site morbidity. Nevertheless, propeller flaps are associated with higher rates of venous congestion and distal necrosis.

Importantly, the presence of underlying osteosynthesis material significantly increases the clinical impact of partial flap necrosis, often necessitating secondary reconstructive procedures or conversion to free tissue transfer. Thus, implant exposure represents a critical modifying factor in flap selection.



Figure 2. Propeller flap

V. LOCOREGIONAL FLAPS AS PRIMARY RECONSTRUCTIVE OPTIONS

Locoregional flaps such as the medial hemisoleus and reverse sural flap remain reliable solutions for selected distal leg defects. Technical refinements, including preservation of a muscular cuff around the pedicle, have improved flap perfusion and venous drainage. These flaps offer shorter operative times and reduced resource utilization, particularly valuable in medically fragile patients.



Figure 3. Sural flap dissection



Figure 4. Sural Flap on set for lower third defect

VI. VASCULAR IMAGING AND PREOPERATIVE PLANNING

Preoperative vascular assessment has become integral to lower extremity reconstruction. Color Doppler

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ultrasonography and computed tomography angiography enable precise mapping of perforators, recipient vessels, and venous outflow. Such imaging improves flap design, reduces intraoperative uncertainty, and may enhance salvage rates in compromised limbs.

VII. POSTOPERATIVE MANAGEMENT AND REHABILITATION

Postoperative protocols, including dangling regimens, compression therapy, and progressive weight-bearing, vary widely across institutions. Although physiological studies demonstrate improved tissue oxygenation with graduated dangling, evidence linking these protocols to improved clinical outcomes remains limited. Enhanced recovery pathways tailored to lower extremity reconstruction represent a promising area for future investigation

CONCLUSIONS

Distal lower extremity reconstruction has evolved toward an individualized, strategy-based approach. Free flaps remain essential for extensive and complex defects, while propeller and locoregional flaps provide effective alternatives in selected patients. The presence of fixation hardware, vascular disease, and diabetes significantly influences reconstructive outcomes. Current evidence is limited by methodological heterogeneity and lack of robust comparative trials. Future research should focus on standardized outcome measures, risk-adjusted algorithms, and optimized rehabilitation protocols.

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