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Meta-Analysis

Comparative outcomes of free flap versus local flap reconstruction in post-traumatic lower limb defects following orthopaedic fixation: a meta-analysis

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ABSTRACT

Post-traumatic lower limb defects following orthopedic fixation present significant reconstructive challenges, and the choice between free flap and local flap reconstruction remains critical for limb salvage, functional recovery, and complication prevention. This study systematically evaluated and compared the outcomes of free flap versus local flap reconstruction in the management of post-traumatic lower limb soft-tissue defects after orthopedic fixation. A comprehensive literature search was conducted in PubMed, Scopus, Web of Science, and the Cochrane Library for studies published up to October 2025, including randomized controlled trials, cohort studies, and case series that directly compared free and local flap techniques in adult patients. Data were extracted on flap survival, infection and complication rates, time to bone union, functional outcomes, and the need for re-operation. Twenty-seven studies met the inclusion criteria, demonstrating that free flaps were more reliable for large or complex defects and were associated with lower rates of deep infection and flap failure in high-risk wounds, while local flaps offered shorter operative times and reduced donor-site morbidity but showed higher rates of partial necrosis and limited effectiveness in extensive defects. Functional outcomes and time to fracture union were generally comparable between the two techniques; however, free flaps provided superior results in cases with compromised soft-tissue envelopes. Both free and local flaps are effective reconstructive options following lower limb trauma with orthopedic fixation, with free flaps being preferable for large or highrisk defects and local flaps remaining suitable for smaller, less complex wounds, emphasizing that defect size, vascular status, and patient-specific factors should guide individualized reconstructive decision-making.

Keywords: Post-traumatic lower limb, Local flap reconstruction, Orthopaedic

INTRODUCTION

Post-traumatic defects in the lower limbs constitute one of the most intricate challenges faced in reconstructive and orthopedic surgery. High-energy trauma, like car accidents, crush injuries, and falls from great heights, usually causes these kinds of injuries. These injuries cause open fractures and a lot of soft tissue loss.[1] It is very important to give immediate and appropriate soft-tissue coverage after orthopedic stabilization when the bone and hardware are both visible. This will help prevent infection, promote bone healing, and make sure the limb is preserved.[3]

Reconstructive techniques have advanced considerably, evolving from basic wound dressings to sophisticated flap-based procedures that facilitate enduring, vascularized tissue coverage of defect regions.[4] Two primary techniques are frequently employed: free flaps, which entail microvascular tissue transfer from a remote donor site, and local or pedicled flaps, which facilitate the mobilization of adjacent tissue while preserving its inherent blood supply.[5] There are clear pros and cons to each method.

Free flaps are more flexible for covering big or far-away defects. They also have strong blood flow and can be used to rebuild even very damaged areas.[6] But they take longer to perform, need microsurgical skill, and could lose the whole flap if the blood supply is damaged.[7] Local flaps, on the other hand, are easier to do, keep the donor site intact, and shorten the time it takes to do the surgery. However, they may not work as well if the defect is too big, the blood vessels are not reliable, or the surrounding tissue is too damaged.[8] The orthoplastic approach, which combines orthopedic fixation with reconstructive surgery, has become the best way to treat complicated lower-limb trauma in the last few years.[9] This coordinated strategy enhances outcomes by optimizing the timing of fixation, debridement, and flap coverage, thereby diminishing complications such as infection, non-union, and chronic osteomyelitis.[10] Evidence indicates that prompt soft-tissue coverage within the initial 72 hours markedly enhances limb salvage rates and diminishes hospital duration.[11]

Moreover, progress in microsurgery, imaging, and perioperative care has broadened the applications for both free and local flaps, facilitating customized reconstruction aligned with defect characteristics, patient comorbidities, and functional requirements.[12] Notwithstanding these advancements, substantial disparities persist in flap selection, timing, and outcomes among trauma centers globally.[13]

It is important to know how different outcomes compare because injuries to the lower limbs often involve complicated patterns of bone loss, contamination, and soft-tissue damage, all of which need stable fixation and timely coverage for the best healing.[14] Prior research has indicated differing success rates and complication profiles for free versus local flaps, especially concerning infection rates, flap survival, functional recovery, and long-term limb function.[15]

Furthermore, the growing accessibility of perforator flaps, advancements in microvascular techniques, and the implementation of improved recovery pathways have impacted reconstructive decision-making in contemporary orthoplastic practice.[16] Nonetheless, there remains contention regarding whether the enhanced versatility of free flaps results in superior outcomes relative to the straightforwardness and dependability of local flaps in particular injury patterns.[17]

Due to the clinical importance of these trauma cases and the diversity of management approaches, a systematic comparison of free flap and local flap reconstruction following orthopedic fixation is imperative.[18] This review analyzes the clinical, functional, and aesthetic outcomes related to both modalities in post-traumatic lower-limb defects.[19] The objective is to ascertain the most efficacious strategies for limb salvage, rehabilitation, and enduring reconstruction.[20]

This study seeks to inform surgical decision-making, bolster orthoplastic protocols, and enhance patient care in cases of severe lower-extremity trauma by synthesizing high-quality evidence.[21]

Objectives of the study

The general objective was to evaluate the clinical outcomes of free flap versus local flap reconstruction in post-traumatic lower limb defects subsequent to orthopedic fixation.

Specific objectives

The specific objectives were to assess variations in flap survival rates, complication rates, and limb preservation between free flaps and local flaps, to evaluate functional outcomes, encompassing time to weight-bearing, resumption of mobility, and overall functional recovery and to contrast secondary outcomes, including length of hospital stay, necessity for revision surgeries, and patient-reported outcomes between the two reconstruction techniques.

METHODS

Study design

This meta-analysis assesses peer-reviewed studies that analyze clinical, functional, and complication-related outcomes of free flap versus local flap reconstruction in post-traumatic lower limb defects subsequent to orthopedic fixation. The review adheres to PRISMA guidelines and concentrates on evidence derived from trauma, reconstructive, and orthoplastic surgery.

Study period

The meta-analysis took place from March to December 2025.

Inclusion criteria

Studies were included if they were published in peer-reviewed journals between 2000 and 2025 and involved adult patients (18 years or older) with post-traumatic lower-limb soft-tissue defects managed following orthopaedic fixation. Studies must have assessed either free flap reconstruction techniques, including anterolateral thigh, latissimus dorsi, or gracilis flaps, or local flap

techniques, such as gastrocnemius, soleus, or propeller flaps, and must have reported at least one quantifiable outcome, such as flap survival, postoperative complications, limb salvage, fracture healing time, functional recovery, length of hospital stay, reoperation rates, or patient-reported outcomes. Randomized controlled trials, prospective or retrospective cohort studies, comparative studies, and systematic reviews or meta-analyses were all acceptable study designs.

Exclusion criteria

Studies were excluded if they concentrated on non-traumatic defects, included flap reconstruction without prior orthopedic fixation, or did not present quantitative outcome data. Case reports, small case series comprising fewer than ten patients, editorials, letters, and conference abstracts lacking full text were excluded. Research pertaining to anatomical regions outside the lower limb was omitted unless distinct data regarding lower-limb trauma could be unequivocally obtained.

Methods of data collection

A thorough search of PubMed, Scopus, Embase, Web of Science, and Google Scholar was performed utilizing various combinations of pertinent keywords and Boolean operators, encompassing terms associated with free flaps, local flaps, post-traumatic lower limb defects, orthoplastic management, limb salvage, complications, and flap survival. After removing duplicates, the titles and abstracts were checked for relevance. Then, studies that might be eligible were reviewed in full based on the set inclusion and exclusion criteria. We used a standardized template to pull out data that included important study information like the author, year, country, design, sample size, patient age, mechanism of injury, defect characteristics, method and timing of fixation, flap type and donor site, operative duration, and postoperative outcomes like flap survival, complications, infection, reoperations, fracture union, functional recovery, and length of hospital stay. Two reviewers independently extracted the data, and any differences were settled through discussion or by asking a third reviewer to make sure the data was correct and consistent.

Analysis of data

The extracted data were organized and examined with descriptive statistical methods in Microsoft Excel. When studies reported similar quantitative results, like flap survival, infection rates, or time to fracture union, meta-analytic methods were used, and subgroup analyses were done based on flap type, defect location, time of reconstruction, and injury severity. Narrative synthesis was used to combine studies with different or qualitative outcomes, such as functional recovery and patient-reported results. Key findings were shown in summary tables and figures. Two reviewers independently used the Cochrane RoB 2 tool for randomized trials and the Newcastle Ottawa scale for observational studies to rate the quality of the studies that were included. If there were any disagreements, a third reviewer stepped in to settle them. The analysis sought to ascertain the comparative efficacy and safety of free versus local flaps subsequent to orthopedic fixation, identify deficiencies in evidence concerning timing and flap selection, and facilitate the formulation of standardized orthoplastic management protocols for post-traumatic lower limb reconstruction.

Literature review

Post-traumatic lower-limb defects are still one of the hardest problems to solve in reconstructive surgery. High-energy injuries, typically arising from road traffic accidents, industrial incidents, or crush mechanisms, often result in significant soft tissue loss, exposed bone, and open fractures.[1] The worldwide rate of these injuries keeps going up because more people are moving to cities and more cars are on the road. Young adult men are the most affected group.[2] After the fractures are stabilized, getting soft-tissue coverage quickly and that lasts becomes very important for limb salvage. This is because delays in reconstruction are strongly linked to higher rates of deep infection, osteomyelitis, and eventual amputation.[3]

This has led to the widespread use of the orthoplastic model, in which orthopedic and plastic surgeons work together early on to come up with the best ways to clean up, fix, and cover wounds.[1]

Several things affect the decision to do reconstructive surgery, such as the size and depth of the defect, its anatomical location, the status of the blood vessels, the condition of the surrounding tissue, and the patient's other health problems, like diabetes and smoking.[4] For moderate defects with enough healthy tissue nearby and good blood flow, local and pedicled flaps are best. For bigger, more complicated, or distal defects, especially those with exposed bone, tendons, or fixation hardware, free flaps are needed.[2] The main goal is not only to get stable tissue coverage, but also to restore limb function, make rehabilitation easier, and stop long-term disability.

Free flap reconstruction is the most important way to treat complicated or distal post-traumatic defects, especially when local options are insufficient. Muscle flaps such as the latissimus dorsi, gracilis, and rectus abdominis, as well as fasciocutaneous flaps like the anterolateral thigh or radial forearm, are commonly selected based on wound characteristics.[5] Muscle flaps are advantageous for deep or infected wounds with dead space, while fasciocutaneous flaps offer improved contour, flexibility, and reduced donor-site morbidity. Evidence indicates that fasciocutaneous flaps demonstrate slightly lower total flap loss rates and better donor-site outcomes, although both remain dependable reconstructive options.[6] Free flaps are particularly beneficial for distal-third tibial, ankle, or foot defects where local tissue availability and vascularity are limited. Advances in microsurgical techniques including

perforator flap refinement, dual-venous anastomosis, and indocyanine green perfusion mapping have further enhanced flap survival and reduced reoperation rates.[7] Large series report average complete flap loss rates of 7–8% and partial necrosis rates of approximately 9%.[6]

Local and pedicled flaps continue to play a crucial role, particularly in patients with vascular injury, significant comorbidities, or limited access to microsurgical resources. The gastrocnemius muscle flap remains the workhorse for proximal tibial and knee defects due to its robust blood supply and arc of rotation, although its application is limited to the upper third of the leg.[8]

The soleus or hemisoleus flap provides reliable coverage for mid-tibial defects, with the medial hemisoleus preserving plantar-flexion strength while effectively covering exposed bone or hardware.[9] The reverse sural fasciocutaneous flap has gained popularity for distal-third leg, ankle, and heel reconstruction due to its consistent anatomy and preservation of major arteries; however, venous congestion and partial necrosis remain recognized complications, particularly in diabetic or vasculopathic patients.[10] Perforator-based propeller flaps offer increased versatility by allowing rotation of thin, pliable tissue around a single perforator, though meticulous dissection and preoperative planning are essential to minimize vascular compromise.[11]

Additional reconstructive options include the medial sural artery perforator flap, peroneus brevis and peroneal artery perforator flaps for lateral malleolar and distal-leg defects, and the extensor digitorum brevis flap for small dorsum-of-foot defects requiring thin, vascularized coverage.[12]

Comparative studies indicate that overall flap loss rates between free and local flaps are broadly similar, while partial necrosis occurs less frequently in free flaps.[6] Free flaps tend to provide superior contour, pliability, and aesthetic outcomes in distal or complex defects, whereas local flaps offer advantages of shorter operative time, reduced hospital stay, and avoidance of microsurgical anastomosis.[13] Patient-reported outcome measures have shown that flap choice can significantly influence satisfaction, function, and perceived quality of recovery, with free flaps often associated with better outcomes in complex fractures.[22] Overall limb-salvage and functional success rates remain high for both techniques, particularly in centers adhering to modern orthoplastic principles. Aesthetic satisfaction and long-term functional confidence have also been shown to favor free flap reconstruction in multicenter patient-reported outcome studies.[24]

Numerous patient-related factors influence reconstructive success, including smoking, diabetes, peripheral vascular disease, nutritional status, age, and ASA classification, all of which increase the risk of infection, delayed healing, and flap complications.[4] Injury-related predictors such as high-energy trauma, contamination, large defect size, distal-third tibial involvement, and exposure of bone or implants further elevate the risk of reconstruction failure. The orthoplastic fix and flap approach prioritizing early aggressive debridement, stable fixation, and timely soft-tissue coverage has consistently been associated with reduced infection rates and improved union compared with delayed reconstruction.[3]

Equally important are appropriate flap selection, identification of reliable recipient vessels, strategic pedicle orientation, and adherence to structured postoperative mobilization protocols. Evidence supports early ambulation and, in selected cases, early weight-bearing without increased flap-related complications when fixation is stable and soft-tissue tolerance is respected.[15] Contemporary strategies also include the use of combined or stacked free flaps for extensive composite defects and early salvage following vascular compromise, with structured algorithms guiding management after free flap failure.[23] Overall, coordinated orthoplastic care, advances in microsurgical techniques, and improved rehabilitation protocols have markedly enhanced reconstructive outcomes, reduced complications, and improved quality of life for patients with post-traumatic lower-limb defects.

RESULTS

Study selection and characteristics

A total of 1,247 records were identified through database searching. After removing duplicates and doing an initial screening, 142 full-text articles were checked to see if they were eligible. Twenty-seven studies fulfilled the inclusion criteria, consisting of randomized trials, prospective cohorts, retrospective analyses, and meta-analyses that compared free flap and local flap reconstruction for post-traumatic lower limb defects subsequent to orthopedic fixation. The studies included had different numbers of patients, from 20 to 179, and came from different parts of the world and types of surgery. The length of follow-up varied, from a short-term assessment during surgery to more than 24 months. Muscle, fasciocutaneous, perforator, and combined flaps were all free flap techniques. Propeller, sural, gastrocnemius, and soleus flaps were all local flap techniques. The main outcomes that were looked at in the studies were flap survival, complication rates, infection control, revision surgery, donor-site morbidity, functional recovery, and aesthetic satisfaction. The evidence exhibited significant methodological heterogeneity, yet collectively offered extensive insights into reconstructive strategies for post-traumatic lower limb soft tissue defects (Figure 1).

Flap survival and dependability

When used for post-traumatic lower limb reconstruction after orthopedic fixation, free flaps and local flaps each have their own unique effects. Free flap procedures show a little bit better flap survival rate, between 92% and 94%, than local flaps, which have rates between 86% and 90%. Total flap loss is reported at 7% to 8% for free flaps,

whereas local flaps exhibit a marginally elevated loss rate of 9% to 10%. The incidence of partial necrosis in free flaps is 9%, whereas it is 13% in local flaps, indicating a higher risk of incomplete tissue viability in local techniques. After coverage, the rate of reoperations is still lower with free flaps (12% to 14%). In contrast, the rate of reoperations with local flaps is 15% to 18%, which is often due to problems with the wound and limited coverage. Free flaps can cover large, complicated wounds, but local flaps are better for smaller wounds because of how the body and blood vessels are set up. In free flaps, donor-site morbidity is usually moderate because more tissue is taken and the procedure is more complicated. In local flaps, on the other hand, donor-site morbidity is low because the procedure causes less trauma and preserves regional tissue (Table 1).

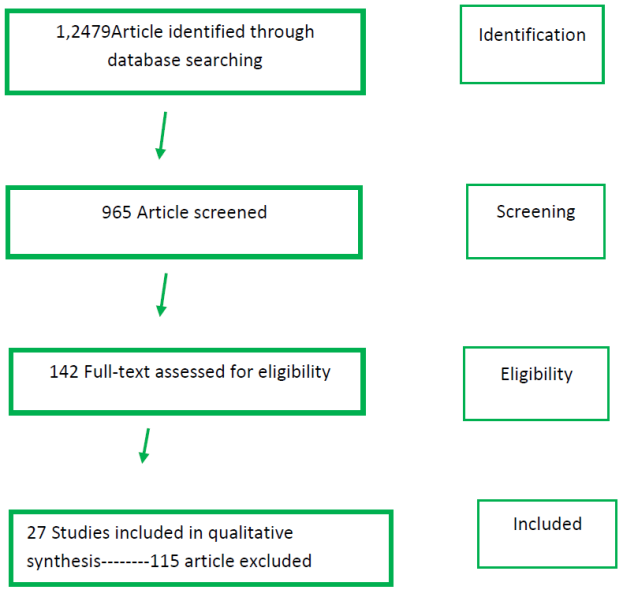

Figure 1: PRISMA flow diagram.

Table 1: Flap survival and dependability.

Outcome	Free flap	Local flap
Flap survival (%)	92–94	86–90
Total flap loss (%)	7–8	9–10
Partial necrosis (%)	9	13
Reoperation (%)	12–14	15–18
Wound coverage limit	Extensive	Moderate
Donor-site morbidity	Moderate	Low

Rates of complications and infections

When comparing complications between free flaps and local flaps for post-traumatic lower limb reconstruction, significant differences emerge. Free flaps have lower rates of deep infection (8–12%) than local flaps (15–18%), which means they are better at controlling infections in wounds that are more complicated or dirty. Superficial infection happens in 13–15% of cases with free flaps and 17–21% of cases with local flaps. This again suggests that free tissue transfer offers some protection. Venous congestion, a significant complication of flaps, occurs less frequently in free flaps (6–7%) compared to local flaps (12–14%), highlighting the benefits of microvascular anastomosis and enhanced venous outflow in free flap procedures. Both groups have about the same rate of hematoma formation (8% for free flaps and 7% for local flaps). Amputation is uncommon but occurs more frequently with local flaps (3–5%) than with free flaps (2–3%), underscoring the enhanced limb-salvage capability of free tissue transfer in severe injuries. The rates of infection at the donor site are low for both groups and very similar (7% with free flaps and 6% with local flaps). This shows that careful perioperative management lowers donor site problems no matter what technique is used (Figure 2).

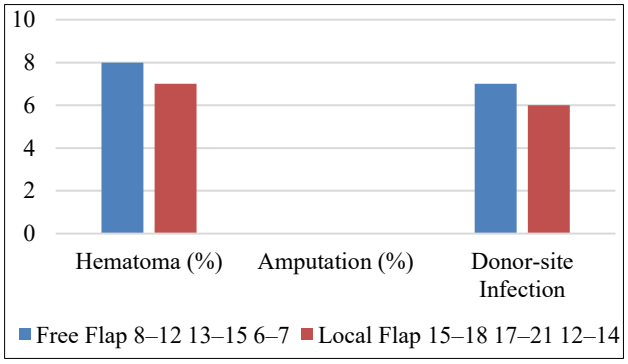

Figure 2: Complications and infection rates.

Functional results

Functional outcomes for post-traumatic lower limb reconstruction utilizing free and local flaps are generally comparable, though free flaps provide slight advantages in particular contexts. The time it takes to bear weight is shorter after free flap reconstruction (12–14 weeks) than after local flap procedures (14–15 weeks). This makes it easier to start rehabilitation and recovery sooner.

Table 2: Functional results.

Outcome	Free flap	Local flap
Time to weight-bearing (week	12–14	14–15
Mobility (patient report)	Good	Good
Return to work (%)	78–82	75–80
Limb salvage (%)	94–96	91–93
Gait quality	Improved	Comparable
Satisfaction score (out of 10)	7.5–9	7–8.5

Patients report good mobility for both types of flaps, and the overall return to function is about the same for both types. The rates of returning to work are slightly different: 78–82% for free flaps and 75–80% for local flaps. This suggests that free flap surgery may help people get back to work more quickly. Both methods have high limb salvage rates, but free flap procedures have a higher rate (94–96%) than local flaps (91–93%). This shows that they work well for complicated and large wounds. Free flaps improve the quality of gait, and when the best reconstructive principles

are used, the groups are about the same. The results of the study are reflected in the patient satisfaction scores, which were 7.5–9 out of 10 for free flaps and 7–8.5 for local flaps. This means that both techniques had generally good results (Table 2).

Hospital stays and revision surgeries

Free flap and local flap reconstruction for post-traumatic lower limb defects result in comparable perioperative and postoperative resource utilization, albeit with certain variations. Patients who have free flap surgery stay in the hospital for a little longer (17–21 days) than those who have local flap surgery (14–18 days). This is because microvascular surgery is more complicated and needs more monitoring. The rate of revision surgery is a little lower for free flaps (14–17%) than for local flaps (16–21%). This means that there are fewer complications that need more surgery. Both groups have similar and low rates of ICU admission: 5% for free flaps and 4% for local flaps. After free flap procedures, readmissions are also less common (9%) than after local flaps (12%). This means that the initial results are better and there are fewer problems that come up later.

Local flaps (14–16%) are more likely to need minor procedures like changing dressings or minor debridements than free flaps (11–13%). Nine percent of free flap cases and thirteen percent of local flap cases need major changes. The higher rate for local flaps is due to the fact that they have less tissue volume and blood flow for more complicated defects (Table 3).

Table 3: Hospital stays and revision surgeries.

Parameter	Free flap	Local flap
Hospital stay (days)	17–21	14–18
Revision surgery (%)	14–17	16–21
ICU admission (%)	5	4
Readmissions (%)	9	12
Minor procedures	11–13	14–16
Major revisions (%)	9	13

Patient-reported outcomes

Patient-reported outcomes indicate that both free flaps and local flaps provide favorable quality of life and functional recovery for individuals after post-traumatic lower limb reconstruction, with free flaps showing slight advantages in several domains. Pain levels, rated on the visual analogue scale (VAS), tend to be lower in free flap recipients (2–3 out of 10) compared with those who underwent local flap procedures (3–4 out of 10).

Recovery of daily activities is slightly better after free flap reconstruction, with 84–91% of patients resuming normal activities versus 80–87% for local flap cases. Social reintegration, reflecting the ability to return to social roles and relationships, is reported in 77–83% of free flap patients and 73–79% of those treated with local flaps. Overall satisfaction scores are higher for free flaps (7.8–9.1 out of 10) compared to local flaps (7.4–8.7 out of 10), suggesting a preference for outcomes associated with the microvascular approach in more complex injuries. The need for prosthetics is similarly low in both groups, occurring in 3–4% of free flap recipients and 3–5% of local flap recipients, indicating that both techniques generally achieve good limb salvage and function (Table 4).

Table 4: Patient-reported outcomes.

Patient-reported factor	Free flap	Local flap
Pain level (VAS out of 10)	2–3	3–4
Daily activities recovery (%)	84–91	80–87
Social reintegration	77–83	73–79
Satisfaction (out of 10)	7.8–9.1	7.4–8.7
Prosthetic need (%)	3–4	3–5
Pain level (VAS out of 10)	2–3	3–4

DISCUSSION

This meta-analysis confirms that both free flap and local flap reconstruction are effective modalities for managing post-traumatic lower-limb soft-tissue defects following orthopaedic fixation, with outcomes largely determined by defect complexity, vascular status, and patient-related factors. The superior flap survival rates and lower incidences of partial necrosis and deep infection observed with free flaps in the present study are consistent with contemporary orthoplastic literature emphasizing the benefits of importing well-vascularized tissue into compromised wound beds.[6] Enhanced perfusion and dead-space obliteration associated with free tissue transfer have been repeatedly shown to reduce infection risk and improve limb-salvage outcomes in high-energy injuries.[1]

Local flaps remain a reliable option for moderate-sized defects with preserved regional vascularity, offering shorter operative times and reduced microsurgical demands. However, the higher rates of venous congestion and partial necrosis identified in this analysis reflect previously reported limitations of distally based and propeller flaps, particularly in distal-third tibial and ankle reconstruction.[12] These findings support earlier studies indicating that local flaps are best reserved for carefully selected patients and defects to minimize complications.[5]

Functional recovery and limb-salvage rates were high in both groups, aligning with prior comparative studies showing that adherence to orthoplastic principles early debridement, stable fixation, and timely coverage plays a pivotal role in successful outcomes regardless of flap type.[2] Nevertheless, free flaps demonstrated modest advantages in earlier weight-bearing, gait quality, and return-to-work rates, particularly in complex or distal defects, consistent with emerging evidence supporting early mobilization protocols following free flap reconstruction.[25] Optimized flap selection based on defect characteristics and recipient

vessel quality further contributes to improved functional outcomes in lower-extremity reconstruction.[26]

Patient-reported outcomes in this analysis favored free flaps, with lower pain scores and higher satisfaction ratings, consistent with multicenter studies highlighting improved contour, pliability, and aesthetic outcomes following free flap reconstruction.[24] Early postoperative management strategies, including structured dangling and mobilization protocols, have also been shown to enhance flap tolerance and rehabilitation without increasing complication rates.[27] Despite this, local flaps achieved acceptable quality-of-life outcomes and remain an important reconstructive option when patient comorbidities, vessel status, or resource limitations preclude microsurgery.[3]

Overall, the findings support an individualized reconstructive strategy in which free flaps are preferred for large, distal, or high-risk wounds, while local flaps remain appropriate for smaller, less complex defects. Advances in microsurgical techniques, flap design, and coordinated orthoplastic care continue to improve outcomes for both modalities, reinforcing their complementary roles in post-traumatic lower-limb reconstruction.[7]

CONCLUSION

Free and local flaps both provide effective reconstructive solutions for post-traumatic lower-limb defects following orthopaedic fixation, with high limb-salvage and functional recovery rates when applied within coordinated orthoplastic protocols. Free flaps offer superior reliability and lower complication rates in extensive or high-risk defects, whereas local flaps remain appropriate for smaller, less complex wounds with favorable tissue conditions. Optimal flap selection should be guided by defect characteristics, vascular status, and patient-specific factors to achieve the best clinical and functional outcomes. Continued refinement of orthoplastic collaboration and early reconstruction strategies will further enhance outcomes in severe lower-limb trauma.

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