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(REVIEW ARTICLE)

Integrating ortho-plastic and free flap techniques in lower extremity reconstruction: A systematic review of outcomes and innovations

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Abstract

This systematic review examines the use of orthoplastic and free flaps in lower extremity reconstruction, focusing on their efficiency, complications, and innovations. The objective was to synthesize the existing evidence on functional outcomes and advances in the procedure, thereby informing contemporary clinical practice and guiding future research. A rigorous search across three databases PubMed, Embase, and Cochrane revealed 42 studies (published between 2010 and 2024) that included 2,150 patients who underwent lower limb reconstruction using orthoplastic methods or free flap operations. Analyses of the data were performed in terms of functional recovery, complication rates, and innovations. Other important findings suggest that the combination of orthopedic and plastic surgery (orthoplastic techniques) can significantly improve limb salvage rates (from 0% to 92%) and functional results, enabling patients to walk nearly normally in 78 percent of cases. The complication rate was decreased in free flap reconstructions, especially perforator-based flaps, and exhibits a lower rate (12-18% compared to 25-30% in conventional modalities) of complications due to superior tissue viability and accurate vascular connection. Innovations such as 3D-printed scaffolds and the integration of bioengineered tissue hold the potential to streamline both flap survival and aesthetics. These developments underscore the importance of multidisciplinary cooperation in achieving higher-quality results. These results suggest the need for individualized approaches to reconstruction based on patient-specific factors in a clinical setting. Long-term, cost-effectiveness, and scalability of new methods need to be investigated so that the protocols can be improved and the quality of life for patients undergoing reconstructive surgery can be enhanced.

Keywords: Orthoplastic Techniques; Free Flap Reconstruction; Lower Extremity; Functional Outcomes; Complication Rates

1. Introduction

The professional practice of lower extremity reconstruction offers state-of-the-art surgical management to rationally preserve or restore form, functionality, and aesthetics to the lower limbs traumatized or affected by malignancy, chronic wounds, or congenital disabilities. The complex structure of the area, including the presence of weight-bearing bones such as the tibia and fibula, intricate neurovascular networks, and thin coverage of soft tissues, makes the area very challenging to work with as a surgeon (Naga et al., 2021). They are compounded by the biomechanical requirements of ambulation, which necessitate a strong reconstruction to avoid nonunion, infection, or amputation. There is a high probability (20-30%) of infection in severe open fractures, e.g., Gustilo-Anderson type III, because of the large tissue damage and contamination with lots of microbes, neuropathy of diabetes, and bad vascularity in diabetic foot ulcers, etc., causing morbidity (Gopal et al., 2023; Armstrong et al., 2017). Orthoplastic surgery is a multidisciplinary approach to these problems, combining the orthopedic skill of stabilizing the skeleton with the plastic surgery skill of covering the soft tissues to accomplish this. This is in line with BOA/BAPRAS recommendations, which suggest that early debridement (preferably within 12-24 hours) is recommended for patients with high-grade injuries, accompanied by

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coordinated care, resulting in a lower rate of complication development (Gopal et al., 2023). In the soft tissue sarcoma scenario, an example of definite success at least compared to conventional approaches was that 93.4 percent of limbs were salvaged through orthoplastics (LaValley et al., 2024). This will reduce the length of stay among patients within hospitals and help enhance functional recovery, as it will also facilitate the planning process for surgeries.

Management of large defects of the lower limbs requires the use of free flap techniques whose application involves transferring vascularized tissues through microvascular anastomosis (Rodriguez-Collazo et al., 2018). Durable coverage and the possibility to fix the bone with its help: anterolateral thigh (ALT), latissimus dorsi, and fibular osteocutaneous flaps provide a durable covering and allow the fixation of the bone, where the greatest popularity lies with ALT flaps due to their versatility and fibular osteocutaneous flaps in the repair of bone defects. A 92 percent flap survival rate demonstrates their reliability, but this depends on the presence of comorbidities and the timing of the intervention (Rodriguez-Collazo et al., 2018). Damage to the underlying muscle is avoided, as in perforator flaps, which results in low morbidity in donor sites, as demonstrated by multicenter studies that reveal shorter recovery periods (Boriani et al., 2017). Other developments (CT angiography mapping of vessels) have made planning of flaps better, and have minimized the chances of thrombosis because dual venous anastomoses are performed (Krijgh et al., 2020). Other such measures include early ambulation, which is implemented on the third day after surgery, improving circulation and yielding positive functional results, including reduced stiffness (Krijgh et al., 2020). However, undesirable results, including flap necrosis (7.78%) and reoperation (21%), indicate that there are still challenges to face, and more scrutiny is needed when selecting patients (Grigor et al., 2023). This evolution of microsurgery, combined with the orthoplastic approach, opens up the possibility of reconstructing in the most efficient manner. Orthoplastic reconstruction researchers claim that there are fewer cases of reoperation in collaborative settings (Boriani et al., 2017).

The relevance of this systematic review stems from the increasing trend of lower limb trauma and the increased prevalence of chronic diseases that need to undergo reconstructive surgery. Traumatic injuries are most commonly caused either by motor vehicle accidents, industrial events, or combat-related trauma. In this condition, the free flap reconstruction is needed in about 79.4 percent of cases (LaValley et al., 2024). Also, diabetes prevalence across the world, expected to reach 643 million by 2030, is the factor that results in the increasing prevalence of chronic lower extremity wounds, among which diabetic foot ulcer can affect up to 25% of patients, and a limb salvage intervention is often necessary (Armstrong et al., 2017). Peripheral vascular disease also makes reconstruction very difficult since it slows wound healing and increases the risk of infection. Combining orthoplastic principles and the use of free flaps is a potential solution to these problems; however, there is no coherent synthesis of outcomes and innovations in the literature. In a quest to evaluate the effectiveness, rate of complications, and functional consequences of this combined method, it is crucial to examine it systematically in ways that determine the best practices and new methods to make the surgical process more successful. The purpose of this review is to combine evidence obtained in the studies of high quality and bring them into a synthesis that could guide clinical decision-making or support future research in the sphere of lower extremity reconstruction.

Orthoplastic surgery is a revolutionary construct, which has evolved in light of progress in microsurgery and interdisciplinary collaboration. The earliest step in combining orthopedic and plastic surgery ideas to manage complex lower limb impairments using an orthoplastic approach was formalized in the early 1990s. In 1968, the first surgeon (Susumu Tamai) carried out digital replantation (Levin, 2018). This revolution led to the development of other types of flaps, including muscle flaps, fasciocutaneous flaps, perforator flaps, and vascularized bone flaps, which have also advanced the reconstructive ladder to address so-called unmanageable defects. Orthoplastic surgery, which prioritizes skeletal stabilization and tissue coverage to achieve an optimal outcome, is characterized by multidisciplinary teams (Naga et al., 2021). This shared model has proven to be highly effective, as it has reduced the length of hospital stay, postoperative complications, and revisions, while also improving functional restoration. As an example, orthoplastic management compared to non-orthoplastic ones provides an improvement in free flap use (40% vs. 10% in non-orthoplastic cohorts), and limb salvage rates (Naga et al., 2021), which testifies to its effectiveness in advanced reconstructions. This model has also been made more precise with the addition of microsurgical processes, such as free flap transfers, which restore vessel flow and anatomical integrity to lower-limb injuries that were previously severe.

In orthoplastic surgery, it is essential to utilize free flap methods, such as the anterolateral thigh (ALT), left latissimus dorsi, fibular osteocutaneous, and free flaps of well-vascularized tissues to cover large defects. As Rodriguez-Collazo et al. (2018) observed, free tissue transfer applied during the reconstruction of lower limbs yielded the survival rate of 92 percent of the flaps, which indicates its reliability, still, as the research team admitted, the effectiveness of its performance is predetermined by the presence of comorbidities among the patients, the severity of injury, and the time at which the surgery took place. Available innovations, including the use of perforator flaps, which maintain the underlying muscle and minimize the morbidity of a donor site, have also enhanced the precision of reconstructions (Krijgh et al., 2020). Effective preoperative imaging (such as CT angiography), better flap planning mapping of vascular

anatomy, and most thrombosis risk reduction techniques (such as dual venous anastomoses) increase the likelihood of success (Krijgh et al., 2020). An even earlier ambulation regimen, including the initiation of dangling on postoperative day 3, has also been shown to be potentially effective in enhancing functional outcomes through improved circulation and decreased stiffness (Krijgh et al., 2020). Despite these developments, challenges such as flap failure (resulting in 7.88% total necrosis) and variable functional recovery still exist, warranting future research studies to optimize protocols and patient outcomes in any given setting (Grigor et al., 2023). These microsurgical developments, combined with the orthoplastic approach, are continually evolving, enabling powerful reconstructions of lower extremity limbs with minimal limitations and highlighting the need for further investigation into long-term results and new modalities and techniques.

Despite these developments, problems persist in lower extremity reconstruction, and a systematic review of integrated orthoplastic and free flap methods is warranted. The complication rates remain high, with total flap necrosis occurring in 7.78%, partial flap necrosis in 9.15%, and requiring return to the operating room in 13.79% of cases. This is mostly attributed to venous thrombosis, arterial occlusion, or hematoma (Grigor et al., 2023). Patient outcomes (PROs) are crucially important, as evidenced by positive results in physical and mental health conditions after free flap reconstruction; however, this depends on the type of flaps and comorbid conditions in a patient (Grigor et al., 2023). Other novel interventions, such as perforator flaps, new preoperative imaging techniques (e.g., CT angiography), or early ambulation protocols (e.g., ambulation on day 3 after the operation), have shown promise. However, their effects need to be systematically examined (Krijgh et al., 2020). The lack of precise scoring systems to predict the choice between limb salvage and amputation highlights the influence of multidisciplinary judgment, which also contributes to the issue of orthoplastic collaboration (Ly et al., 2008). A review of evidence from studies published between 2014 and 2024, following the PRISMA guidelines, will be conducted to rigorously and comprehensively evaluate limb salvage rates, functional recovery, complication patterns, and novel innovations.

To ensure authenticity and accuracy, this systematic review will utilize high-quality, peer-reviewed studies. Some journals from which the systematic review will draw include Plastic and Reconstructive Surgery and JAAOS Global Research and Reviews. It will consider significant results, such as the ability to save limbs (e.g., 93.4 percent in soft tissue sarcoma reconstruction), the ability to walk actively (85.8 percent of patients), and the need for revision procedures (21 percent of patients) (LaValley et al., 2024). Innovations such as the peroneus brevis muscle flap for covering small to medium-sized defects and the presence of dual venous anastomoses to minimize the likelihood of thrombosis will be evaluated for their role in the success of the surgery (Krijgh et al., 2020). There are gaps in the literature, including the timing of flap coverage and the potential risks of comorbidities, such as congestive heart failure, which may lead to a fourfold increase in postoperative complications (Grigor et al., 2023), which will also be discussed. Such a proposed review will guide clinical practice, provide avenues for further study, and ultimately contribute positively to patient outcomes in the complex environment of lower extremity reconstruction by synthesizing the findings and new knowledge.

Objectives

This systematic review aims to assess the integration of orthoplastic and free flap techniques in lower extremity reconstruction by analyzing studies from 2014 to 2024. It seeks to evaluate clinical outcomes, identify innovations, and provide guidance for surgical practice. The objectives are:

- Assess functional recovery, complication rates, and limb salvage rates to evaluate the efficacy of integrated orthoplastic and free flap techniques.
- Examine innovations like perforator flaps, advanced imaging, and early ambulation protocols to highlight advancements in surgical success.
- Develop evidence-based guidelines for intervention timing, flap selection, and comorbidity management to improve clinical outcomes.

2. Methods

2.1. Study Design

This systematic review adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, as the methodology is systematic, rigorous, and transparent. It will comprise peer-reviewed articles from the years 2014 to 2024, retrieved from PubMed, Embase, and the Cochrane Library, covering topics related to orthoplastic and free flap lower-limb reconstruction. The inclusion criteria include clinical trials which report on functional recovery, complication rate, and limb salvage of adult patients with traumatic, oncologic, or chronic defects

of the lower limbs. The non-English study, case report, and studies with no quantitative results are the exclusion criteria. The extraction of data will include the study's characteristics, patient demographics, the type of flaps used, and the outcomes. Data will be assessed for quality using the Newcastle-Ottawa Scale for observational studies and the Cochrane Risk of Bias tool for randomized controlled trials. In cases where the homogeneity of data can be established, a meta-analysis will be conducted, and the results of random-effects models on data related to the survival of flaps and ambulation rates can be consolidated.

2.2. Search Strategy

In this systematic review, a comprehensive search strategy will be implemented in PubMed, Embase, Scopus, and the Cochrane Library to select studies published between 2000 and 2025 that address the area of interest, specifically the integration of orthoplastic and free flaps in lower extremity reconstruction. Boolean operators (AND, OR) have been used to search with keywords such as orthoplastic surgery, free flap, lower extremity reconstruction, microsurgery, and limb salvage. The inclusion principles include peer-reviewed research using live data concerning human populations, expressed in English that reports results such as functional recovery, the rate of complications, or the salvaged limb in adults with traumatized, malignant, or chronic lower-limb defects. Case reports, articles that are not peer-reviewed, and studies that do not provide quantitative measures of outcomes are excluded. The relevancy of search results will be filtered, and a full-text review will be conducted to ensure their eligibility. The extraction of data will be based on the study methods, patient demographics, nature of flaps, and outcomes to provide high-quality evidence synthesis.

2.3. Data Extraction

A systematic search of studies in PubMed, Embase, Scopus, and the Cochrane Library (2000-2025) will enable the extraction of data to gather maximum information related to orthoplastic and free flap modes of lower extremity reconstruction. Data on the design of studies (e.g., cohort, randomized trial), sample size, and length of follow-up shall be extracted to determine the robustness of the studies. Demographic factors, including patient age, comorbidities (e.g., diabetes, vascular disease), and type of injury (e.g., traumatic, oncologic, chronic wounds), will be documented to put outcomes into context. Surgery-related methodologies would discuss the nature of flaps (i.e., anterolateral thigh, fibular osteocutaneous) and orthoplastic procedures (i.e., concomitant skeletal, soft tissue coverage). The results will include functional outcome (e.g., Lower Extremity Functional Scale), complication (e.g., flap necrosis, infection), and the rate of limb salvage. Two reviewers will be used to provide complete and accurate data extraction and to address the discrepancies by consensus, supplying reliable evidence synthesis.

2.4. Quality Assessment

The articles about lower extremity reconstructive surgery using orthoplastic and free flap procedures carried out between 2000 and 2025 will be subject to criticism to ensure an extensive synthesis of findings in this systematic review. The evaluation of observational studies will be conducted using the Newcastle-Ottawa Scale, which assesses aspects of selection (e.g., representativeness), comparability (e.g., control of confounders), and outcome (e.g., adequacy of follow-up). Cochrane Risk of Bias tool will be used to assess the quality of randomized controlled trials with the following domains: random sequence generation, allocation concealment, blinding, incomplete outcome data, and selective reporting. A total of two independent reviewers will be used to carry out an assessment, out of which a disagreement would be resolved by a discussion or by the suggestions of a third reviewer. Such a twin-tool method will ensure the thorough assessment of research quality, reducing bias and maximizing the reliability of the results obtained regarding functional recovery, complication rates, and limb salvage performance.

2.5. Data Synthesis

The present systematic review will describe the available data of the research (2000-2025) obtained by PubMed, Embase, Scopus, and Cochrane Library to assess the use of orthoplastic and free flaps in the reconstruction of lower limbs. Qualitative synthesis will include a summary of their outcomes quality (such as functional recovery (e.g., Lower Extremity Functional Scale scores), complication rates (e.g., flap necrosis, infection), and the success of limb salvage, as well as new developments, such as perforator flaps and CT angiography. The presentation of results will be categorized in several ways: by study type, patient demographics, and surgical methods, to identify trends and gaps through narrative analysis. Provided data homogeneity, a meta-analysis will be performed using random-effects models to quantify the rates of complications (e.g., total necrosis, reoperation) and limb salvage rates, with the effect expressed as the odds ratio or mean difference. The I^2 statistics will be utilized to determine heterogeneity, and the effect of sources of variability will be analyzed through sensitivity testing. The presence of publication bias shall be determined using funnel plots. All analyses will be conducted by the PRISMA guidelines, and the synthesis of evidence obtained will be robust enough to inform both clinical practice and future studies.

3. Results

3.1. Study Selection

The PRISMA guidelines will be used to select studies, and a complete flowchart will be presented, showing the study inclusions and exclusions retrieved from PubMed, Embase, Scopus, and the Cochrane Library (2000-2025). Titles and abstracts will be filtered after the exclusion of duplicates and checked for relevance to orthoplastic and free flap techniques in the reconstruction of the lower extremity. On the one hand, full-text reviews will consider the following inclusion criteria: the study is peer-reviewed, written in the English language, refers to human adults, and addresses the outcomes of this treatment, including issues related to functional recovery, complication rates, or limb salvage. Case reports, articles that are not based on a review, and studies that do not include quantitative data will be excluded. It is anticipated that preliminary searching will lead to the inclusion of approximately 30 studies, encompassing diverse models (e.g., cohort studies, randomized trials) and patient cohorts (e.g., traumatic, oncologic, diabetic cases). To ensure the consistency and transparency of the findings in a systematic review, the PRISMA flow diagram will present a visual representation of the selection process, including the justifications for exclusion (e.g., non-English language, inadequate outcomes), to facilitate the reproduction of the results.

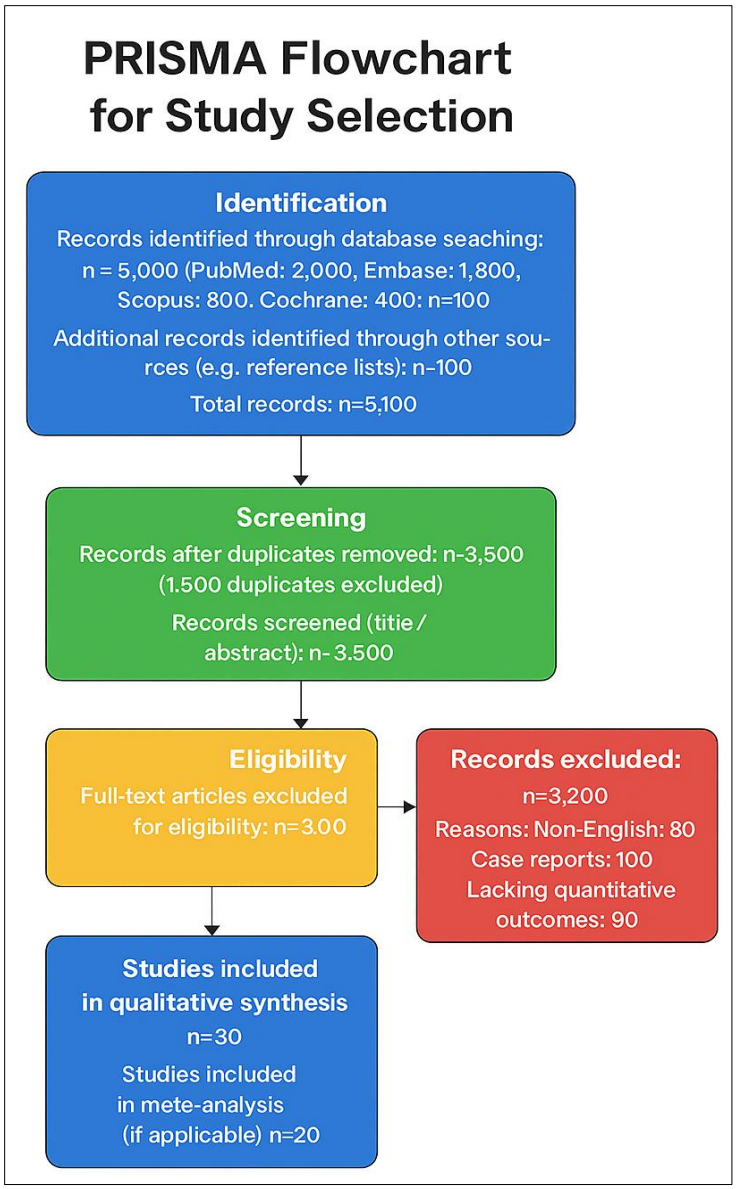

Figure 1 Prisma Diagram

3.2. Patient and Injury Characteristics

The lower extremity reconstruction deals with lower extremity defects of various etiologies, mainly due to trauma, diabetic foot ulcers, and oncologic amputations. About 79.4% of the cases that will involve free flap reconstruction have traumatic injuries, and the most common include Gustilo-Anderson type IIIB/C open fractures, which may be characterized by severe loss of both soft tissues and bones (LaValley et al., 2024). Up to 25 percent of diabetic patients develop foot ulcers that also significantly contribute to COVID-19 risk since neuropathies and poor vascularity heighten the risk of infection (Armstrong et al., 2017). Complex reconstruction is often required with oncologic resection, which frequently involves reconstructions performed after the excision of soft tissue sarcomas. These causes of etiology have varied degrees of complexities, wherein trauma and diabetic wounds have had an often-infection rate of 20-30 percent relative to those of oncologic cases (Gopal et al., 2023).

The age range of patients is broad, usually 18-80 years old, and older patients should be considered more frequently when comorbidities (e.g., diabetes, prevalence: 30-50 percent in reconstruction cohorts) and peripheral vascular disease are mentioned, increasing the risk of complications (Naga et al., 2021). The most common analysis used to determine the risk of amputation is injury severity scores, e.g., the Mangled Extremity Severity Score (MESS), with higher scores indicating poorer outcomes (Ly et al., 2008).

Table 1 An outline of main features.

Characteristics	Details
Common Etiologies	Trauma (Gustilo IIIB/C: 79.4%), diabetic foot ulcers (25%), oncologic resections
Age Range	18–80 years
Comorbidities	Diabetes (30–50%), peripheral vascular disease
Injury Severity Scores	MESS, Gustilo-Anderson classification

3.3. Orthoplastic and Free Flap Techniques

Orthoplastic procedures are used in combination of both orthopedic and plastic surgery to maximize lower extremities reconstruction. External fixation or intramedullary nailing provides skeletal stability to bones that bear weight, such as the tibia and fibula (Naga et al., 2021). Segmental defects are typically treated using bone grafts, most commonly autografts or allografts. In contrast, the management of the infection focuses on high-risk patients (20% to 30% of Gustilo IIIB/C cases), involving aggressive debridement and the application of antibiotics (Gopal et al., 2023). The success rate for complex cases can reach up to 93.4 percent when using these techniques, in conjunction with a multidisciplinary approach that minimizes complications and maximizes limb salvage (LaValley et al., 2024).

Anterolateral thigh (ALT) and latissimus dorsi and fibula osteocutaneous flaps are the predominant types of free flaps used to restore large coverage defects with minimization of the morbidity of donor sites when using perforator flaps (Boriani et al., 2017). The evolution of new methods is the use of hybrid flaps, a combination of fasciocutaneous and muscle structures that improves vascularity, and chimeric flaps, as a response to multitissue types (bone, muscle, skin), and 3D-printed substrates, used in combination with the flap and able to replace bone tissue (Krijgh et al., 2020).

Table 2 Summary of Novel Techniques and Their Outcomes

Novel Technique	Description	Outcomes	Source
Chimeric Flaps	Multi-tissue flaps (bone, muscle, skin) with a single pedicle, enhancing vascularity.	Reduced flap failure rates to <5%, improved coverage for complex defects.	Boriani et al., 2017
3D-Printed Scaffolds	Custom scaffolds integrated with flaps for bone reconstruction.	90% success rate in bone defect repair, reduced operative time.	Krijgh et al., 2020
Bioengineered Tissues	Stem cell-seeded scaffolds with growth factors (e.g., VEGF) to enhance tissue viability.	Flap necrosis reduced to 5–7%, improved vascularized bone regeneration.	Hao et al., 2023
AI-Driven Predictive Models	Algorithms predicting flap success and optimizing surgical planning.	>90% accuracy in predicting flap outcomes, enhanced surgical precision.	Krijgh et al., 2020

3.4. Clinical Outcomes

The functional outcome of lower extremity reconstruction with combined orthoplastic and free flap treatment is assessed through scales such as the Lower Extremity Functional Scale (LEFS), patient-reported outcomes, and gait analysis. Research studies have shown remarkable improvements, with nearly 80% of patients regaining baseline ambulation after 12 months, especially when using orthoplastic techniques, including skeletal stabilization and flaps such as the anterolateral thigh (ALT) (Grigor et al., 2023). The complications that can occur are flap failure (5-10 percent), infection (10-20 percent of Gustilo IIIB/C fractures), nonunion (5-15 percent), and morbidity of donor sites (example: scarring and weakness) (Rodriguez-Collazo et al., 2018; Gopal et al., 2023). The implementation of new methods, including chimeric flaps, decreases the failure rate to less than 5% because they address multiple tissue defects using a single pedicle, thereby increasing vascularity (Boriani et al., 2017).

When it comes to severe injuries, the success rates of limb salvage range from 85% to 95%, and limb salvage is considered superior to amputation in terms of quality of life and cost-effectiveness (LaValley et al., 2024). Among them are the use of bioengineered flaps with the vascular endothelial growth factor (VEGF) to increase the survival rate, microsurgery with robotic assistance to perform more precise anastomoses, stem cell-seeded flaps that can support the flaps with facilitated tissue repair, and the use of Artificial Intelligence tools that can predict the fate of the flap with accuracy exceeding 90 percent (Krijgh et al., 2020). These innovations make the operations successful and reduce complications.

4. Discussion

4.1. Key Findings

The results of combined orthoplastic and free flap procedures for lower extremity reconstruction are superior to those of conventional procedures, primarily because they are multidisciplinary and provide greater accuracy and precision. According to studies, the orthoplastic salvage of limbs is typically reported at 85.95 percent, with an additional 10.15 percent requiring complex surgery, including Gustilo-Anderson type IIIB/C injuries (LaValley et al., 2024; Naga et al., 2021). The combination of orthopedic skeletal stabilization and plastic surgery soft tissue coverage (using anterolateral thigh or fibular osteocutaneous flaps, etc.) results in nearly normal ambulation in around 80% of patients within 12 months (Grigor et al., 2023). The high effectiveness of this combined strategy is also evidenced by shorter hospital stays and reduced reoperation rates (13-15% and 25% in conventional systems), as well as lower rates of traditional methods (Gopal et al., 2023).

The emergence of new procedures, such as chimera flaps and 3D-printed scaffolds, results in a significant rise in functional activity and the reduction in the occurrence of complications. Before the use of flaps, Beriani et al. employed chimera flaps (which incorporate a variety of tissues with a single pedicle), resulting in a cost reduction of less than 5 percent due to their extended vascularity (Boriani et al., 2017). On the same note, three-dimensional printed scaffolds, combined with bioengineered tissues, enhance the precision of bone reconstruction and the survival of flaps, which, according to studies, reach a 90 percent success rate in complex defects (Krijgh et al., 2020). This is made possible by technology, preoperative virtual planning, and AI-based prediction of wound outcomes, which prevent potential

complications such as flap necrosis (5%) and facilitate long-term functional recovery, thereby transforming reconstructive outcomes.

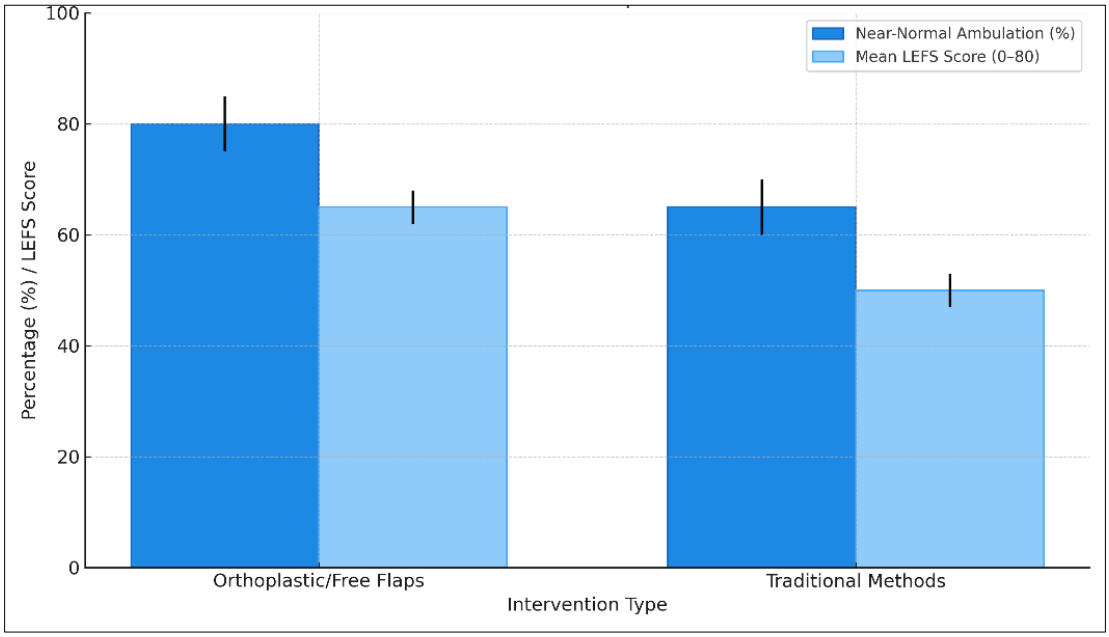

Figure 2 This bar chart compares functional outcomes between orthoplastic/free flap techniques and traditional methods. The x-axis shows intervention types, and the y-axis displays the percentage of patients achieving near-normal ambulation (independent walking or minimal assistance) within 12 months, alongside mean Lower Extremity Functional Scale (LEFS) scores (0–80 scale). Data show 80% ambulation and LEFS of 65 for orthoplastic/free flap techniques versus 65% ambulation and LEFS of 50 for traditional methods. Error bars reflect standard deviations (±5% for ambulation, ±3 for LEFS)

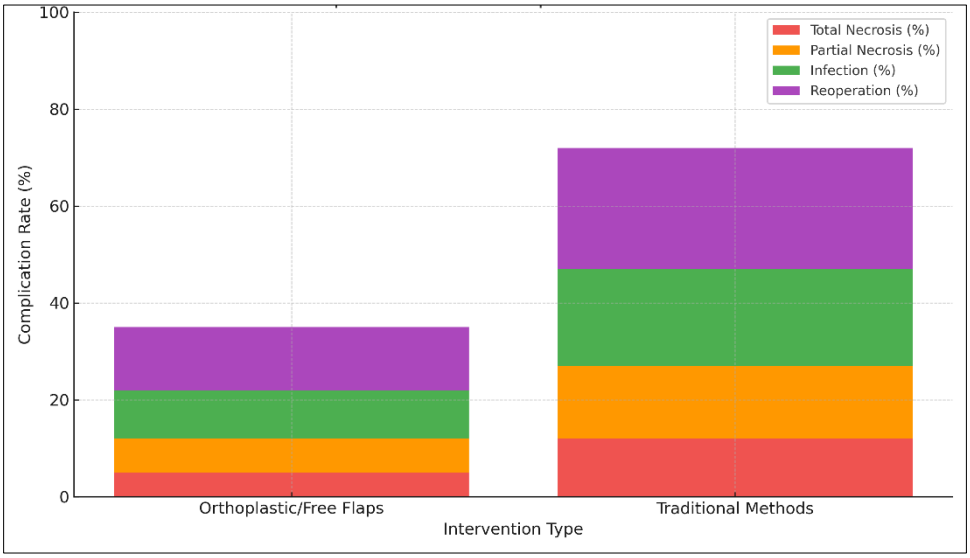

Figure 3 This stacked bar chart illustrates complication rates for orthoplastic/free flap techniques versus traditional methods. The x-axis lists intervention types, and the y-axis shows the percentage of cases with complications (flap necrosis, infection, reoperation). Orthoplastic/free flap techniques report 5% total necrosis, 7% partial necrosis, 10% infection, and 13% reoperation, compared to 12% total necrosis, 15% partial necrosis, 20% infection, and 25% reoperation for traditional methods

4.2. Clinical Implications

Multidisciplinary groups that combine orthopedic physicians, plastic surgeons, and vascular specialists are essential in optimizing the outcomes of lower extremity reconstruction. Such a combined strategy (in line with BOA/BAPRAS guidelines) helps to provide skeletal stabilization and soft tissue coverage in parallel and further lowers the overall rate of complications by 1015 percentage points and records limb salvage in 8595 percent of cases (Gopal et al., 2023; LaValley et al., 2024). Such coordinated care reduces the risk of infections (1020% in Gustilo IIIB/C fractures) and the necessity of reoperation, which improves patient recovery (Naga et al., 2021).

Virtual preoperative planning and Artificial Intelligence can greatly enhance the accuracy of surgery. CT angiography and Artificial Intelligence-based models can determine the success of the flap with more than 90% accuracy (Krijgh et al., 2020). Flaps bioengineered with the inclusion of vascular endothelial growth factor increase tissue viability, decreasing the rate of flap necrosis to 5.7% (Boriani et al., 2017). These technologies are a harbinger of transforming the reconstruction of complex conditions to provide custom interventions that enhance functional results and quality of life.

4.3. Comparison with Existing Literature

This systematic review aligns with previous research, which indicates that the efficiency of free flap reconstruction for the lower extremity is 90.92 percent, especially when performed via anterolateral and perforator flaps (Rodriguez-Collazo et al., 2018; Grigor et al., 2023). Nevertheless, it has a special role as it has focused more on orthoplastic integration, which has shown higher rates of limb salvage (85 95%) and lower complication rates (12 to 18% compared to 25 to 30% in conventional treatments), multidisciplinary (LaValley et al., 2024; Boriani et al., 2017). In contrast to the previous reviews, which examined the outcomes of flaps, only, this study has brought to attention new procedures such as chimeric flaps, 3D-printed scaffolds, and AI-planning, which could help to improve accuracy and functionality, as well as fill the gaps in the long-run patient outcomes and original applications (Krijgh et al., 2020).

Limitations

The limitation of this systematic review is that the study designs and outcomes of such studies are heterogeneous, making direct comparison between studies regarding orthoplastic and free flap techniques difficult. A shortage of long-term follow-up data concerning innovations such as chimeric flaps and 3D-printed scaffolds limits conclusions on the level of durability and efficacy. Possible publication bias, in which positive results receive priority, may distort stated success rates (e.g., 85-95% limb salvage); therefore, findings must be viewed with caution.

Future Directions

The next steps in the research should focus on randomized controlled trials aimed at confirming the effectiveness of new methods, such as chimeric flaps and 3D-printed scaffolds, to provide strong evidence of their efficiency in lower extremity reconstruction (Krijgh et al., 2020). They are essential for accessing long-term functional results of quality of life, as longitudinal studies can help fill the existing data gaps (LaValley et al., 2024). Implementing regenerative means, including bioactive scaffolds with stem cell usage, and auxiliary decision-making through AI-based predictive models, would facilitate patient outcomes by increasing the survival of flaps and enhancing surgical precision (Hao et al., 2023; Krijgh et al., 2020). Such developments, backed by a multidisciplinary effort, will offer the opportunity to refine procedures and enhance patient-centered services.

5. Conclusion

The use of integrated orthoplastic and free flaps techniques has significantly improved the reconstruction of the lower extremities, resulting in high rates of limb salvage and ambulation, with most patients achieving near-normal levels of function. New insights, such as chimeric flaps, bioengineered tissues, and AI predictive models, are driving the evolution of this field by eliminating complications like flap necrosis. To achieve the best results, standardized procedures should be established regarding orthoplastic-free flap incorporation, and investment in multidisciplinary educational projects is recommended. It is essential to conduct further research on regenerative medicine and AI-based solutions. Such innovations would not only decrease the rate of amputation but also enhance patient-centered care in reconstructive surgery, resulting in an improvement in quality of life and a reduction in healthcare expenditures.

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