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**Systematic Review**

# Perforator flaps in soft tissue reconstruction: clinical outcomes in reconstructive plastic surgery

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## ABSTRACT

Perforator flaps constitute a significant advancement in soft tissue reconstruction within reconstructive plastic surgery, relying on perforator vessels that supply the skin and subcutaneous tissue without requiring large muscle or fascia volumes. This innovative approach allows for more refined and less invasive reconstructions, preserving muscular integrity and reducing functional deficits at the donor site. These flaps have become increasingly important in the management of complex defects resulting from oncologic resections, traumatic injuries, or chronic wounds particularly in anatomically complex regions. Advances in preoperative imaging and intraoperative navigation have enhanced the accuracy of flap planning and reduced complication rates. Additionally, the evolution of flap design-such as propeller, free-style, and supermicrosurgical flaps-has expanded reconstructive options. This systematic review aimed to evaluate recent innovations, surgical techniques, and clinical outcomes associated with perforator flaps across a range of reconstructive scenarios. A total of 30 studies were included, comprising clinical trials and observational research focusing on different anatomical sites (extremities, head and neck, breast, and trunk). The findings reveal a flap survival rate ranging from 93% to 98%, lower complication rates compared with conventional musculocutaneous methods, and high patient satisfaction. Nevertheless, heterogeneity in outcome measures and lack of randomized studies with large sample sizes underscore need for more standardized protocols and multicenter research to draw stronger conclusions.

**Keywords:** Perforator flaps, Soft tissue reconstruction, Reconstructive plastic surgery, Surgical technique, PRISMA

## INTRODUCTION

Plastic reconstructive surgery has shown remarkable progress in recent decades thanks to a deeper understanding of vascular anatomy and the incorporation of increasingly sophisticated microsurgical technology.[1] Among the most notable innovations, perforator flaps have gained relevance by allowing the transfer of cutaneous and subcutaneous tissue with a secure vascular supply from specific perforator vessels.[2] The main difference between perforator flaps and musculocutaneous flaps lies in the preservation of muscle mass, which reduces donor site morbidity and improves functional and aesthetic outcomes.[3,4] Representative examples include the anterolateral thigh (ALT), thoracodorsal thigh (TDAP), and gluteal perforator flaps, each with specific indications depending on the region to be reconstructed.[5]

The introduction of these flaps has not only broadened reconstructive possibilities but also improved the quality of life of patients by enabling less invasive harvesting techniques, shorter hospital stays, and more natural results. Moreover, perforator flaps align with modern trends prioritizing functional restoration while minimizing collateral tissue damage. In oncologic reconstruction, particularly breast surgery, the deep inferior epigastric

perforator (DIEP) flap has largely replaced traditional TRAM flaps due to its superior preservation of abdominal wall integrity and reduced postoperative pain.

Several classification systems have been proposed to better define perforator anatomy and guide flap design, such as the Gent consensus and the perforasome theory. These frameworks aid in understanding vascular territories and optimizing flap planning, contributing to greater flap reliability. The Gent consensus provides standardized terminology for naming perforators based on source vessels and anatomical zones, enhancing interdisciplinary communication. The perforasome theory describes the dynamic perfusion zones supplied by individual perforators, helping surgeons predict flap behavior during elevation and rotation. Moreover, preoperative planning using CT angiography and intraoperative fluorescence angiography have become invaluable tools for perforator selection, allowing precise localization, flow assessment, and flap tailoring. These imaging modalities not only reduce operative time but also decrease the risk of flap failure by identifying dominant vessels and collateral networks. Incorporating these strategies into routine practice strengthens surgical outcomes and advances the precision of microsurgical reconstruction.

Despite its advantages, perforator flap surgery requires detailed planning and a steep learning curve, as selection and dissection of the appropriate perforator vessel requires surgical expertise and the use of vascular mapping methods such as Doppler ultrasound and angiographic computed tomography.[6,7] This systematic review analyzes the techniques, clinical outcomes, and complications of perforator flap surgery in soft tissue reconstruction, with a view to establishing guidelines to enhance clinical practice and identify areas of research pending.[8]

The objective of this work was to describe the main innovations and techniques used in perforator flaps in soft tissue reconstruction, evaluate the clinical efficacy of these flaps in terms of survival, complications, and cosmetic outcomes, and analyze the nature and frequency of adverse events associated with the use of perforator flaps.

## METHODS

This study was developed in accordance with the PRISMA (Preferred reporting items for systematic reviews and meta-analyses) statement.[9]

The review process was conducted between September 2023 and October 2023 at the department of surgery, general hospital of Mexico, in collaboration with the department of internal medicine, Medica Sur hospital, Mexico City.

### *Databases searched*

PubMed, Scopus, and Web of Science used for databases search.

### *Search period*

Search period was from January 2010 to June 2023.

### *Terms and strategy*

Combinations of the keywords "perforator flaps," "soft tissue reconstruction," "reconstructive plastic surgery," "microsurgery," and "PRISMA" were used, using Boolean operators (AND, OR) and language restrictions (English or Spanish).

### *Inclusion criteria*

Inclusion criteria for study-Publications in English or Spanish between 2010 and 2023, ensuring linguistic accessibility and contemporary relevance of the data. Randomized clinical trials, observational studies (cohorts, case-control studies), and case series (n>10), to ensure adequate statistical relevance generalizability. Studies involving the use of perforator flaps in soft tissue reconstruction of any anatomical region, including but not limited to extremities, trunk, head and neck, or breast. Reporting of results in terms of flap survival, complication rates, and/or aesthetic or functional evaluations, whether through objective scales, clinical assessments, or validated patient-reported outcome measures. Studies were required to present measurable and analyzable clinical endpoints, contributing directly to the review's objectives.

### *Exclusion criteria*

Exclusion criteria for study-Preclinical studies (animal models or in vitro experiments), as they do not provide direct clinical applicability or human outcome data. Narrative reviews, expert opinions, or editorials without original primary data, which do not contribute quantifiable results suitable for systematic analysis. Case reports with fewer than 10 patients, given their limited statistical power and potential for selection bias. Articles published prior to 2010 unless they contained seminal or historically relevant findings directly influencing current clinical practices. Studies with outdated techniques or reporting standards were excluded to maintain consistency with modern reconstructive principles and ensure methodological relevance.

### *Study selection*

Fifty references were initially identified through systematic searches across PubMed, Scopus, and Web of Science, based on the defined inclusion criteria. Among these, five duplicate entries were removed after automated and manual cross-checking. The remaining 45 titles and abstracts were screened independently by two reviewers. During this stage, ten articles were excluded due to irrelevance, incomplete methodological data, or failure to meet design requirements. Subsequently, 35 full-text articles were assessed for eligibility. Of these, five were excluded for not providing detailed or quantifiable data on

complications, flap viability, or clinical outcomes. The most common reason for exclusion at this stage was lack of clear outcome measures or absence of survival rate analysis. Ultimately, 30 high-quality studies fulfilled all the inclusion criteria and were incorporated into the final synthesis and data extraction process (Table 1). This selection reflects a comprehensive and methodologically rigorous process, ensuring the relevance and reliability of the evidence analyzed in this review.

**Table 1: Study selection process according to PRISMA.[9]**

| Review stages | Number of articles |
|---|---|
| **Initial references** | 50 |
| **Duplicates removed** | 5 |
| **Title/abstracts reviewed** | 45 |
| **Full texts evaluated** | 35 |
| **Included in final analysis** | 30 |

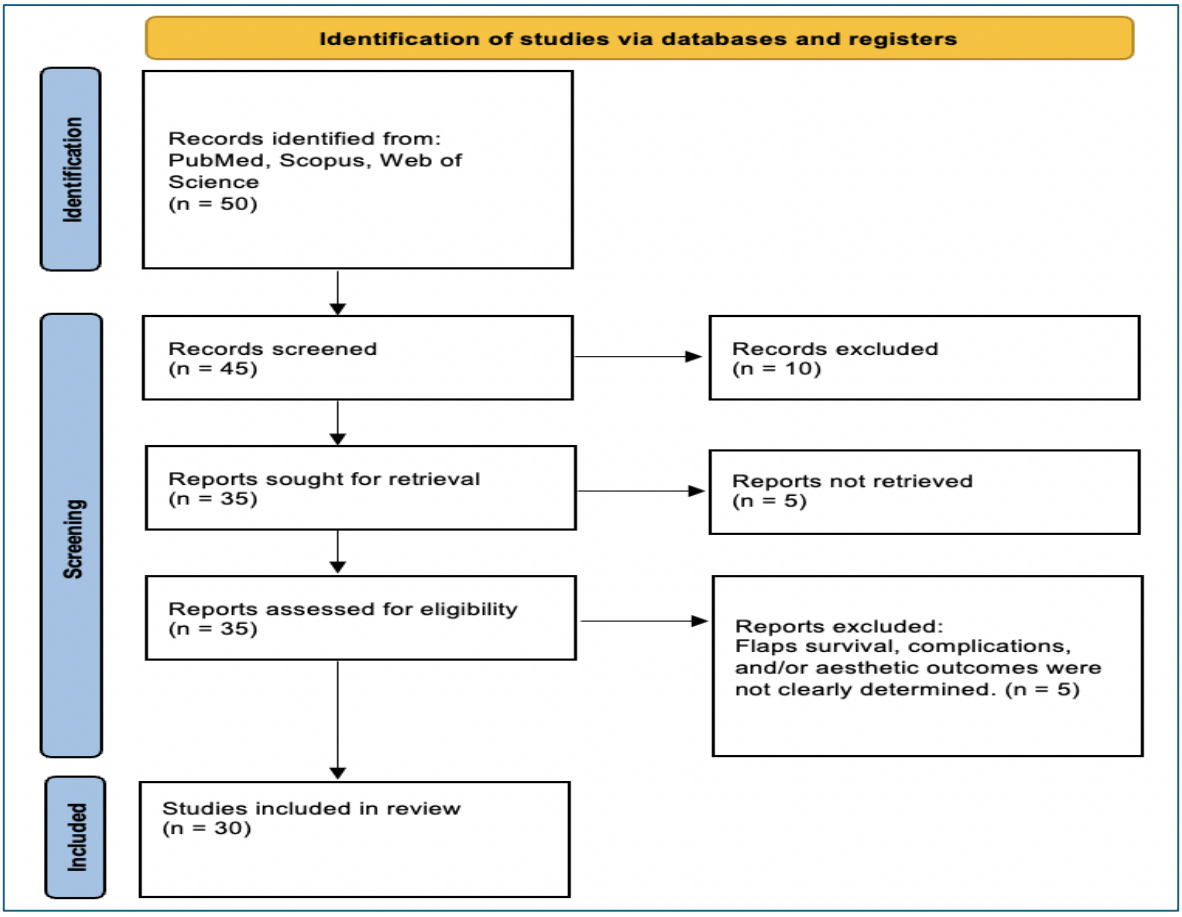


**Figure 1: Identification of studies via database and registers.**

## RESULTS

### *General characteristics of the studies*

Among the 30 included studies, 12 were clinical trials (randomized or quasi-randomized) and 18 were observational studies (prospective, retrospective cohorts, and case series).[10-12] The average sample size ranged from 20 to 150 participants, with follow-up ranging from 6 to 24 months.[13,14] In clinical trials, the interventions often compared perforator flaps with conventional musculocutaneous techniques, while observational studies predominantly focused on reporting outcomes related to flap viability, complications, and patient satisfaction. The diversity of study designs allowed for a broad evaluation of clinical scenarios, encompassing oncologic reconstruction, trauma, and chronic soft tissue defects. Most studies provided detailed intraoperative data, including flap dimensions, vascular pedicle length, and operative time, which are critical variables in flap selection and surgical planning. Additionally, postoperative assessments varied but frequently included clinical evaluation, photographic documentation, and, in some cases, validated quality-of-life instruments. This methodological diversity reflects both the evolving nature of perforator flap surgery and the increasing interest in evidence-based evaluation of surgical outcomes.

### *Types of perforator flaps and locations*

Anterolateral thigh (ALT) and thoracodorsal artery perforator (TDAP) flaps were the most frequently

mentioned, aimed at extremity and trunk coverage.[15,16] The ALT flap, in particular, was noted for its long vascular pedicle, versatility in design (e.g., chimeric, thinned), and low donor-site morbidity, making it a preferred option in head, neck, and lower limb reconstruction. The TDAP flap was favored in cases requiring pliable tissue with consistent anatomy and concealed donor sites, especially in trunk and axillary defects. Other flaps described included those based on inferior epigastric artery perforators (DIEP) for breast reconstruction and radial or gluteal perforators for specific defects.[17,18] These alternatives were selected based on defect location, tissue requirements, and surgeon expertise. Several studies also highlighted intraoperative decision-making algorithms for flap selection and the utility of preoperative imaging to map perforator anatomy and reduce operative time.

**Table 2: Frequency of use of perforator flaps in the studies (n=30).**

| References | Perforator flap | Number of studies | Percentage (%) |
|---|---|---|---|
| **Wei et al, Wei et al, Saint-Cyr et al, Li et al, Ribuffo et al[5,14-16,24]** | ALT (anterolateral thigh) | 14 | 46.7 |
| **Blondeel et al, Choi et al[4,18]** | TDAP (thoracodorsal) | 8 | 26.7 |
| **Koshima et al, Schaverien et al, Banchini et al, Seidenstuecker et al[3,20-22]** | DIEP (inferior epigastric) | 5 | 16.7 |
| **Georgescu, Pang et al[17,25]** | Others (glutes, radial) | 3 | 10.0 |

The ALT flap showed great versatility in different reconstructive scenarios.[15-18] Flap survival and complications (Table 2).

The average flap survival rate was 93% to 98%, with partial or total necrosis ranging from 2% to 7% of cases.[19] This high rate of viability reflects the improved understanding of perforator anatomy, meticulous dissection techniques, and the integration of preoperative imaging such as Doppler ultrasound or CT angiography. The most frequent complications included vascular thrombosis (1-3%), local infection (2-4%), and suture dehiscence (1-5%), associated with factors such as smoking, comorbidities, or inadequate microsurgical technique.[20,21] Some studies reported that early identification of compromised perfusion and prompt surgical revision significantly improved salvage rates. Others emphasized the role of systemic factors such as diabetes, peripheral vascular disease, and nutritional status in influencing complication rates. Donor site complications, although less frequent, included seroma formation, contour deformities, or delayed healing, particularly in obese or elderly patients. These findings underscore the importance of careful patient selection, intraoperative vigilance, and postoperative monitoring to optimize outcomes in perforator flap surgery.

**Table 3: Complications associated with the use of perforator flaps.**

| References | Complications | Frequency range (%) | Associated factors |
|---|---|---|---|
| **Maldaun et al, Schaverien et al[19,20]** | Partial/total necrosis | 2-7 | Thrombosis, poor vessel selection |
| **Maldaun et al, Banchini et al[19,21]** | Local infection | 2-4 | Inefficient bacterial control, comorbidities |
| **Schaverien et al, Banchini et al[20,21]** | Vascular thrombosis | 1-3 | Surgical technique, smoking |
| **Banchini et al, Pang et al[21,25]** | Suture dehiscence | 1-5 | Overvoltage, malnutrition, local care. |

The most frequent adverse events and predisposing factors are shown (Table 30).[19-21]

***Aesthetic and functional outcomes***

Twenty-two studies evaluated aesthetic outcomes using subjective scales (patient satisfaction) and/or objective assessments (clinical evaluations of color, thickness, and texture).[22,23] Most reported high levels of satisfaction, highlighting the similarity in contour and the lower morbidity at the donor site.[24,25] Some studies employed standardized tools such as the BREAST-Q or visual analog scales (VAS) to quantify patient-perceived outcomes, especially in breast and facial reconstruction. Others incorporated third-party evaluations by independent surgeons or photographic comparisons over time. Patient satisfaction was frequently attributed to the thin, pliable nature of perforator flaps and their ability to conform to complex anatomical contours. In addition, concealed donor sites and preservation of function further enhanced cosmetic acceptance. However, certain cases reported contour irregularities/pigmentation mismatch, particularly in skin types IV-VI, underlining need for individualized planning and long-term aesthetic monitoring.

***Bias analysis and methodological quality***

The quality review of the studies revealed that several trials lacked strict blinding, and in most observational studies, confounding factors such as defect size, surgical team experience, or patients' systemic conditions were not adequately controlled.[26] Tools such as the Cochrane scale for clinical trials and the STROBE guidelines for observational studies were used, revealing disparities in evaluation methods and patient selection.[27,28] Some studies failed to report key methodological aspects such as sample size calculation, intention-to-treat analysis, or dropout rates. Furthermore, heterogeneity in outcome definitions and follow-up intervals limited the ability to synthesize data quantitatively. Inter-rater variability in clinical assessments and lack of standardized cosmetic evaluation tools further impacted result comparability. Although a few studies demonstrated high methodological rigor, the overall variability underscores the need for adherence to standardized reporting frameworks in future research to ensure transparency, reproducibility, and comparability across studies on perforator flap outcomes.

## DISCUSSION

The results of this systematic review agree that perforator flaps offer a highly reliable and effective reconstructive alternative, characterized by high survival rates and better preservation of underlying tissues compared to traditional musculocutaneous flaps.[10,15] The ALT flap stands out as one of the most versatile due to its relatively consistent anatomy and its ability to cover larger defects.[5,16] Its adaptability to various contouring needs and tolerance to flap thinning make it ideal for both aesthetic and functional reconstructions.

Proper selection of perforator vessels is essential, a factor that can be optimized through preoperative vascular mapping using Doppler ultrasound or computed tomography angiography.[7,29] Recent studies have also explored the role of intraoperative indocyanine green (ICG) fluorescence for real-time perfusion assessment. However, there is heterogeneity in the aesthetic and functional evaluation scales, as well as in the follow-up periods, which limits the comparability of findings.[22,23] Lack of standardization in outcome reporting hampers the ability to draw strong evidence-based conclusions across clinical settings.

Moreover, the learning curve is a critical factor in the incidence of complications. Centers with extensive experience in microsurgery tend to report lower rates of partial necrosis or thrombosis, reinforcing the importance of specialized training and standardized protocols[24] Additionally, institutional infrastructure-such as access to specialized equipment and dedicated microsurgical teams-plays a critical role in outcomes. The implementation of simulation-based training programs and anatomical dissection labs has proven beneficial in accelerating the acquisition of microsurgical skills. Future efforts should prioritize multicenter collaborations, prospective registries, and universal classification systems for flap outcomes to advance the field and support continuous quality improvement. Setting standardized benchmarks for surgical performance and incorporating patient-centered metrics will further enhance quality and reproducibility.

## CONCLUSION

Perforator flaps have emerged as a pivotal innovation in reconstructive plastic surgery, offering a reliable balance between aesthetic and functional outcomes with minimal donor site morbidity. Their high survival rates (93-98%) and versatility-particularly seen in the extensively studied ALT and TDAP flaps-make them valuable options across various anatomical regions. These techniques enable tailored tissue replacement while minimizing trauma to donor sites, contributing to faster recovery and improved patient satisfaction. Furthermore, their compatibility with supermicrosurgical techniques and the possibility of combining them with vascularized lymph node transfer or neurotized flaps expand their functional potential.

However, their success relies heavily on accurate perforator identification and microsurgical expertise to avoid complications such as thrombosis or infection. The integration of advanced imaging and surgical precision has improved outcomes, yet the field still requires high-quality, multicenter clinical studies with standardized evaluation tools. Comparative effectiveness research between different perforator designs and long-term functional follow-up are also needed to validate durability. Strengthening the scientific foundation will optimize clinical decision-making and further consolidate the role of perforator flaps in modern reconstructive strategies, particularly as demand for complex, patient-specific reconstruction continues to grow in oncology, trauma, and congenital care. Lastly, establishing international registries and encouraging cross-specialty collaboration may enhance data pooling and innovation, shaping the future of evidence-based reconstructive microsurgery.

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