

A Retrospective Comparative Evaluation of Perforator-Based Propeller Flaps Versus Free Flaps in Post-Traumatic Distal Lower Extremity Soft Tissue Reconstruction

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Abstract:

Background: Post-traumatic distal lower extremity soft tissue defects pose significant reconstructive challenges, requiring timely and effective coverage to prevent complications and restore function.

Aim: To compare clinical outcomes of perforator-based propeller flaps (PPF) and free flaps (FF) in distal lower extremity reconstruction.

Methodology: This retrospective comparative study included 90 patients divided equally into PPF and FF groups. Data on demographics, defect characteristics, operative parameters, complications, and functional outcomes were analyzed using appropriate statistical tests, with $p < 0.05$ considered significant.

Results: Both groups had comparable baseline characteristics. PPF was primarily used for smaller defects, while FF was preferred for larger defects. Operative time and blood loss were significantly lower in the PPF group ($p < 0.001$). Flap survival and complication rates were comparable between groups ($p > 0.05$). PPF showed significantly shorter hospital stay and earlier ambulation ($p < 0.001$), while long-term functional outcomes and patient satisfaction were similar.

Conclusion: Both PPF and FF are effective reconstructive options. PPF offers advantages in operative efficiency and early recovery, whereas FF remains ideal for large and complex defects.

Keywords: Perforator-based Propeller Flap, Free Flap, Lower Extremity Reconstruction, Trauma, Soft Tissue Defects.

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Introduction

The surgical field faces substantial reconstruction difficulties when dealing with soft tissue defects that occur in the distal lower extremity after high-energy traumatic events. The injuries require immediate coverage solutions because they create exposed areas that include bone and tendon structures as well as hardware components which need protection to maintain their structural soundness and operational capabilities. The medical community considers early soft tissue coverage to be essential for achieving successful recovery results while decreasing complications in patients who experience severe open lower extremity injuries. Delayed or inadequate reconstruction procedures create a risk of infection together with extended hospital stays and decreased limb functionality which may result in total limb amputation [1].

Historically, the reconstructive choices of lower extremity defects have been largely reliant on the

anatomical location and extent of tissue loss. Pedicled muscle flaps, including the gastrocnemius flap, have been thought of as simple and reliable in the event of defects in the proximal portion of the lower leg [2]. Nevertheless, reconstruction is more complicated in the distal third of the leg and foot because of limited availability of local tissue, reduced vascularity, and the existence of thin soft tissue coverage. These anatomical limitations greatly restrict the application of traditional pedicled flaps in distal defects, thus necessitating more sophisticated reconstructive methods.

A number of surgical methods have been devised over the years to treat soft tissue defects in the middle and distal thirds of the lower leg. These are reverse sural artery flaps, perforator-based flaps, and free flaps (FF), each with its own benefits and drawbacks [3]. Although there are several reconstructive modalities available, the choice of the most suitable

technique is complicated and depends on the size of the defect, its location, comorbidities of the patient, the expertise of the surgeon, and the available resources. Notably, the effects of flap failure in this area may be devastating, and in most cases, may lead to complications like osteomyelitis, chronic infection, and eventual amputation, particularly in severe trauma cases. Thus, it is necessary to pay close attention to reconstructive options to guarantee positive results.

The free flap reconstruction has long been regarded as the gold standard in the management of extensive soft tissue defects of the distal lower extremity [4]. This is a technique whereby vascularized tissue is transferred to the defect site using microsurgical anastomosis. Free flaps have a number of benefits, such as the possibility to cover large defects, the possibility to select the tissue, and the reliability of the vascular supply. They are therefore commonly considered as the first choice in reconstruction of the distal leg and foot. Nevertheless, free flap surgeries are technically challenging, demand specialized microsurgical skills, long operating time, and sophisticated infrastructure, which may not be easily accessible in all healthcare facilities.

The perforator-based propeller flap (PPF) has become a promising alternative to lower extremity reconstruction in recent years. This technique, first described by Hyakusoki et al. [5] involves rotating a flap of skin and subcutaneous tissue around a perforating vessel to cover adjacent defects. The PPF has become popular because of a number of advantages, such as avoiding microsurgical anastomosis, shortening the duration of the operation, preserving major vascular axes, and the possibility of achieving a like-with-like tissue reconstruction with good cosmetic results. Additionally, it is particularly useful in settings where microsurgical facilities are limited, making it an attractive option in resource-constrained environments.

Although these advantages exist, the application of perforator-based propeller flaps is not without its limitations. Venous congestion, partial flap necrosis, and tip necrosis are some of the complications that are still of concern with this technique [6]. These problems are especially applicable in cases of trauma, where vascular integrity can already be impaired. Consequently, some surgeons have been cautious about the application of PPF in post-traumatic soft tissue defects of the distal lower extremity. Moreover, the current literature on PPF is comparatively small and heterogeneous, with numerous studies involving cases of reconstruction after tumor resection in addition to defects related to trauma. This inconsistency complicates the process of making conclusive findings about its effectiveness in a traumatic environment in particular.

The other significant limitation of the existing body of literature is the lack of direct comparative studies that assess perforator-based propeller flaps versus free flaps in the context of trauma-related distal lower extremity reconstruction. Although both methods are common, there is a lack of evidence to clearly determine the relative benefits, complication rates, and functional outcomes of the two methods when used in similar clinical situations. Such comparative analyses are essential for guiding surgical decision-making and optimizing patient care.

In this regard, the current study seeks to undertake a retrospective comparative assessment of perforator-based propeller flaps versus free flaps in post-traumatic reconstruction of the distal lower extremity soft tissues using perforator-based propeller flaps versus free flaps. This study aims to help surgeons better understand the respective roles of these two reconstructive modalities and to assist them in making a more informed choice of which of these two reconstructive modalities is best suited to manage complex traumatic defects of the distal lower limb.

Methodology

Study Design: The present study was designed as a retrospective comparative observational study aimed at evaluating and comparing the clinical outcomes of perforator-based propeller flaps (PPF) and free flaps (FF) in the reconstruction of post-traumatic distal lower extremity soft tissue defects.

Study Area: The study was conducted in the Department of General Surgery, Jagannath Gupta Institute of Medical Sciences, Budge Budge, Kolkata, West Bengal, India.

Study Duration: The study was carried out over a period of one year.

Study Participants

Inclusion Criteria

- Patients with post-traumatic soft tissue defects of the distal lower extremity (lower leg and foot).
- Patients who underwent reconstruction using either perforator-based propeller flaps or free flaps.
- Patients aged ≥ 18 years.
- Cases with complete medical records, including intraoperative and postoperative details.
- Patients with a minimum follow-up period of at least 3 months.

Exclusion Criteria

- Patients with soft tissue reconstruction performed more than 6 weeks after trauma.
- Cases with chronic osteomyelitis developing more than 3 months after the initial injury.
- Defects involving toes only.

- Patients treated with pedicled flaps such as reverse sural artery flap or gastrocnemius muscle flap.
- Patients with incomplete clinical or follow-up data.
- Patients with severe systemic illness rendering them unfit for surgery.

Sample Size: A total of 90 patients were included in the study. These patients were divided into two groups based on the type of reconstructive procedure performed: the perforator-based propeller flap (PPF) group and the free flap (FF) group.

Procedure: Retrospective data of patients undergoing reconstruction for post-traumatic distal lower extremity defects were collected from hospital records. Information regarding patient demographics, comorbidities, and preoperative systemic conditions was retrieved and categorized, including assessment using the American Society of Anesthesiologists (ASA) classification system. Details of soft tissue defects, including size and location, were obtained from surgical records, operative notes, and available intraoperative photographs.

Patients were categorized into two groups based on the reconstructive modality used: perforator-based propeller flaps and free flaps. In cases of perforator-based propeller flaps, preoperative planning involved the use of color Doppler ultrasound to identify suitable perforator vessels near the defect site. The flap was designed to include the identified perforator, raised subfascially, and carefully dissected to preserve vascular integrity. The flap was then rotated to cover the defect without tension, ensuring adequate perfusion as assessed intraoperatively through flap color and capillary refill. Donor sites were managed either by primary closure or skin grafting. Postoperatively, patients were kept on bed rest for approximately three days, and complications such as venous congestion were managed using appropriate interventions including stitch release or leech therapy when necessary.

For free flap reconstruction, the choice of flap (fasciocutaneous or myocutaneous) depended on the size, depth, and configuration of the defect. Recipient vessels were selected based on local vascular status, and microvascular anastomosis was performed using either end-to-end or end-to-side techniques. Patients were managed postoperatively with strict immobilization and bed rest for approximately one week. In selected cases, pharmacological support such as prostaglandin infusion was administered in the early postoperative period. Smoking was strictly prohibited for all patients for at least three weeks postoperatively to optimize flap survival.

Postoperative outcomes were evaluated in terms of flap viability, complications, and need for secondary procedures. Flap necrosis was categorized as complete or partial. Cases requiring additional surgical interventions such as debridement, secondary closure, or additional flap coverage were considered as partial necrosis. Complications were further classified into early (within 3 weeks) and delayed (after 3 weeks) categories. Coverage failure was defined as the requirement of a secondary flap due to failure of the primary reconstruction. All patients were followed up for a minimum duration of three months, and functional outcomes such as gait and mobility status were assessed.

Statistical Analysis: All collected data were entered into Microsoft Excel and subsequently analyzed using Statistical Package for the Social Sciences (SPSS) version 27.0. Continuous variables were expressed as mean \pm standard deviation, while categorical variables were presented as frequencies and percentages. Comparative analysis between the two groups (PPF and FF) was performed using appropriate statistical tests. The chi-square test or Fisher's exact test was used for categorical variables, while the independent t-test or Mann-Whitney U test was applied for continuous variables depending on data distribution. A p-value of less than 0.05 was considered statistically significant. Odds ratios and 95% confidence intervals were calculated where applicable to assess the strength of associations.

Result

Table 1 shows the distribution of patients according to demographic and clinical characteristics among the PPF and FF groups. The mean age of patients was comparable between the two groups, with 38.6 ± 10.2 years in the PPF group and 40.1 ± 11.5 years in the FF group, resulting in an overall mean age of 39.3 ± 10.8 years. A male predominance was observed in both groups, accounting for 71.1% in the PPF group and 66.7% in the FF group, while females constituted 28.9% and 33.3%, respectively. The prevalence of diabetes mellitus was slightly higher in the FF group (26.7%) compared to the PPF group (22.2%), with an overall rate of 24.4%. Similarly, a history of smoking was reported in 31.1% of patients in the PPF group and 35.6% in the FF group, totaling 33.3% across the study population. In terms of anesthetic risk, the majority of patients in both groups belonged to ASA Grade I-II (80.0% in PPF and 75.6% in FF), whereas a smaller proportion fell under ASA Grade III-IV (20.0% and 24.4%, respectively), indicating a largely comparable baseline clinical profile between the two groups.

Variable	PPF Group (n = 45)	FF Group (n = 45)	Total (n = 90)
Age (years, mean ± SD)	38.6 ± 10.2	40.1 ± 11.5	39.3 ± 10.8
Male	32 (71.1%)	30 (66.7%)	62 (68.9%)
Female	13 (28.9%)	15 (33.3%)	28 (31.1%)
Diabetes Mellitus	10 (22.2%)	12 (26.7%)	22 (24.4%)
Smoking History	14 (31.1%)	16 (35.6%)	30 (33.3%)
ASA Grade I–II	36 (80.0%)	34 (75.6%)	70 (77.8%)
ASA Grade III–IV	9 (20.0%)	11 (24.4%)	20 (22.2%)

Table 2 shows the characteristics of soft tissue defects among the study population (n = 90). The mean defect size was notably smaller in the PPF group (42.5 ± 12.3 cm²) compared to the FF group (78.6 ± 20.4 cm²), with an overall mean of 60.5 ± 24.1 cm². A higher proportion of small defects (<50 cm²) was observed in the PPF group (62.2%), whereas the FF group predominantly had medium (44.4%) and large defects (33.3%), indicating that free flaps were more commonly used for extensive defects. In terms of

location, defects were slightly more frequent in the lower leg (55.6%) than in the foot (44.4%), with a fairly even distribution between both groups. Additionally, vessel calcification was present in 21.1% of total cases, being somewhat more common in the FF group (24.4%) than in the PPF group (17.8%). Overall, the findings suggest that PPF was preferred for smaller defects, while FF was utilized for larger and more complex soft tissue defects.

Parameter	PPF Group (n = 45)	FF Group (n = 45)	Total (n = 90)
Defect Size (cm ² , mean ± SD)	42.5 ± 12.3	78.6 ± 20.4	60.5 ± 24.1
Small (<50 cm ²)	28 (62.2%)	10 (22.2%)	38 (42.2%)
Medium (50–100 cm ²)	15 (33.3%)	20 (44.4%)	35 (38.9%)
Large (>100 cm ²)	2 (4.4%)	15 (33.3%)	17 (18.9%)
Location – Lower Leg	26 (57.8%)	24 (53.3%)	50 (55.6%)
Location – Foot	19 (42.2%)	21 (46.7%)	40 (44.4%)
Vessel Calcification Present	8 (17.8%)	11 (24.4%)	19 (21.1%)

Table 3 shows that intraoperative and surgical parameters differed notably between the two groups, with the PPF group demonstrating significantly shorter operative time (120.4 ± 18.6 minutes) compared to the FF group (185.7 ± 25.3 minutes), and substantially lower mean blood loss (75.2 ± 20.1 ml vs 140.6 ± 35.4 ml), both being statistically highly significant (p < 0.001). The requirement for donor site skin grafting was higher in the PPF group (40.0%) than in the FF group (26.7%), although this difference was not statistically significant (p = 0.18).

In the FF group, end-to-end (ETE) and end-to-side (ETS) anastomosis were performed in 28 and 17 cases respectively, while this parameter was not applicable to the PPF group. Intraoperative complications were slightly more frequent in the FF group (8.9%) compared to the PPF group (4.4%), but the difference was not statistically significant (p = 0.4), indicating comparable safety profiles between the two techniques despite differences in surgical complexity.

Parameter	PPF Group (n = 45)	FF Group (n = 45)	p-value
Operative Time (minutes, mean ± SD)	120.4 ± 18.6	185.7 ± 25.3	<0.001
Blood Loss (ml, mean ± SD)	75.2 ± 20.1	140.6 ± 35.4	<0.001
Need for Skin Grafting (Donor Site)	18 (40.0%)	12 (26.7%)	0.18
Type of Anastomosis (ETE/ETS)	–	28/17	–
Intraoperative Complications	2 (4.4%)	4 (8.9%)	0.4

Table 4 presents the postoperative outcomes and complications among the two study groups, showing comparable results between the perforator-based propeller flap (PPF) and free flap (FF) groups. Complete flap survival was slightly higher in the FF group (88.9%) compared to the PPF group (84.4%), although the difference was not statistically significant (p = 0.52). Partial necrosis occurred in 13.3%

of PPF cases and 8.9% of FF cases (p = 0.5), while complete flap loss was identical in both groups (2.2%; p = 1). Early complications within 3 weeks were observed in 17.8% of PPF patients and 22.2% of FF patients (p = 0.6), whereas delayed complications beyond 3 weeks were seen in 11.1% and 13.3% of cases, respectively (p = 0.75). Coverage failure requiring a secondary flap procedure was slightly

higher in the PPF group (6.7%) than in the FF group (4.4%), but this difference was also not statistically significant ($p = 0.64$). Overall, both techniques

demonstrated similar safety and efficacy profiles with no significant differences in postoperative outcomes.

Table 4: Postoperative Outcomes and Complications (n = 90)

Parameter	PPF Group (n = 45)	FF Group (n = 45)	p-value
Complete Flap Survival	38 (84.4%)	40 (88.9%)	0.52
Partial Necrosis	6 (13.3%)	4 (8.9%)	0.5
Complete Flap Loss	1 (2.2%)	1 (2.2%)	1
Early Complications (<3 weeks)	8 (17.8%)	10 (22.2%)	0.6
Delayed Complications (>3 weeks)	5 (11.1%)	6 (13.3%)	0.75
Coverage Failure (Secondary Flap Required)	3 (6.7%)	2 (4.4%)	0.64

Table 5 shows the comparison of functional outcomes and hospital stay between the PPF and FF groups, where the PPF group demonstrated a significantly shorter length of hospital stay (4.2 ± 1.3 days) compared to the FF group (7.8 ± 2.1 days) with a highly significant p-value (<0.001). Similarly, the time to ambulation was significantly lower in the PPF group (6.5 ± 2.0 days) than in the FF group (10.2 ± 3.1 days), also showing strong statistical significance (<0.001), indicating faster recovery in PPF patients. However, no statistically

significant differences were observed in functional gait outcomes, as independent gait was achieved by 86.7% in the PPF group and 91.1% in the FF group ($p = 0.49$), while assisted gait was reported in 13.3% and 8.9% of patients respectively ($p = 0.5$). Patient satisfaction levels were also comparable between the two groups, with 82.2% in the PPF group and 86.7% in the FF group reporting good to excellent satisfaction ($p = 0.57$), suggesting similar long-term functional outcomes despite differences in recovery speed.

Table 5: Functional Outcome and Hospital Stay (n = 90)

Parameter	PPF Group (n = 45)	FF Group (n = 45)	p-value
Length of Hospital Stay (days, mean \pm SD)	4.2 ± 1.3	7.8 ± 2.1	<0.001
Time to Ambulation (days, mean \pm SD)	6.5 ± 2.0	10.2 ± 3.1	<0.001
Independent Gait Achieved	39 (86.7%)	41 (91.1%)	0.49
Assisted Gait	6 (13.3%)	4 (8.9%)	0.5
Patient Satisfaction (Good/Excellent)	37 (82.2%)	39 (86.7%)	0.57

Discussion

The study established that both PPF and FF groups were identical at their initial point which allowed researchers to evaluate their results. Koh et al. (2018) [7] found that both groups studied showed identical demographic characteristics because their PPF and FF groups had an average age of 41.2 years and 43.5 years which showed no statistical difference in medical conditions between groups ($p>0.05$). The study by Innocenti et al. (2019) [8] found that diabetes showed similar rates between the two groups with 22% in PPF and 25% in FF while smoking history showed 30% in PPF and 33% in FF thus demonstrating that similar patient traits help research results through reduced confounding. The current research shows male dominance which matches earlier studies about trauma epidemiology that found males represented 70 to 80 percent of all lower extremity trauma cases (Scampa et al., 2022) [9].

The current study results demonstrate that defect characteristics and flap selection choices match existing reconstructive algorithms. The treatment of smaller and moderate defects primarily utilized PPF while clinicians used FF to treat larger defects. El-Sabbagh (2011) [10] found that PPF serves as the

most suitable treatment for defects measuring between 50 and 70 square centimeters whereas clinicians should use FF to treat defects that surpass 100 square centimeters. Noaman et al. (2022) [11] found that free flap coverage became necessary for 68% of patients with large ankle and distal leg defects because their available local tissue proved insufficient. The present study found that the FF group had a slightly increased occurrence of vascular calcification which mirrors the findings by Cajozzo et al. (2020) [12] who demonstrated that microvascular reconstruction becomes essential when patients have impaired vascular status and face complex trauma situations.

The current research findings display an advantage for PPF because they demonstrated shorter operation times and smaller amounts of blood lost during surgery. The study by Abdelrahman et al. (2016) [13] showed similar findings because they measured PPF operation time at 120 ± 25 minutes while FF operation time reached 360 ± 40 minutes ($p<0.001$) and they recorded blood loss at 150 ml for PPF and 450 ml for FF. The study by Gupta et al. (2022) [14] demonstrated that PPF reduced operation time by approximately 40 to 50 percent because of its simple technical requirements. The current findings

demonstrate that PPF functions as an efficient resource-saving technique which requires fewer hospital resources and benefits areas with restricted surgical skills.

The viability of PPF flaps remains a concern despite the benefits that exist during surgical procedures. The current research revealed that both groups showed identical flap survival rates which directly opposes the findings from Bekara et al. (2018) [15] that showed PPF had a higher partial necrosis rate of 6.88% than FF which had a 2.70% rate. The researchers Vathulya et al. (2021) [16] established that pedicled flaps experienced complication rates between 18% and 22% in trauma cases. The current results have been demonstrated by other studies which showed similar outcomes; for instance, Koh et al. (2018) found that both groups achieved flap survival rates beyond 94% but there was no statistically relevant difference between the groups ($p=0.32$). The results demonstrate that PPF can achieve equivalent results to FF when surgeons choose appropriate patients and demonstrate their surgical skills.

The present study found PPF and FF surgical procedures produced identical rates of postoperative complications which Scampa et al. (2022) established through their meta-analysis which showed no significant difference in overall complication rates between PPF and FF with rates of 21% and 18% respectively ($p>0.05$). The research through various studies shows that PPF raises the danger of hazardous situations when it gets used for repairing traumatic defects. The study by Guillier et al. (2021) [17] showed that 48% of PPF cases developed either partial necrosis or wound complications while 14% of cases needed secondary FF reconstruction. The study showed fewer secondary procedures because of improved outcomes that resulted from selecting cases and using advanced surgical methods.

The present research showed better functional results for PPF during the initial recovery period because PPF reduced hospital time and allowed patients to walk sooner. The results of this study match the findings of Abdelrahman et al. (2016) who observed that PPF patients had a hospital stay of 5.2 ± 1.8 days while FF patients stayed for 9.6 ± 2.5 days ($p<0.001$). The research by Innocenti et al. (2019) showed that PPF patients finished rehabilitation activities about 3 to 4 days before their FF counterparts reached the same milestone. The benefits arise from three factors which include faster surgical procedures and less surgical damage plus no need for microvascular anastomosis. The research study found that both groups achieved similar functional results at the study endpoint which matches the findings of Koh et al. (2018) who reported equal long-term results in limb functionality and patient satisfaction scores between the two groups ($p>0.05$).

The primary factor which reconstructs trauma cases faces two main threats which include infection risk and delayed complications that lead to osteomyelitis. The current study found no significant differences between the two groups studied, but earlier research indicates that specific conditions increase the danger of PPF. Diabetic patients who undergo PPF face higher complication rates according to Kim et al. (2021) [18] which includes delayed wound healing that occurs in 26% of their cases. Cajozzo et al. (2020) showed that pedicled flaps face higher infection risk because both their vascularity becomes impaired and their wounds remain exposed for extended periods.

The current research findings match existing contemporary literature which shows that PPF and FF both function as dependable surgical reconstruction methods which can be applied in particular medical situations. The combination of PPF operational benefits together with its quick recovery period makes it superior for use in most cases, but surgeons consider FF to be the best choice for treating extensive intricate defects that have insufficient blood supply. The two techniques produce similar long-term results which demonstrate that surgeons must create personalized surgical plans that consider the patient's defect size and vascular conditions and existing health issues.

Conclusion

The present study demonstrates that both perforator-based propeller flaps (PPF) and free flaps (FF) are effective and reliable techniques for reconstruction of post-traumatic distal lower extremity soft tissue defects, with comparable flap survival, complication rates, and long-term functional outcomes. While free flaps remain the preferred option for large and complex defects, PPF offers significant advantages in terms of shorter operative time, reduced blood loss, decreased hospital stay, and earlier ambulation. These benefits make PPF a practical and efficient alternative, particularly for small to moderate defects and in resource-limited settings. Therefore, the choice of reconstructive modality should be individualized based on defect characteristics, patient factors, and available expertise to achieve optimal clinical outcomes.

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