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Comparing the Versatility of Anterolateral Thigh (ALT) Free Flap and Superficial Circumflex Iliac Artery Perforator (SCIP) Free Flap for Hand Reconstruction Due to Electric Burn Injuries: Case-Based Literature Review

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ABSTRACT

Electrical injuries, often caused by high-voltage currents from sources like arc flashes or ignited clothing, frequently result in extensive burns, particularly to the hands. The upper extremities, being common contact points for electrical injuries, are susceptible to severe tissue damage, including burns, nerve, muscle, and vascular damage. High-voltage electrical burns often require surgical intervention, with an emphasis on restoring both function and form. This study aims to compare the effectiveness of two free flap techniques—Anterolateral Thigh (ALT) and Superficial Circumflex Iliac Artery Perforator (SCIP)—in the reconstruction of hand burns resulting from electrical injuries.

Authors conducted a literature review based on cases from the burn unit at Pertamina Central Hospital, Jakarta, focusing on two patients who underwent reconstruction using the ALT and SCIP free flaps. The ALT free flap, characterized by its versatile and reliable tissue coverage, was utilized in one case, while the SCIP free flap, known for its thin and pliable tissue, was employed in the other. The study reviews the anatomy, advantages, and limitations of each flap, considering factors such as functional outcomes, aesthetic results, donor site morbidity, and surgical complexity. Both techniques were shown to offer significant benefits in reconstructing complex burn injuries, with the ALT flap providing robust coverage and the SCIP flap offering superior contour and functional outcomes for smaller defects.

The findings underscore the versatility of both flaps in electrical burn reconstruction, highlighting the importance of choosing the appropriate technique based on the size and location of the defect. This study contributes valuable insights into the selection of free flap techniques for reconstructing hand injuries caused by electrical burns, aiming to optimize patient outcomes in terms of both functionality and aesthetics.

KEYWORDS: electrical injuries, burn, hand burn, free flap, anterolateral thigh (ALT) flap, superficial circumflex iliac artery perforator (SCIP) flap, microsurgery, surgical outcomes, functional restoration

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I. INTRODUCTION

Electrical injuries occur when high-energy current from an electrical source passes through the human body. Arc flashes and ignited clothing are common sources of such electrical currents. When electricity enters the body, it transforms into heat, causing thermal burns.[1] The upper extremity frequently serves as a contact point for electrical injuries. High-voltage electrical burns often cause extensive tissue damage, affecting muscles, neurovascular bundles, and the skin at contact points on the hand. Bones, due to their high resistance, generate heat and burn surrounding tissue from the inside out.

Electrical injuries commonly cause hand burns. Burn injuries to the hands frequently result in functional impairments, restrict the patient's ability to work, and necessitate evaluations for potential long-term disabilities. Restoring mobility and replacing lost soft tissue in the hand play critical roles in achieving functional reconstruction.[2] For effective

hand burn reconstruction, surgeons must ensure sufficient blood flow and a healthy wound bed to support proper healing, especially in cases of extensive tissue loss. The size and location of the defect directly influence the choice of reconstruction methods, which vary widely based on individual patient needs.[3] Among the techniques, free flap, which requires microsurgical expertise, offers versatility and robustness used for wound coverage and protection of nerves, vessels, joints, and tendons.[2,3] A retrospective study by Shih and colleagues in 2017 demonstrates that high-voltage injuries often require surgical interventions, occurring in 79.6% of cases. These injuries also show a notable incidence of reconstructive flap surgeries, reported at 11.4%.[4] The anterolateral thigh (ALT) free flap and the superficial circumflex iliac artery perforator (SCIP) free flap offer versatile options for hand reconstruction. These flaps deliver reliable tissue coverage, which actively restores both form and function.[3]

We conducted this study by analyzing cases from the burn unit at Pertamina Central Hospital Jakarta and highlighting two case illustrations of acute full-thickness hand burns caused by electrical injuries. The patients underwent defect closure using an anterolateral thigh (ALT) free flap in one case and a superficial circumflex iliac artery perforator (SCIP) free flap in the other. This study aims to compare the versatility and effectiveness of anterolateral (ALT) and superficial circumflex iliac artery perforator (SCIP) free flaps in reconstructing electrical burn-induced hand injuries. By performing a case-based literature review, we evaluate the strengths, advantages, and suitability of each flap. We analyze their performance regarding functionality, aesthetics, and long-term outcomes. Our findings aim to identify the most suitable free flap for complex hand reconstructions in burn patients.

II. ANATOMY AND VERSATILITY OF FREE FLAPS

1. Anterolateral Thigh (ALT) Free Flap

Microsurgery has advanced significantly, focusing on achieving optimal functional and aesthetic outcomes while minimizing donor site morbidity.[5] Clinicians agree that a free flap is recommended when the defect exceeds a manageable size.[6] The anterolateral (ALT) free flap is a highly versatile and pliable option for reconstructive surgery, particularly useful in hand and extremity reconstruction.[2,5]

First described by Song in 1984, the anterolateral thigh (ALT) flap is a fasciocutaneous flap based on the septocutaneous or musculocutaneous perforators of the descending branch of the lateral circumflex femoral artery, which allows for selective harvesting of perforators at various anatomic levels. It features a lengthy pedicle, approximately 12 cm in length, and a vessel diameter of 2.1 mm. This flap facilitates the coaptation of the lateral femoral cutaneous nerve, enabling the creation of a sensate flap. Additionally, the vastus lateralis muscle can be transferred to provide motor function. Its advantages include versatility, ease of elevation, and the long pedicle.[3,5,7,8]

The lateral circumflex femoral artery branches from the profunda artery, which itself branches off the femoral artery. It travels laterally, crossing the femoral nerve and passing under the sartorius and rectus femoris muscles, which form the lateral boundary of the femoral triangle. This artery gives off three branches: ascending, descending, and transverse. The descending branch travels toward the knee joint. A reliable perforator is usually within 3 cm of the midpoint between the superolateral border of the patella and the anterosuperior iliac spine. More than half of these perforators pass through the vastus lateralis muscle. The descending branch, along with its corresponding veins, runs between the vastus lateralis and rectus femoris muscles, accompanied by the nerve to the vastus lateralis. This branch can typically be dissected safely up to its major branch, which supplies the rectus femoris and should be preserved during flap harvest.

To identify a cutaneous perforator, surgeons use a handheld Doppler probe both before and during the surgery. The position of the perforator may shift depending on whether the patient is standing or lying down. The perforator is generally detectable within 3 cm of the midpoint between the anterior superior iliac spine and the superolateral border of the patella, which helps in designing the flap accurately.[3,5,9] In theory, we can use almost the entire anterolateral thigh as a skin paddle. Operator designs the paddle to be slightly larger than the defect size to reduce tension and make primary donor site closure easier, then later trim any excess skin during inset. The fascia lata typically forms the deep layer of the flap, but surgeons can also harvest it suprafascially. The position of the nerve to the vastus lateralis varies in relation to the vascular pedicle. Including the lateral femoral cutaneous nerve enhances sensation after transfer. The motor weakness is usually mild and temporary. If the flap width is less than 8 cm, we can close the donor site primarily.[5,10]

The ALT (Anterolateral Thigh) free flap is widely used, particularly in Asian countries, because of its consistent anatomy, variable size, minimal donor site complications, and ability to be combined with other tissues like fascia, adipose tissue, and muscle. This flap can be harvested quickly and modified as musculocutaneous, fasciocutaneous, adipofascial, or suprafascial. Musculocutaneous flaps provide both vascularized muscle and skin to cover wounds, while fasciocutaneous flaps supply vascularized fascia and skin for defect coverage.[2,5,6]

The anterolateral thigh (ALT) free flap has several benefits for the recipient site, especially due to its versatility in design. Its large tissue volume allows it to be adjusted in size, from covering up to half the surface of the thigh to smaller sizes, and it can be made thick or as thin as 3 to 5 mm, depending on the needs. If the defect is less than 8 cm wide, the donor site can be closed directly with minimal scarring. The flap can

include various tissue components from one pedicle, such as a large, flexible skin area, fascia lata for tendon repair, and the vastus lateralis muscle for muscle restoration. Osseous components can also be included by connecting them to the descending branch of the lateral femoral circumflex artery. The flap has a good texture, but hair may grow in some male patients, and it can be reinnervated to regain sensation if the lateral femoral cutaneous nerve is included. Additionally, the ALT flap is easy to debulk because there is no large artery in the subcutaneous layer, and it can be trimmed to fit areas like the forearm and thenar web. It also combines flexibility and strength, supported by a solid aponeurosis. Using a two-team approach without changing the patient's position significantly reduces operation time.[5,7]

The anterolateral (ALT) free flap has several advantages for the recipient site. In complex reconstructions, it is especially beneficial due to its long and wide pedicle. This flap can even work as a flow-through flap, meaning that both the proximal and distal ends of the vascular pedicle are connected to provide blood flow to the flap tissue at the far end.[8,10]

However, the anterolateral (ALT) flap still has some pitfalls, such as the thickness of the subcutaneous tissue. The required anterolateral (ALT) flap thickness is from 2 to 4 cm in average. In certain cases, this may require secondary thinning procedures to achieve a more suitable contour, especially in regions where a thinner flap is necessary for functional or aesthetic reasons. Kimura and colleagues introduced a thinning technique for the anterolateral (ALT) flap, which can be performed in two ways: primary thinning or microdissection.[11-13] This method allows the flap to be thinned down to 3–4 mm, making it a highly valuable and reliable option for reconstructive procedures. The thinned anterolateral (ALT) free flap has proven satisfactory in covering various defects across the body, offering both functional and aesthetic benefits in regions requiring thinner tissue coverage.[6]

2. Superficial Circumflex Iliac Artery Perforator (SCIP) Free Flap

The inguinal region has some of the thinnest skin (with a dermis to epidermis thickness of 625.9 to 273.4 μm in a Korean population), making it an ideal area for soft-tissue defect reconstructions, especially when contour is important. First introduced by Koshima and colleagues in 2004, the superficial circumflex iliac artery perforator (SCIP) flap has become a reliable choice for limb reconstruction, particularly for small to medium-sized defects.[15-19] Over time, the superficial circumflex iliac artery perforator (SCIP) flap has gained popularity as a thin, pliable, and versatile solution for reconstructing extremities. It provides large, thin flaps without the need for defatting, making it especially suitable for delicate areas like the dorsal side of the hands. With a success rate of over 90% for moderately sized defects, the superficial circumflex iliac artery perforator (SCIP) flap maintains both functionality and aesthetics, preserving range of motion, as seen in hand reconstructions where full function is achieved within months of surgery. Additionally, the flap offers low donor-site morbidity, even with anatomical variations in the origins of the artery.[16,18]

The chimeric superficial circumflex iliac artery perforator (SCIP) flap offers a major advantage by providing a relatively large skin paddle with hairless skin. It can also include a muscle flap if needed. Using a double surgical team approach can reduce the operating time. Moreover, the scar can be easily concealed within the underwear line.[7,16,17]

The superficial circumflex iliac artery perforator (SCIP) flap is valuable for reconstructing multiple lesions using a single source vessel. However, it has limitations, as perforator flap surgery can be complex. Challenges arise from the short arterial pedicle, variability in arterial anatomy, and the small size of the vessels. The superficial circumflex iliac artery (SCIA) originates from the femoral artery, superficial femoral artery, deep femoral artery, or lateral circumflex artery. After branching from the femoral artery, the superficial circumflex iliac artery (SCIA) splits into superficial and deep branches. The superficial branch supplies perforators to the skin, while the deep branch provides blood to the sartorius muscle, lateral femoral cutaneous nerve, and iliac crest. The transverse branch of the deep branch, which runs laterally, emerges from the superficial circumflex iliac artery (SCIA) below the anterior superior iliac spine (ASIS). When a large skin paddle is needed, including perforators from the deep branch of the superficial circumflex iliac artery (SCIA) is safe. These perforators run in the axial direction, supplying blood to the skin near the antero-superior illiac spine (ASIS). In most cases, the superficial branch of the superficial circumflex iliac artery (SCIA) is exposed first. If the bifurcation point is identified, the surgeon can trace the superficial branch toward the bifurcation site, located 6 cm from the pubic tubercle to the antero-superior illiac spine (ASIS) along the inguinal ligament, and 3 cm below this point to locate the deep branch of the superficial circumflex iliac artery (SCIA), which supplies blood to the sartorius muscle.[16,18]

Surgeons usually elevate the flap in the suprafascial plane to avoid debulking. This plane is identified by the difference in fat lobule sizes: smaller lobules are located superficially, while larger lobules are found in deeper layers. Preoperative color Doppler sonography (CDS) mapping and computed tomographic angiography (CTA) are used to precisely locate the superficial circumflex iliac artery (SCIA), determine its course, and identify its perforator branches, enabling accurate flap design.[19,21]

III. CASE ILLUSTRATION 1:

Anterolateral Thigh Free Flap for Hand Electric Burn Injury

A 32-year-old male with acute full thickness burns due to electric trauma, referred to our burn unit with extensive soft tissue loss on the palmar to ventral of the right hand, exposed

muscles, tendon, and neurovascular structure, and necrotic fifth finger.

Figure 1: Oblique view of the full thickness burns of the right hand with 5th finger necrotic (A). Anterior view of the full thickness burns of the right hand with 5th finger necrotic (B).

After initial management and stabilization of airway, breathing mechanism and haemodynamic, our team performed debridement and treated the wound using Negative Pressure Wound Therapy (NPWT) for 5 days to limit the exudate. Our surgeon author also performed proper necrotomy as needed, then proceeded to close the defect with free flap coverage.

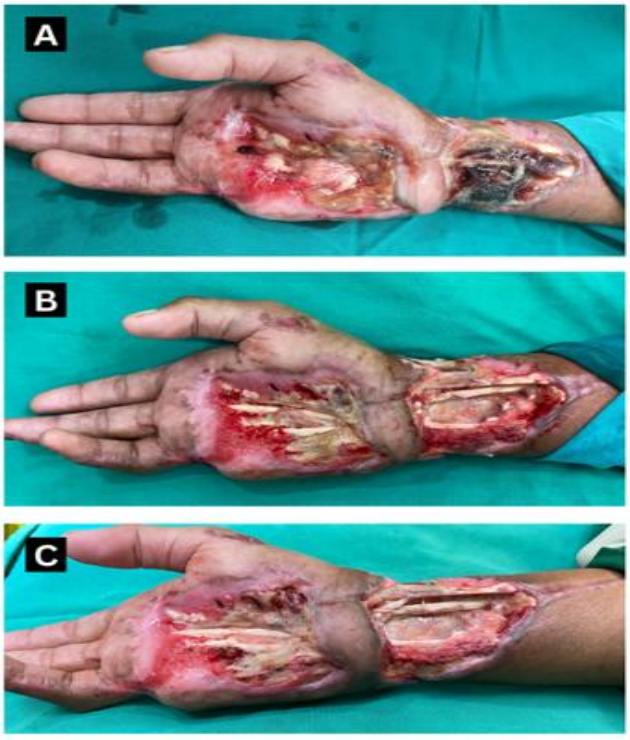

Figure 2: Anterior view of the right hand after debridement and amputated the 5th finger (A). Anterior view of the right hand after 5 days of using NPWT (B).

Before harvesting a free flap, our surgeon author carried out several appropriate preparations including marking the cutaneous perforator before the incision is made. Our surgeon author identified the midpoint between the anterior superior iliac spine and the superolateral edge of the patella, used a handheld Doppler both preoperatively and intraoperatively

(since the position of the perforator may shift from erect to supine positions) to locate a cutaneous perforator within 3 cm of this midpoint and marked where the point of the perforator comes to the skin paddle.

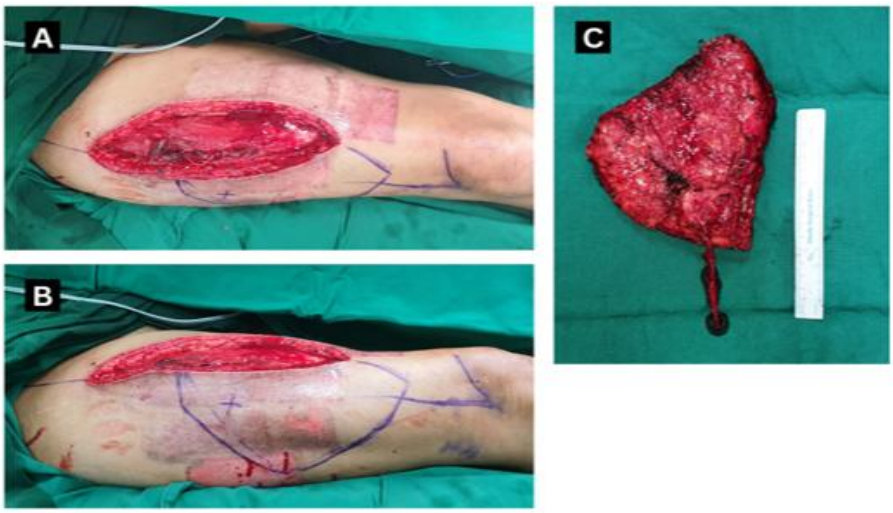

Figure 3: anterior view of ALT free flap (A). Oblique view of ALT free flap (B). Free ALT fascio-cutaneous flap donor (C).

Our surgeon author made an incision along the medial edge of the skin flap, then dissected down to the subfascial plane (fascia lata) to expose the descending branch and perforators of the lateral circumflex femoral artery (LCFA). The team traced the perforators in a retrograde direction toward their source. They elevated the fascio-cutaneous flaps with independent perforators based on the size of the skin defect. Flap thinning was performed across the entire skin flap, starting from the outer edges and moving toward the center. The surgeon maintained a fascia island of the required size around the perforator. Finally, our surgeon author lifted the thinned anterolateral (ALT) flap and detached the pedicle from the descending branch of the the lateral circumflex femoral artery (LCFA).

The flap was transferred to the recipient site for reconstruction, with the lateral femoral cutaneous nerve aligned. The pedicle was then connected end-to-end to the branches of the radial artery. The defect was covered with a thin anterolateral thigh (ALT) free flap, and the donor site was closed primarily. The flaps were monitored frequently during the first three days after surgery. Complications included venous thrombosis and hematoma. Ten days later, the patient was discharged, with careful monitoring of flap survival, contour, and donor site healing. At the six-month follow-up, significant improvements in range of motion and grip strength were observed, along with a well-contoured and aesthetically pleasing result.

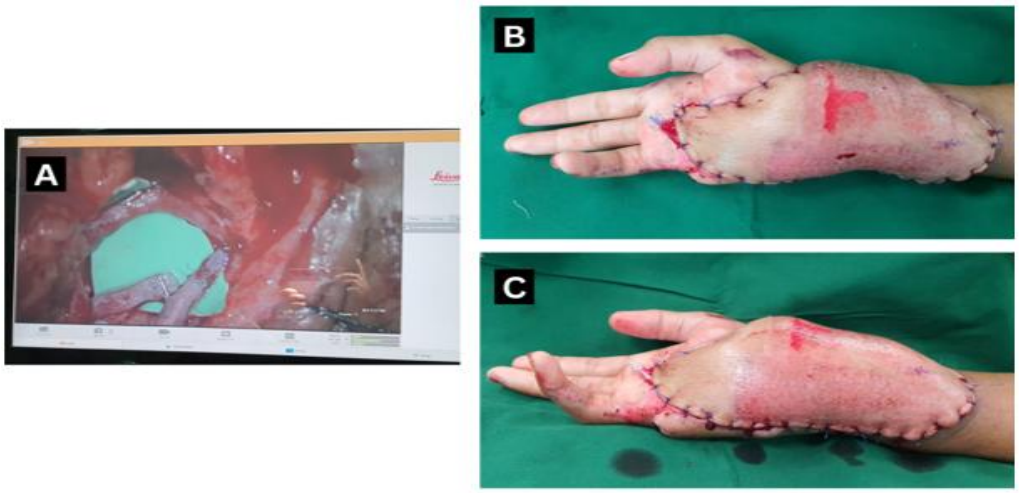

Figure 4: Vascular anastomosis and microsurgery reconstruction of the LCFA (A). Anterior view of closed defect by ALT free flap (B). Oblique view of closed defect by ALT free flap (C).

Figure 5: Anterior view of the right hand after 6 month (A). Oblique view of the right hand after 6 month (B).

IV. CASE ILLUSTRATION 2

Superficial Circumflex Iliac Artery Perforator (SCIP) Free Flap for Hand Electric Burn Injury

A 23-year-old male with acute full thickness burns due to high-voltage electric trauma, referred to our burn unit with full thickness defect at the site of the contact between his left thumb and index finger. After initial management on securing his airway, breathing mechanism, and hemodynamic state, our surgeon author performed thorough debridement of the necrotic skin and soft tissue, then trimming the edges of the defect.

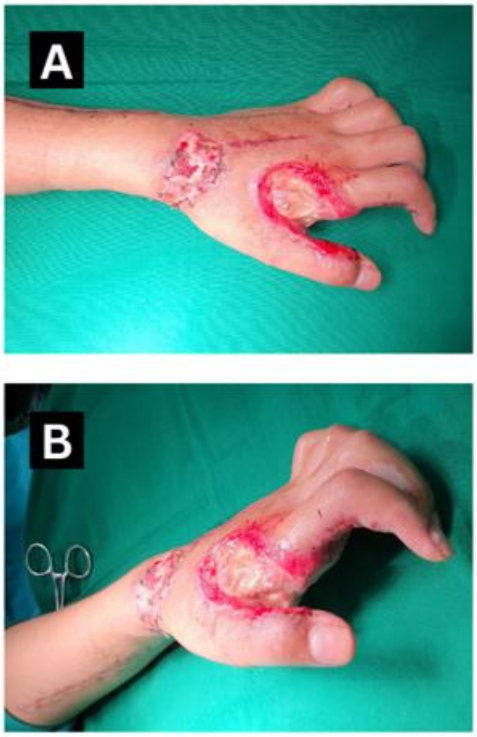

Figure 6: Anterior view of the full thickness burns of the left hand (A). Oblique view of the full thickness burns of the left hand (B).

Our surgeon author then performed microsurgical closure of the defect using a superficial circumflex iliac artery perforator (SCIP) free flap. The anterior superior iliac spine (ASIS) and pubic tubercle were marked 5 cm laterally along the sagittal plane.

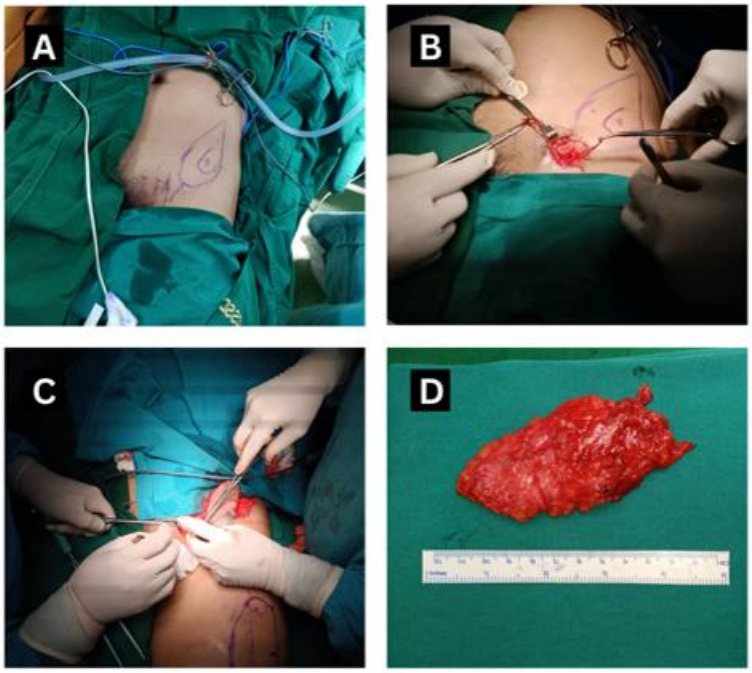

Figure 7: SCIP free flap design (A). Incision made from ASIS to pubic tubercle (B-C). Free superficial circumflex iliac artery perforator (SCIP) fascio-cutaneous flap donor (D).

Preoperatively, our surgeon author carried out several appropriate preparations including marking the cutaneous perforator before the incision is made. Our surgeon author identified the superficial branch of the superficial circumflex iliac artery (SCIA) with aid of handheld Doppler ultrasound, and made an incision between the antero-superior iliac spine (ASIS) and the pubic tubercle. The surgeon carefully dissected through the subcutaneous tissue and the tendinous membrane of the external oblique to expose the superficial circumflex iliac artery perforator (SCIP) while meticulously dissecting and cauterizing small vessels, then opened the deep fascia above the sartorius muscle to identify the deep branch of the superficial circumflex iliac artery (SCIA) along the medial edge of the sartorius muscle. Surgical loupes helped confirm the superficial circumflex iliac artery (SCIA). Our author surgeon performed pedicle dissection to harvest the flap. The procedure included subcutaneous tissues and arteriovenous vessels for anastomosis. The team transferred the superficial circumflex iliac artery perforator (SCIP) flap to the recipient site. The design of the skin paddle followed the superficial branch as a guide. Finally, the surgeon closed the donor site with primary closure.

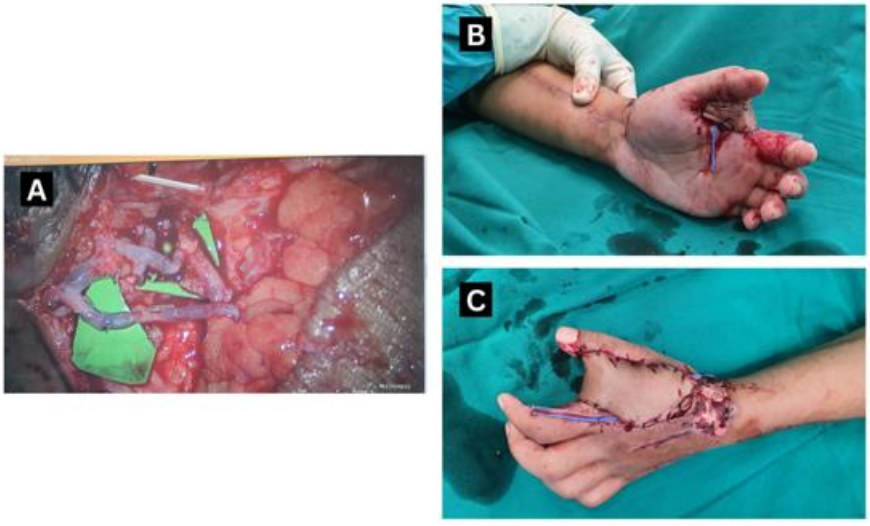

Figure 8: Vascular anastomosis & microsurgery reconstruction of the superficial circumflex iliac artery perforator (SCIP) (A). Posterior view of closed defect by superficial circumflex iliac artery perforator (SCIP) free flap Day-0 (B). Oblique view of closed defect by superficial circumflex iliac artery perforator (SCIP) free flap Day-0 (C).

During the follow-up, the flap showed a good contour. Early monitoring during the first three post-surgical days identified minor complications, such as venous thrombosis and hematoma, but no signs of secondary infection appeared. The patient demonstrated improvements in grip strength and range of motion. The skin color of the flap appeared aesthetically pleasing.

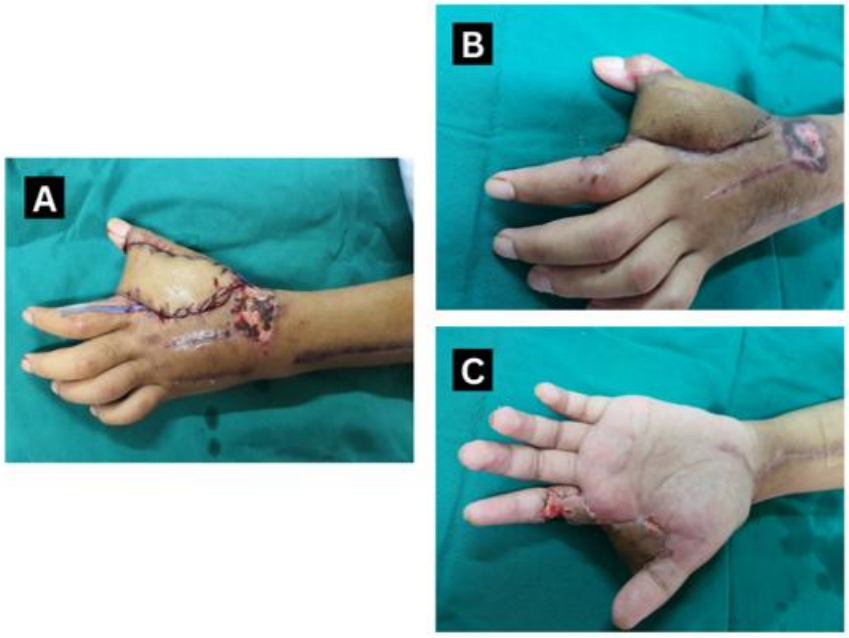

Figure 9: Oblique view of left hand post reconstruction Day-2 (A). Oblique view of left hand post reconstruction Day-14 (B). Posterior view of left hand post reconstruction Day-14 (C).

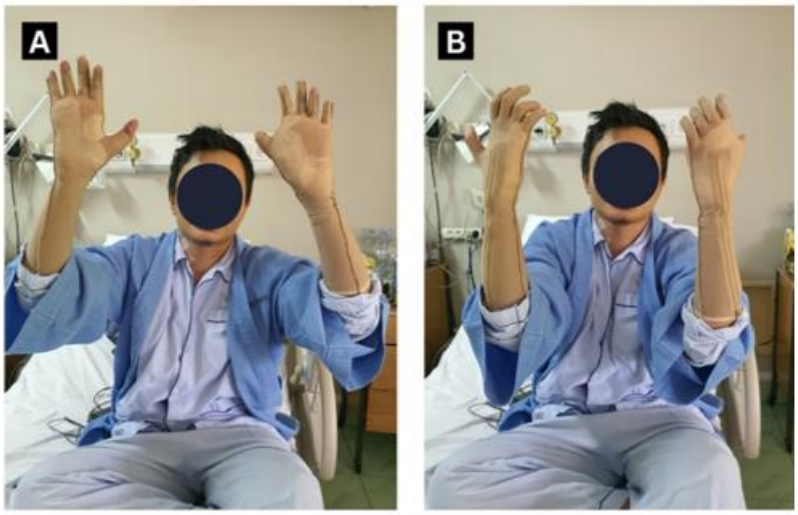

Figure 10: Patient profile. Supine hand position wearing pressure garment (A). Prone hand position wearing pressure garment (B).

V. DISCUSSION

When reconstructing larger or circumferential defects of the hand, surgeons may need to use a distant pedicled flap or a free flap. The surgeon makes the choice of flap based on their preference and experience, considering the defect's size, location, and the functional and aesthetic needs of the hand's units and sub-units. Resurfacing both dorsal and volar skin areas typically requires a thick, glabrous, and sensate surface, which surgeons most commonly achieve by using a fascio-cutaneous flap.[7] immediate reconstruction of severe upper extremity injuries provides better function, reduces complications, shortens hospital stays, and lowers overall costs compared to delayed reconstruction.[2] This approach allows for early mobilization. Early mobilization plays a crucial role in maintaining the range of motion (ROM) of the joints and preventing tendon adhesions. Delayed repair often leads to tendon adhesions. In this series, rehabilitation started

as early as 24 hours after surgery. Starting rehabilitation early helped prevent significant muscle strength loss.[5]

When comparing the anterolateral (ALT) free flap and the superficial circumflex iliac artery perforator (SCIP) free flap for hand reconstruction, each flap provides distinct benefits for specific clinical needs. The anterolateral (ALT) flap offers versatility and effectively covers large defects, especially when robust tissue integration is required. On the other hand, the superficial circumflex iliac artery perforator (SCIP) flap provides precise and delicate coverage while minimizing donor site complications.[15,20,22] Functional restoration is an important consideration for both flaps. Both effectively restore protective sensation and mobility. However, their differences in pliability and bulk make each more suitable for specific applications. Surgeons prefer the anterolateral thigh (ALT) flap for covering large dorsal defects. In contrast, they choose the superficial circumflex iliac artery perforator (SCIP) flap for intricate areas like the palm.[11-13] Donor site considerations also vary significantly: while the anterolateral (ALT) flap often leads to more noticeable scarring, it provides the advantage of incorporating muscle, making it suitable for addressing intricate defects. In contrast, the superficial circumflex iliac artery perforator (SCIP) flap tends to offer superior aesthetic results with reduced donor site morbidity, making it a favorable option for patients prioritizing cosmetic outcomes while still ensuring functional restoration.[3,14]

The choice of recipient vessels, such as the radial or ulnar artery, depends on the position of the flap and the anatomical features of the vessels. These vessels must be the right size, have good quality, and be at a safe distance from the trauma site to ensure the flap's viability and integration. Microvascular factors are crucial in flap selection, especially the length of the vascular pedicle, which affects the viability and success of the flap. It is essential to thoroughly assess vascular injuries and compression in patients with electrical burns, as deep, circumferential burns often lead to amputation. Complications like vessel thrombosis and flap ischemia require close intraoperative monitoring, with techniques like vascular Doppler assessment playing a key role in improving outcomes.[5,14]

Long-term functional and aesthetic outcomes help distinguish these flaps. The anterolateral thigh (ALT) flap can be bulky, so secondary debulking procedures may be needed to improve cosmetic results. In contrast, the superficial circumflex iliac artery perforator (SCIP) flap has a thinner profile, often leading to better aesthetic outcomes, particularly for patients concerned about the appearance of their hands. Flap thinning is often necessary for both free flaps to achieve the desired contour and flexibility. However, this process can increase the risk of skin necrosis if not managed carefully.[6,23] Ultimately, the choice between anterolateral (ALT) and superficial circumflex iliac artery perforator (SCIP) flaps should be guided by the specific defect characteristics, patient needs, and surgeon expertise, ensuring a balanced approach to functional restoration and aesthetic satisfaction.

VI. CONCLUSION

Early microsurgical reconstruction plays a significant role in management of acute and sub-acute full-thickness electrical injuries, leading to better outcomes in limb salvage, functional recovery, and appearance. Previous studies suggested both ALT and SCIP free flaps are highly versatile for hand reconstruction after electric burns, with the choice guided by the defect size, location, and patient factors.

The choice between the anterolateral thigh (ALT) and superficial circumflex iliac artery perforator (SCIP) flaps should depend on characteristics of the wound as well as the needs of the patients. When comparing ALT and SCIP free flaps for hand burn reconstruction, SCIP flaps excel in their thinness, pliability, and aesthetic resemblance to hand skin, enabling better functional outcomes and minimizing the risk of re-contracture. They are ideal for delicate reconstructions, requiring meticulous preoperative perforator mapping due to their variable vascular anatomy. ALT flaps, on the other hand, provide robust coverage for extensive defects with reliable vascularity, but their thickness often necessitates secondary thinning procedures and may impair joint mobility. SCIP flaps are preferable for fine motor areas, while ALT flaps are better suited for large or padded coverage requirements, balancing patient-specific needs and surgical expertise.

A multidisciplinary approach and advanced techniques such as intraoperative Doppler monitoring, will help surgeons to improve both functional and aesthetic outcomes and ultimately enhance the quality of life of the patients.

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