Review

Pioneering First Web Reconstruction: Insights from Literature and Hands-On Experience

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Pioneering First Web Reconstruction: Insights from Literature and Hands-On Experience

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Abstract: The first web space of the hand plays a fundamental role in daily hand function, facilitating crucial movements such as pinching, grasping, and opposition. Structural anomalies and acquired defects of this anatomical region, whether congenital or secondary to trauma, burns, or surgical resections, necessitate meticulous reconstructive strategies to ensure both functional restoration and aesthetic integrity. Given the complexity and variability of first web defects, a broad spectrum of reconstructive techniques has been developed, ranging from skin grafting and local flap reconstructions to advanced microsurgical approaches. This review comprehensively examines the existing literature on first web reconstruction techniques, analyzing their indications, advantages, and limitations. Additionally, it explores innovative techniques and emerging trends in the field, such as tissue engineering, regenerative medicine, and composite tissue allotransplantation, which may revolutionize future reconstructive strategies. The primary objective is to provide clinicians with an evidence-based guide to selecting the most appropriate reconstructive strategy tailored to individual patient needs. Furthermore, we incorporate our institutional experience in managing first web defects, highlighting key surgical principles, patient outcomes, and challenges encountered. Through this analysis, we aim to refine the understanding of first web reconstruction and contribute to the ongoing evolution of hand surgery techniques.

Keywords: first web space; hand reconstruction; soft tissues reconstruction; first commissure

1. Introduction

The first web space is a definite anatomical region that is critical to the overall functionality of the hand. It is triangular in shape, with the apex pointing at the junction of the first and second metacarpal bone heads, and the base is made up of dorsal and palmar skin that spans from the first to the second metacarpophalangeal joints (MCP). The thenar fibromuscular system makes up the inner part of the first web, and its external angle with the thumb in maximal abduction is typically 100°. This unique anatomy facilitates essential hand movements such as abduction, opposition, and precision grip, which are indispensable in performing everyday tasks. Consequently, deformities or contractures affecting the first web space significantly compromise hand function and overall quality of life, necessitating surgical intervention [1,2]. The upper limb and hand, in particular, are frequently involved in traumatic lesions or congenital anomalies, which have a profound impact on the patient's quality of life at a high socioeconomic cost [3]. Congenital conditions such as syndactyly often allow for reconstruction using adjacent tissues, whereas acquired defects—resulting from trauma, burns, tumors, or infections—pose more complex reconstructive challenges [4].

The literature reports a prevalence of hand scar contractures ranging from 5% to 40% in burned patients [5]. Scar contractures of the first web, in particular, are caused by a combination of skin deficiency, fascia and muscle fibrosis, and the underlying bony structure. It typically appears with the adduction and supination of the thumb, which accounts alone for 40%-50% of total hand functionality [2,6]. The degree of contracture varies, and Sandzén's classification system (mild, moderate, severe) provides a useful framework for determining the severity and corresponding surgical approach [7].

Reconstructive techniques must address both soft tissue deficits and underlying structural deformities. While traditional surgical methods, such as Z-plasty and local flaps, remain essential in

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mild to moderate cases, more extensive defects require advanced reconstructive solutions, including pedicled and microsurgical free flaps. Recent advances in biomaterials, vascularized composite allotransplantation (VCA), and three-dimensional (3D) bioprinting offer potential new frontiers for restoring complex hand defects.

This review examines the current state of first web space reconstruction, focusing on various reconstructive options, their indications, and long-term outcomes. We critically analyze the literature while integrating our institutional experience to offer insights into the practical applications of these techniques. By exploring the evolving surgical strategies for first web reconstruction, we aim to provide an academic foundation for improved clinical decision-making.

2. Materials and Methods

This review is based on an extensive analysis of existing literature, supplemented by our institutional experience in first web space reconstruction between 2010 and 2024. We systematically reviewed publications on reconstructive techniques, including skin grafts, local flaps, pedicled flaps, and microsurgical approaches. Key studies were selected based on their relevance, clinical outcomes, and contribution to current surgical practices. Additionally, we assessed innovative reconstructive techniques, including stem cell therapy and bioengineered tissue grafts.

In addition, we retrospectively analyzed cases treated at our institution, including pediatric and adult patients requiring first web reconstruction. The selection criteria included patients with post-traumatic, post-burn, and congenital first web anomalies requiring surgical intervention. Surgical techniques were categorized based on defect complexity and reconstructive approach, with outcome measures including first web space angle pre- and postoperatively, functional recovery, donor site morbidity, and complications. Data were analyzed using descriptive statistics and comparative studies where applicable.

3. Results

At our institution, first web reconstruction procedures were performed in pediatric and adult patients using various techniques from the reconstructive ladder. The majority of pediatric cases were successfully managed with Z-plasty, local flaps, and skin grafting, whereas more extensive defects necessitated pedicled or microsurgical flaps.

- Skin Grafts and Dermal Substitutes: Employed primarily for superficial defects, these techniques yielded satisfactory results when the underlying fascial structures were preserved. Split-thickness skin grafts from the foot instep were preferred due to their textural compatibility.
- Local Flaps and Z-Plasty: First-line treatments for scar contracture release, particularly in burn sequelae. Multiple Z-plasty techniques, including 4-flap and 5-flap modifications, were employed to maximize web depth and length.
- Pedicled Flaps: Posterior interosseous artery flaps were used in cases requiring extensive soft tissue coverage, providing optimal pliability and skin texture match. These flaps were particularly advantageous due to their minimal donor site morbidity.
- Microsurgical Flaps: In complex reconstructions involving multi-tissue loss, free flaps such as the anterolateral thigh (ALT) flap were utilized. SCIP flaps were considered in smaller defects where a thinner and more pliable tissue was required.

Postoperative outcomes demonstrated a mean improvement in the first web space angle from 20° preoperatively to 75° postoperatively, with restored hand function in the majority of cases. Complications were minimal, with flap survival rates exceeding 90%. Additionally, emerging techniques such as bioengineered scaffolds and tissue regeneration therapies showed promise in preliminary clinical applications.

3.1. Local Flaps and Skin Grafts

3.1.1. Skin Grafts and Dermal Substitutes (Table 1)

Skin grafting is a simple technique frequently used in first web contractures treatment. Split-thickness skin grafts are a good choice for restoring dorsal superficial defects, such as post-burns contractures. Skin can be picked up manually with a blade or with a dermatome, depending on the extension of the defect and the donor site. The volar side of the wrist, the inner part of the arm, the inguinal fold are the most frequent donor sites for small defects. The instep of the foot is also good

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donor site for palm reconstruction because it bears a small-medium area of glabrous skin with comparable thickness and texture to the recipient site [8]. The use of the dermatome is limited to big-sized defect, obtaining skin usually from anterior part of the thigh. One of the main advantages of this technique is the possibility to obtain, when needed, large patch of skin, adjustable in size and shape secondary to the defect, with limited morbidity of the donor site. Nonetheless, there are some drawbacks to skin-grafting procedure, such as a lack of sensation, inadequate thickness, and the risk of recurrence due to secondary contracture. In a review by Yuste et al., the authors reported that skin grafts, both split and full thickness, have a high rate of reintervention [3]. In some cases, especially when scarring affects deep layer of the skin, the use of dermal substitutes in union with split-thickness skin graft is a valid option after contracture release. Dermal substitute (which can be derived from ovine, swine and bovine substrate) thanks to their high content of collagen, elastin and hyaluronic acid offer a scaffold which is colonized in two-three weeks by fibroblast and angiocytes of the patient. These matrices give good elasticity to the skin. After a period of two or three weeks it is possible to cover the dermal substitute with a skin graft or heal the wound for second intention changing moisturized dressing twice a week. Abbound and colleagues discuss their outcomes with dermal substitutes in patients with recessive dystrophic epidermolysis bullosa. Long-term results for long fingers were encouraging, with 57% of cases demonstrating good function for more than 3 years and 33% demonstrating good function for more than 5 years. Although, the data for the first web contractures were disappointing, as almost all patients experienced a rapid recurrence of contractures on the grafted areas within one year of surgery. The authors also reported a lower risk of recurrence when full-thickness skin grafts were used [9].

Table 1. This is a table describing Indications and Techniques of skin grafts in soft tissue defects of the hand.

Author	Type of Study	Number of Cases/Studies	Indications	Technique
Ward, 1985 [8]	case series	13	Hand burn contracture.	Split thickness graft from plantar and volar instep donor site.
Yuste, 2017 [3]	Review	29	First web contractures after full-thickness burns.	Skin grafts and dermal matrices, random flaps, pedicled fasciocutaneous flaps, free flaps, other techniques.
Abboud, 2022 [9]	retrospective review	18	Obliteration of the interdigital spaces, adduction contracture of the thumb.	Fixation with kirschner wires, cover with dermal substitutes or skin graft .

3.1.2. Local Flaps and Z-Plasties (Table 2)

For first web space small-sized contractures, common reconstructive options include local flaps and Z-plasties. Frequently this kind of contracture affects children and is secondary to burns with hot surfaces, limiting the mobility of the fingers and the use of the hand. The availability and integrity of the surrounding tissues are crucial since these flaps depend on the skin that is immediately adjacent to the defect. There are many designs that could be used, according to the Literature, but the most common flaps are the 4-flap Z-plasty, 2-flap Z-plasty, 5-flap Z-plasty, one Y-V advancement, and rotational flaps from the dorsum of the hand and index finger [2]. The 4-flap Z-plasty, first reported by Limberg [10], is made up of two 45° angle flaps that are transposed to gain length from a 90° angle flap. In order to increase both length and depth, it is also possible to contrapose two Z-plasties with a Y-V advancement in between [11,12]. Fraulin and Thomson demonstrated that 4-flap Z-plasties deepen web spaces more than 5-flap Z-plasties. The 120° 4-flap Z-plasty provided 2.0 times the depth of the 5-flap Z-plasty and approximately 1.3 times the depth of the 90° 4-flap Z-plasty. Although the 120° angles achieved greater depth, they were more difficult to design and close by primary intention [13].

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Table 2. This is a table describing Indications and Techniques of local flaps and Z plasties in soft tissue defects of the hand.

Author	Type of study	Number of cases/studies	Indications	Techniques
Moody, 2015 [2]	review	10	First web space contractures of different degrees.	Z plasties, reverse posterior interosseous artery (PIA) flap, Free lateral arm flap, Reverse radial forearm flap, Groin flap.
Hirshowitz, 1977 [12]	techniqe description	-	Axillary web correction leaving the apex of the axilla intact and in situ.	5-flap procedure: 2 Z-plasties with an intervening Y-V advancement.
Fraulin, 1999 [13]	experimental study	12 (plastic frames + 3 pigs	First web space deepening.	120 and 90 degrees four-flap Z-plasty. Five-flap Z-plasty.

3.1.3. Local Axial and Perforator Flaps (Table 3)

Larger defects, extending on the dorsal or ventral skin, may require local axial or perforator flaps to bring healthy tissue in the first web space, after contracture removal. Loco-regional flaps can have an axial or perforator vascularization pattern based on the dorsal metacarpal arteries. Dorsal metacarpal artery flaps and the distal-based Dorsal Metacarpal Artery Perforator Flap (Quaba flap) are preferred due to their reliable blood supply [14,15]. In addition, the bilobed and V-Y advancement first dorsal metacarpal artery flaps are a safe, simple and versatile options that take advantage of the elasticity and mobility of the dorsal hand skin [16]. The first dorsal metacarpal artery (FDMA) flap was first described for thumb reconstruction [17]. It can be designed as a skin island to cover dorsal hand defects or transferred to the first web space. This allows for increased web width and a simple reconstruction with a consistent blood supply and minimal donor site morbidity [18]. Finally, Trimaille et al., published a case report in which they successfully remobilized a flap from a previous trauma repair site. The authors then transposed it to the contracted web space as an axial flap based on FDMA [19].

Table 3. This is a table describing Indications and Techniques of local axial perforator flaps in soft tissue defects of the hand.

Author	Type of study	Number of cases/studies	Indications	Techniques
Quaba, 1990. [14]	anatomical study and case series	21	Resurfacing of web spaces, dorsal metacarpal and phalangeal skin defects.	The distally-based dorsal hand flap.
Perera, 2014 [15]	case report	1	First web space defect of the hand with 3 × 2-cm skin deficit exposing neurovascular structures to the index finger.	Distally based dorsal metacarpal artery perforator flap (Quaba).
Doğan, 2014 [16]	retrospective study	6	Burn wound adduction contractures of the first web space and acute wounds resulting from electrical burns, defects of the first web space and on the dorsum of the thumb.	V-Y Advancement First Dorsal Metacarpal Artery Flap. Bilobed FDMA Flap.

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El Andaloussi, 2007 [18]	case series	12	Skin defects on the dorsum of the distal phalanx of the thumbs, on the dorsum of both the distal and proximal phalanges and on the volar aspect of the thumb.	The Foucher's "kite-flap"
Trimaille, 2015 [19]	Case report	1	Skin loss in a post-traumatic thumb defect in a 5-year-old child + secondary first web space narrowing.	First dorsal metacarpal artery flap associated with a toe-to-hand transfer + remobilization of FDMAF to open the first web space.

3.2. Locoregional Flaps (Table 4)

In extensive defects, the surgeon must consider the use of distant pedicled flaps or free flaps. Important contracture release of the first web, composite multi-tissue defects, exposed hardware, and poor-quality local skin are all conditions which necessitate distant or free flaps to restore the integrity of first commissure. In some cases, composite reconstruction including tendon or nerve grafts may be needed, especially after high energy injuries. These are the most used pedicled flap for first web reconstruction described in the literature.

Table 4. This is a table describing Indications and Techniques of locoregional flaps in soft tissue defects of the hand.

Author	Type of Study	Number of cases/Studies	Indications	Techniques
Usami, 2017 [20]	case series	13	Fingertip reconstructions.	Posterior interosseous artery perforator flap used for small defects.
Costa H, 2007 [21]	Anatomy study and retrospective review	102 clinical cases + 100 anatomical dissections	Large hand defects after crush-degloving injuries, burn contractures, or skin necrosis subsequent to chemotherapy, burns or trauma. Soft tissue reconstruction of the first web space, dorsal and palmar aspects of the hand, including the metacarpal-phalangeal joints and the dorsum of the thumb as well as for metacarpal reconstruction.	Posterior interosseous flap as either a fasciocutaneous island flap or an osteocutaneous flap.
Costa A, 2022 [22]	Systematic Review	55	Post trauma, burn, and infection defects of the hand from the wrist to the fingers.	Reverse posterior interosseous flap.
Pagnotta, 2012 [24]	Anatomical study and clinical application report	2 clinical cases , 5 freshly injected cadavers.	Ulnar nonunion.	Dorsal distal radius vascularized bone graft pedicled on the posterior interosseous artery.

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Zhang, 2013 [25]	Retrospective review	11	Soft tissue loss of first web space and dorsum of the hand or palmum ,thumb and palm, ulnar or dorsal palm, wrists and the radial aspect of the thenar.	Reverse bipaddle posterior interosseous artery perforator flap.
Kai, 2013 [26]	case series	12	Severe first web contractures after burn injury (chemical, thermal, electrical).	Reverse posterior interosseous flap.
Vergara-Amador, 2015 [27]	Retrospective study	12	Defects on the volar or dorsal hand, first web space and the base of the long fingers.	Retrograde Ulnar Dorsal Flap.
Karacalar, 1999 [28]	anatomic description and case report	2	First web and thumb IP joint contracture and multiple fractures, loss of the extensor tendons and dorsal skin.	Distally pedicled dorsoulnar flap.
Uygur, 2009 [29]	case series	36	Flexion contractures of palms and fingers after burn injuries, traumatic soft tissue loss, tumor exicision. Defects of the palm site and on the dorsum of the hand.	Dorsoulnar flap as either pedicle or free flap.
Moody, 2015 [2]	review	10	First web space contractures of different degrees.	Z plasties, reverse posterior interosseous artery flap, free lateral arm flap, Reverse radial forearm flap, groin flap.

3.2.1. Reverse Posterior Interosseous Artery Flap (rPIA)

The rPIA flap is one of the best options for restoring defects from the wrist to the fingertips and has been widely employed in the first web reconstruction [20]. The flap's vascular supply is based distally on retrograde flow from the anterior interosseous artery (AIA) dorsal recurrent branch, which commonly anastomoses with the PIA 1.5-2 cm proximal to the distal radioulnar joint. The best methods to assess the presence of this vascular communication are preoperative manual Doppler and direct visualization. Nonetheless, the anastomosis can be absent or unstable in some circumstances, and the surgeon can convert the rPIA flap into a free flap [21]. The PIA branches from the common interosseous artery approximately 4 cm distal to the lateral epicondyle. Its surface landmark is a line connecting the lateral epicondyle to the distal radioulnar joint with the elbow pronated and flexed at 90°. The cutaneous perforators are located in the septum between the extensor carpi ulnaris and extensor digiti minimi. The skin paddle is usually centred between the proximal and middle thirds of the forearm. Furthermore, some findings indicated the most reliable perforators more distally, around the central region of the forearm [22]. The ligature of the anterior interosseous artery (AIA), proximal to the communicating branch with the posterior interosseous artery, has been demostrated to increase the flap rotation arch, preserving both vascular sources and permitting to distally extend the reach of the flap [23]. The donor site can be closed directly up to 6 cm or skin grafted with great results and minimal donor site morbidity. The rPIA flas has acquired widespread popularity due to its several advantages: 1) It has a substantial vascular reliability; 2) It has thin and pliable skin with good color and texture match; 3) It has a wide arch of rotation; 4) It does not sacrifice any major artery in the distal upper limb; and 5) It preserves lymphatic and venous drainages of the hand. The main

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disadvantage of the flap is venous congestion, which can be treated by loosening skin sutures or using leech therapy. Furthermore, supercharging the flap with additional venous anastomoses is an efficient method for reducing congestion [24]. Zhang et al. furtherly addressed the necessity of reconstructing numerous subunits while limiting donor-site morbidity. They divided the flap into two independent skin paddles, each with its own perforator. This chain-link flap enables for the simultaneous restoration of two separate hand subunits, whereas the kiss-flap can resurface a single large defect while attaining primary donor-site closure [25]. Finally, Kai et al. demonstrated with outstanding results that the rPIA flap could enhance the first web length by up to 260% starting from a mean thumb to index angle of 78° [26].

3.2.2. The Retrograde Dorsal Ulnar Flap

The retrograde ulnar dorsal flap pedicle flap is a variant of the Becker's ulnar flap and provides a safe and reproducible reconstructive method for hand and first web dorsal defects. The Ulnar Dorsal Artery (UDA) proximal branch anastomoses with 2-3 perforating branches of the ulnar artery. This establishes a subcutaneous vascular plexus and enables for the design of a big flap with a distal pivot point. The distal branch of the UDA ensures reverse flow after the UDA is ligated at its origin [27]. In addition, authors have described other distant anastomoses that can give a strong vascular supply [28,29]. The main benefits of this flap are the preservation of the ulnar artery and the low donor site morbidity. The reverse radial flap is an alternative to the UDA flap, however it compromises one of the two vascular axes of the hand and leaves a conspicuous scar on the patient's forearm [2].

3.3. Free Flaps (Table 5)

Literature recommends using free flaps for first web reconstruction following severe contracture release or in the presence of exposed muscles, arteries, nerves, bones, and tendons. Furthermore, free flaps are required when the tissue loss extends beyond the first web space and involves the rest of the hand or forearm. In such instances, loco-regional flaps are no longer possible [3]. Nowadays, technology advancements and surgical procedure refinements have rendered the principle of the reconstructive ladder obsolete in favor of the reconstructive "tool box." In consequence, for many reconstructive surgeons, free flaps are now the first line of treatment, even for modest defects. Free flaps can overcome several issues of reconstruction since they can fit any size defect and bring as many good-quality tissues as are required to achieve the reconstructive goals [30].

3.3.1. The AnteroLateral Thigh Flap (ALT)

The ALT flap, defined as the ideal soft tissue flap by Wei et al. [31], is the predominant and most used flap for skin coverage by reconstructive surgeons. It can be harvested as a composite flap with a portion of vastus lateralis muscle, fascia lata, and, in rare situations, iliac crest bone. These auxiliary tissues can be used to minimize dead space, recreate a gliding surface for tendons, and eventually repair the metacarpal bones [32]. The ALT flap is simple in harvesting technique and has a consistent anatomy; it has a long and wide diameter pedicle, and the anastomoses can be positioned distant from the zone of injury. Furthermore, donor site morbidity is minimal because the flap harvest involves no major or relevant anatomic structure [33, 34]. The main concern with the ALT flap in hand reconstruction is its thickness, which can limit fine thumb movements when employed for first web reconstruction. Although further debulking treatments are safe and well tolerated by patients, the flap can be harvested as a thin or ultra-thin flap in the first place, or as a Sandwich Fascial Anterolateral Thigh flap (SALT), as described by Cherubino et al. [35].

3.3.2. Superficial Circumflex Iliac Artery Perforator Flap (SCIP)

The SCIP flap is another excellent option for hand skin coverage, and many surgeons across the world are using it as their first reconstructive. The SCIP flap provides a thin, pliable skin that is perfect for hand reconstruction. Furthermore, it has one of the greatest donor site outcomes because ordinary clothing and undergarments can readily conceal the scar. The flap's typical drawbacks are excessive bulk in overweight patients and the need for subsequent debulking surgeries. These can be avoided by elevating the flap in the suprafascial plane or by raising it as a pure skin perforator flap [36]. The

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main disadvantages of the SCIP are that it is more difficult to dissect and requires more experience than the ALT flap.

3.3.3. Foot Web Free Flap

The aforementioned flaps, despite being reliable and reproducible reconstructive solutions, do not guarantee a like-with-like repair of the initial web space. According to del Piñal et al., free foot first web flaps may be the best option for a like-with-like repair in post-traumatic hand and first web deformities [4]. A template of the first web defect can be translated to the foot web spaces using this technique. The size and nature of the hand deformity determine which foot web space will be used as donor site. The first dorsal metatarsal artery is responsible for vascular supply, and due to its length, it can be anastomosed with the deep branch of the radial artery or with the radial artery itself. The donor site is then either closed by creating a neosyndacty or repaired with dermal substitutes or skin grafts. The flap completely matches the 3D structure of the initial web with a good texture and color match for small-medium defects. In contrast to other free flaps, there is no bulging and the skin folds inwards during adduction, mirroring the biomechanical features of the native first web. Because the donor artery diameter spans from 0.5 to 1 mm, advanced microsurgical skills are required. Furthermore, donor site morbidity may be bothersome for some patients. The formation of a neosyndactily at the donor site is normally well tolerated for the second web flap, but a painful hyperkeratosis may occur in the event of a skin graft for donor site closure.

Table 5. This is a table describing Indications and Techniques of free flaps in soft tissue defects of the hand.

Author	Type of Study	Number of Cases/Studies	Indications	Techniques
Yuste, 2017 [3]	Review	29	First web contractures after full-thickness burns.	Skin grafts and dermal matrices, random flaps, pedicled fasciocutaneous flaps, free flaps, other techniques.
Meky, 2013 [32]	case series	3	Complex defects of hand involving different tissues (bone, tendon, skin).	Composite anterolateral thigh perforator flaps.
Miller, 2016 [30]	review	x	Various hand defects.	Reverse homodigital island flap, Reverse cross-finger flap, Radial artery perforator, Groin, Lateral arm, Posterior interosseous artery, Anterolateral thigh flap, First dorsal metacarpal artery flap.
Wei, 2002 [31]	retrospective study	672	Multitissutal reconstruction of the whole body: head/neck, upper limb, lower limb, trunk.	Anterolateral thigh flap.
Cai, 2021 [33]	Prospective series	14	Soft tissue defects and major forearm vascular axis of the hand.	Anterolateral thigh flap.
Wang L [34]	Retrospective	6	Hand soft tissue defects.	Deep Anterolateral thigh fascial flaps associated to skin grafts.
Cherubino, 2017 [35]	Retrospective	11	Head/Neck reconstruction. Indications can be	Grafted thin adipofascial Anterolateral thigh flap.

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			extended to any other body area.	
Narushima M. [36]	case series	6	Soft tissue defects including middle finger, little finger, thumb, dorsum and palmar hand.	Superficial circumflex iliac artery pure skin perforator-based superthin flap.
Del Piñal, 2015 [4]	Case series	9	Post-traumatic and post-infective hand web contractures .	Foot web free flaps for single-stage reconstruction of hand webs.
Jeon, 2017 [37]	Case series	10	Small sized hand defects of fingers and first web space.	Anconeus free flap.
He, 2017 [38]	Case series	15	Moderate-Sized hand defects: palm, dorsum, finger and 1 first web reconstructions.	Superficial Lateral Sural Artery Perforator Flap.
Wolff, 2011 [39]	Anatomical study	42	Moderate-sized Intraoral defects .	Superficial lateral sural artery free flap.
Lin, 2011 [40]	Case series	14	Small to medium-sized hand defects involving fingers, dorsal hands, palms, and wrist.	Medial sural artery perforator flap.
Xie,2007 [41]	Case series	7	Soft tissue defects of the hand, mainly dorsum of the hand.	Medial sural artery perforator flap.
Toyserkan, 2015 [42]	Retrospective series	10	Small to medium-sized defects of the mouth and lower extremity.	Medial sural artery perforator flap.

3.4. Minor Free Flaps

3.4.1. Anconeus Flap

Jeon et al. advocated the use of the anconeus muscle free flap in a group of ten patients [37]. This flap has the benefit of being harvested within the same surgical field of the affected hand and leaving with small or no functional deficits following its harvest. The recurrent posterior interosseous artery provides vascular inflow. The mean pedicle length was 1.6 cm (range: 1.0 to 2.1 cm), and the artery diameter was about 1 mm. Despite the good results achieved by the authors, interposition vein grafts are frequently necessary to reach the recipient vessel. Finally, the lack of a skin island necessitates the use of a skin graft for wound closure at the recipient site

3.4.2. Superficial Lateral and Medial Sural Artery Flap

In 2017, He et al. published a case series of 15 patients treated with the superficial lateral sural artery perforator (SLSAP) flap for the repair of moderate-sized hand wounds, including the first web space [38]. Notably, in a 2012 anatomical research, the superficial lateral sural artery was present in 36 of 42 specimens (85.8%). However, only 25 of 36 arteries (69.4%) were suitable for free flap harvest [39]. When the lateral vessels are absent or unreliable for microsurgical anastomosis, the surgeon must convert the flap into the more popular superficial medial sural artery perforator flap (MSAP), extending the incision medially and dissecting until the medial sural artery and its perforators are exposed. The flap is soft and thin, suitable for medium-sized defects, donor site morbidity is low, and the harvest technique is relatively simple. The anatomy of the MSAP, on the other hand, is more constant, and surgeons tend prefer it to its lateral counterpart [40, 41]. Finally, both flaps have a medium length pedicle (8cm on average for SLSA, 10cm for MSAP [39,42] and moderate size skin

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paddles (4x6cm on average for SLSA, 10x5cm for MSAP [39,42], making them excellent for moderate-sized defects with anastomosis close to the zone of injury.

4. Discussion and Future Directions

Our findings align with existing literature on first web reconstruction, reaffirming the importance of individualized treatment strategies. The reconstructive approach must consider defect severity, tissue quality, and functional demands. While skin grafts remain a viable option for superficial defects, their tendency for secondary contracture limits long-term effectiveness. Dermal substitutes offer improved outcomes but are still associated with recurrence risks, especially in dynamic areas like the first web space.

Local flaps and Z-plasty techniques provide effective solutions for mild to moderate contractures, offering the advantage of single-stage reconstruction with minimal donor site morbidity. However, deeper structural compromise necessitates the use of pedicled flaps such as the posterior interosseous artery flap, which has demonstrated superior results in providing well-vascularized, pliable tissue with minimal complications. Microsurgical flaps remain indispensable for extensive defects involving composite tissue loss. The anterolateral thigh (ALT) flap has emerged as a preferred option due to its adaptability, large skin paddle, and consistent vascularity, though secondary debulking procedures are often required to optimize hand function.

Recent innovations in microsurgery, such as super-microsurgery and perforator flaps, have enhanced surgical precision and minimized donor site morbidity. The integration of bioengineered scaffolds, tissue engineering, and stem cell applications presents an exciting frontier in reconstructive surgery. These advancements hold promise for improving long-term outcomes, reducing secondary contractures, and potentially eliminating the need for extensive donor sites. Furthermore, the development of nerve regeneration techniques and functional muscle transplantation could play a pivotal role in restoring intricate hand movements in severe first web defects.

Despite these advancements, challenges remain in achieving optimal functional and aesthetic results, particularly in complex cases involving extensive scarring, bone loss, or compromised vascularization. Future research should focus on refining flap designs, optimizing donor site morbidity, and improving functional rehabilitation post-reconstruction. The integration of 3D bioprinting technology, regenerative medicine, and vascularized composite allotransplantation (VCA) may offer groundbreaking solutions for hand reconstruction in the coming decades.

4.1. Our Experience

At our institution, a Level II Trauma Center, we performed numerous first web space reconstructions between 2010 and 2024, addressing both congenital anomalies and acquired defects resulting from trauma and burns. Our approach has evolved over the years to incorporate evidence-based surgical techniques and patient-centered rehabilitation protocols.

4.1.1. Patient Demographics and Case Distribution

Among our patients, the mean age was 44 years, with 80% presenting post-burn contractures and 20% suffering from traumatic crush injuries. Pediatric cases were primarily managed with Z-plasty, local flaps, and skin grafting, whereas adult patients with severe contractures or composite defects required more extensive interventions.

4.1.2. Surgical Techniques and Outcomes

- Skin Grafts and Dermal Substitutes: In cases where contractures were limited to superficial layers, we successfully employed split-thickness skin grafts, often combined with dermal substitutes to reduce recurrence. Donor sites were inguinal fold, volar side of the wrist and the anterior side of the thigh for extended defects. Our findings support the literature, indicating that full-thickness skin grafts have superior long-term durability compared to split-thickness grafts alone. In some cases, when contracture affected the superficial fascia, we decided to use a dermal substitute, skin grafted after three weeks, obtaining a good final texture and pliability. (Figure 1)

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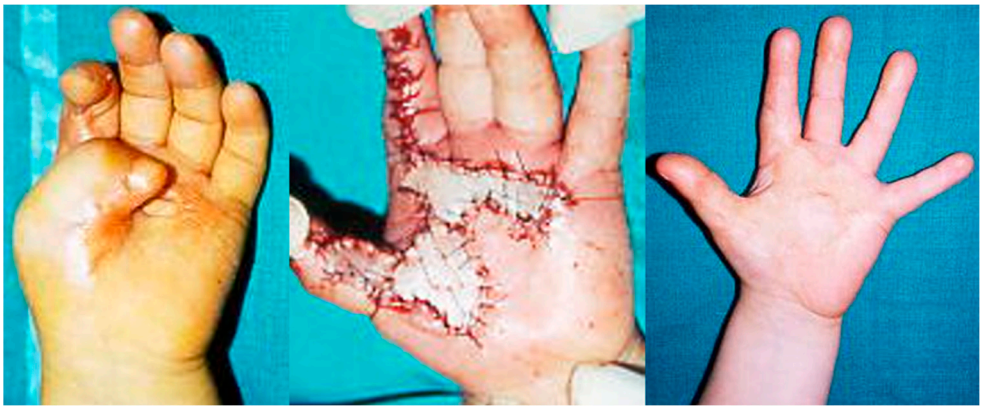

Figure 1. These images illustrate the removal of scar contracture of the first web space and repair with skin graft in a pediatric hand.

- Z-Plasty and Local Flaps: Z-plasty remains our first-line surgery for mild to moderate small-sized contractures, particularly for burn sequelae. By combining multiple Z-plasties with Y-V advancement techniques, we achieved significant first web space widening while preserving mobility. This approach resulted in a mean postoperative angle increase from 20° to 75°. Donor site was closed by primary intention. (Figure 2)

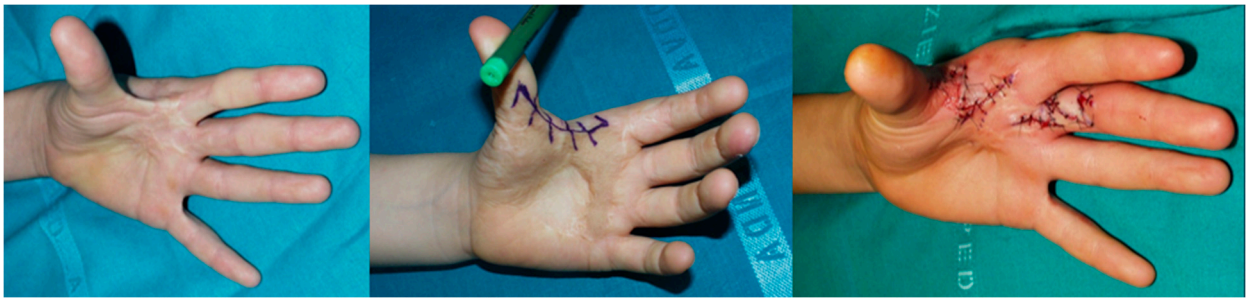

Figure 2. Z-plasty illustrated as a workhorse technique for first web space release.

- Pedicled Flaps: In ten cases involving moderate to severe contractures, we utilized posterior interosseous artery flaps and reverse forearm flaps. The posterior interosseous artery flap demonstrated excellent pliability and integration, with a high success rate and minimal donor site morbidity.
- Microsurgical Flaps: For large, complex defects, we employed free flaps in eight cases, with seven anterolateral thigh (ALT) flaps and one second toe transfer. Microsurgical reconstructions were particularly beneficial for cases involving severe scarring, tendon exposure, and bone loss. The ALT flap provided durable coverage with a high survival rate, though secondary debulking procedures were needed in 40% of cases.

Among our microsurgical cases, six were performed as emergency procedures for mangled hand injuries, requiring meticulous preoperative planning and intraoperative execution. Our experience supports the growing trend of using free flaps as a primary option for extensive defects rather than following the traditional reconstructive ladder approach. (Table 6)

Table 6. This is a table describing cases treated in our hospital for first web contracture and the flap chosen for reconstruction, since 2010 to 2023.

Number of Patients	18, Mean Age 44 yrs
Pedicled flaps	8 posterior interosseous flap, 3 radial forearm flap
Microsurgical flaps	9 anterolateral thigh flap, 1 second toe transfer
Flaps performed in urgency	6 flaps for mangled hand
Mean pre-operative I web space angle	20 degrees
Mean post-operative I web space angle	75 degrees

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We performed a posterior interosseous flap in eight cases among our patients. We consider this flap a first option in first web space reconstruction thanks to his good pliability and match in skin texture. (Figure 3)

In particular, its low thickness, makes this flap easily adapting to the fold between first and second digit, without bulkiness issues. The flexibility of the dorsal skin of the forearm allows, once the flap is turned in its final position, the maintenance of the range of motion of the digit, preventing secondary contractures. The donor site can be closed by primary intention if flap width is under 6 cm, limiting the morbidity of the forearm.

Figure 3. Figure describing a case of first web space post burn contracture managed with reconstruction through a posterior interosseous flap**.**

In case the defect includes more than two units of the hand or is composite (muscle and tendon loss or bone exposure) and cannot be covered with a locoregional flap we usually use a microsurgical flap. We fully concur with Wei et al. that ALT flap is the best choice for upper and lower limb reconstruction, as well as head and neck reconstruction, at our hospital. The ALT flap is a robust flap with a long pedicle that can be anastomosed with the radial artery's deep branch at the anatomic snuffbox or with the radial artery itself. It is compatible with skin texture and color, and the flap harvest can be performed by a different surgical team for timing optimization. (Figure 4)

We prefer to harvest the fascio-cutaneous flap and plan a secondary debulking later on for the patient. In our experience, single or dual stage reconstructions produce comparable results. We experienced the use of this flap in urgency reconstruction for hand trauma and in elective surgery for post scarring contracture of the first web space.

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Figure 4. This is a table describing the use of ALT flap to repair big defects of first commissure and palmar side of the hand after explosion injury**.**

In our experience we consider the SCIP flap as a second option for soft tissue restoration of the fist web space and hand. It has a much shorter pedicle and smaller calibre than the ALT flap. This poses a challenge when dealing with complex defects with a distant site of anastomosis. Furthermore, there is limited tissue available in the groin for composite and chimeric flaps. When dealing with small-medium sized lesions that do not affect the underlying structures, we recommend employing the SCIP flap.

When the first digit of the hand is fully damaged is necessary to restore the use of the hand with the transfer of the hallux or the second toe (Figure 5). We used a second toe transfer in emergency setting to recreate the first digit of the hand, obtaining a good functionality of the hand.

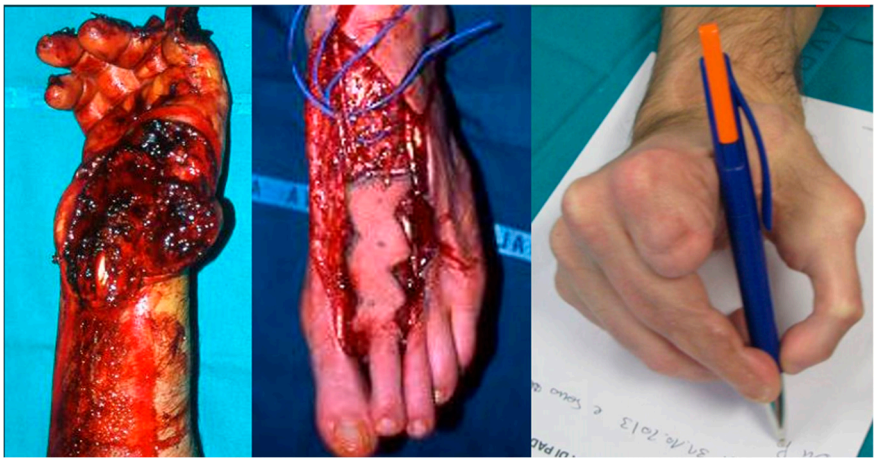

Figure 5. Pictures describing II toe transfer for reconstruction of I digit and web commissure after workplace trauma**.**

4.1.3. Long-Term Functional Outcomes

Overall, our patients demonstrated significant functional improvements, with a majority regaining near-normal thumb-index opposition and grip strength. Long-term follow-ups indicated sustained flap viability, with minimal late-stage complications such as secondary contracture or bulkiness in ALT reconstructions. Patients who underwent SCIP flap reconstructions reported high satisfaction due to the thin and pliable tissue characteristics, though the technique was less frequently utilized due to the shorter pedicle length.

4.2. Future Directions in Clinical Practice

Based on our institutional findings and a review of the literature, we advocate for an individualized, defect-specific approach in first web reconstruction. The combination of advanced microsurgical techniques, improved biomaterials, and optimized rehabilitation protocols has significantly enhanced patient outcomes. Future research at our institution will focus on incorporating regenerative medicine approaches, including stem cell therapy and scaffold-based tissue engineering, to further improve reconstructive options.

In conclusion, first web space reconstruction remains a highly specialized and evolving field in hand surgery. Our institutional experience corroborates the broader surgical literature, emphasizing the importance of technique selection, early intervention, and multidisciplinary management to achieve optimal results

5. Conclusions

The first web space is essential for hand function, and its reconstruction requires a tailored approach based on defect characteristics. The choice of technique should balance functional restoration, aesthetic outcomes, and long-term durability. Continued advancements in surgical techniques and bioengineering will further enhance reconstructive outcomes for first web anomalies.

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Abbreviations

The following abbreviations are used in this manuscript:

MCP	Metacarpophalangeal joints
VCA	Vascularized composite allotransplantation
SCIP	Superficial circumflex iliac artery perforator
ALT	Anterolateral thigh flap
rPIA	Reverse Posterior Interosseous Artery flap
FDMA	First dorsal metacarpal artery
AIA	Anterior interosseous artery
UDA	Ulnar Dorsal Artery
SALT	Sandwich Fascial Anterolateral Thigh flap
SLSAP	Superficial lateral sural artery perforator
MSAP	Sural artery perforator flap
DOAJ	Directory of open access journals
TLA	Three letter acronym
LD	Linear dichroism

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