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Methods of Thumb Reconstruction

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Abstract:

Background: Thumb reconstruction is a critical aspect of hand surgery due to the thumb's essential role in hand function, particularly grip, pinch, and opposition. Various reconstructive techniques are available depending on the level of injury and extent of tissue loss. These include local flaps, regional flaps, free tissue transfer, and reconstructive procedures following thumb amputation. Proper selection of the reconstructive method is essential to achieve optimal functional and aesthetic outcomes.

Keywords: Thumb reconstruction; Local flaps; Moberg flap; V-Y advancement flap; FDMA flap; Free flaps; Toe-to-thumb transfer.

Introduction:

Thumb injury can be the result of a variety of different mechanisms. These include sharp cut, avulsion, and crush. There are some mechanisms that have characteristics of more than one injury type. This phenomenon is best illustrated by saw and lawn mower injuries, which have both cutting and crushing components, resulting in a larger zone of injury **(Vedder, 2014).**

The level of thumb injuries guides the type of reconstruction. Determination of the level of loss is based on physical examination and radiographs **(Germann, 2017).**

The principal goals of distal thumb reconstruction are soft-tissue coverage of bone and length preservation. When there is no bone exposed at the tip of the thumb, closure can be achieved with either healing by secondary intention or skin grafting. When phalangeal bone is exposed at the thumb tip, vascularized coverage is required to preserve length, and there are several flaps that can accomplish these goals. (**Luan, 2019).**

Reconstructive strategies are tailored to the extent of tissue loss, level of amputation, and patient factors such as occupation, age, and functional demand. The modern approach integrates microsurgical techniques, local and regional flaps, and prosthetic innovations to achieve optimal outcomes, **(Fig.1) (Sabapathy & Venkatramani, 2021).**

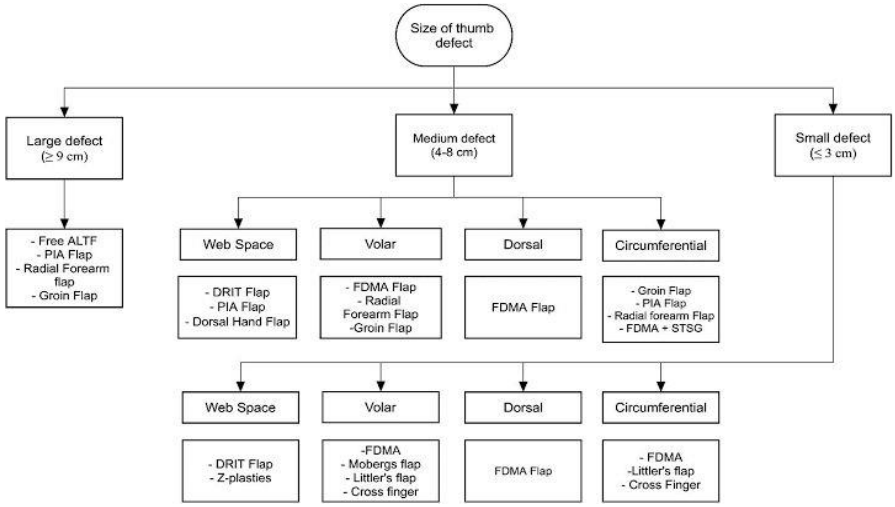

Figure (1): Classification of thumb injuries and their managements **(Khan et al. 2015).**

3. Reconstruction Following Tissue Loss:

3.1. Local Flaps:

Local flaps are ideal for small to moderate defects, offering good color, texture, and sensory match.

- **Moberg Advancement Flap:**
  - Best for volar pulp defects ≤2 cm.
  - Provides sensate coverage using bilateral volar advancement of neurovascular bundles **(Moberg, 1964).**
- **V-Y Advancement Flap:**
  - Simple, reliable flap for distal thumb tip coverage; preserves length and sensibility **(Atiyeh et al., 2021).**
- **First Dorsal Metacarpal Artery (FDMA) Flap:**
  - Used for larger volar or dorsal thumb defects.
  - Based on the FDMA supplying dorsal skin of the index finger
- **Cross-Finger Flap:**
  - Indicated when local tissue is unavailable; based on the dorsal branch of the digital artery of the adjacent finger.
  - Staged procedure with division after 2–3 weeks **(Singh et al., 2021).**

3.2 Regional Flaps:

- **Thenar Flap:**
  - Used for small volar defects; provides sensate glabrous tissue from the thenar eminence.
  - Requires temporary immobilization **(Khan et al. 2015).**
- **Posterior Interosseous Artery Flap:**
  - For larger dorsal defects when local flaps are insufficient; preserves major vessels of the hand **(Venkatramani et al., 2020).**

3.3 Free Flaps:

- Indicated for **large composite defects** or when local options are exhausted.
- Provide sensate, pliable tissue with reliable vascularity. Common options include:
  - **Toe pulp free flap:** For sensate pulp reconstruction.
  - **Medial plantar flap:** Hairless, glabrous skin suitable for palmar thumb defects.

4.Reconstruction Following Thumb Amputation:

4.1 Replantation:

- Microsurgical reattachment is the gold standard for complete thumb amputations when feasible.
- Success depends on mechanism of injury, ischemia time (<12 hours warm, <24 hours cold), and vessel integrity.
- Restores length, sensation, and opposition with excellent functional outcomes **(Venkatramani et al., 2020).**

4.2 Toe-to-Thumb Transfer

When replantation is impossible, microvascular toe transfer provides a functional and aesthetic substitute.

Options include:

- **Great Toe Transfer:** Provides maximum length and strength; suitable for proximal thumb amputations.
- **Second Toe Transfer:** Provides more refined appearance, less donor morbidity; indicated for distal or mid-level loss.
- **Trimmed Toe Transfer:** Modified version preserving donor foot contour **(Sabapathy & Venkatramani, 2021).**

Functional results show 80–90% grip and pinch strength recovery, with satisfactory sensation and motion **(Wei et al., 2022).**

4.3 Osteoplastic Reconstruction

Used when microsurgery is contraindicated. It combines **bone grafting** and **soft-tissue coverage** to restore length and contour.

- **Bone Graft:** From iliac crest or radius.
- **Soft-Tissue Cover:** Local or regional flap (e.g., radial forearm). Although non-sensate, this technique provides stability for opposition and grasp **(Foucher et al., 2019).**

4.4 Pollicization

When the thumb is completely absent (Type V loss), **index finger pollicization** is the preferred reconstructive method.

- The index finger is transposed and rotated to function as a thumb, with reorientation of tendons and neurovascular bundles **(Buck-Gramcko, 1971)**.
- Provides excellent opposition, grasp, and appearance, particularly in congenital or traumatic cases.

I- V-Y Advancement Flap (Atasoy et al.,1970)

➢ **Indications:**

- **Volar oblique or transverse amputations** of the distal thumb or fingertip.
- **Soft-tissue loss** limited to the distal third of the distal phalanx with exposed pulp, bone, or nail bed.
- Defects typically ≤ 1.5–2 cm in length **(Wong et al., 2023).**

➢ **Contraindications:**

- Large or dorsal defects that exceed the advancement capacity.
- Crush injuries with extensive tissue necrosis or vascular compromise.
- Cases with loss of both neurovascular bundles, in which sensate advancement is not possible.
- Infection or delayed presentation with significant fibrosis **(Chiu & Chang, 2021).**

This flap is simple to perform, reliable, and the donor site can be closed linearly. It also preserves good fingertip sensation with glabrous skin. Atasoy and colleagues reported excellent aesthetic outcomes with normal finger range of motion and normal fingertip sensation in 97% of their patients, **(Fig. 2) (Ma et al., 2023).**

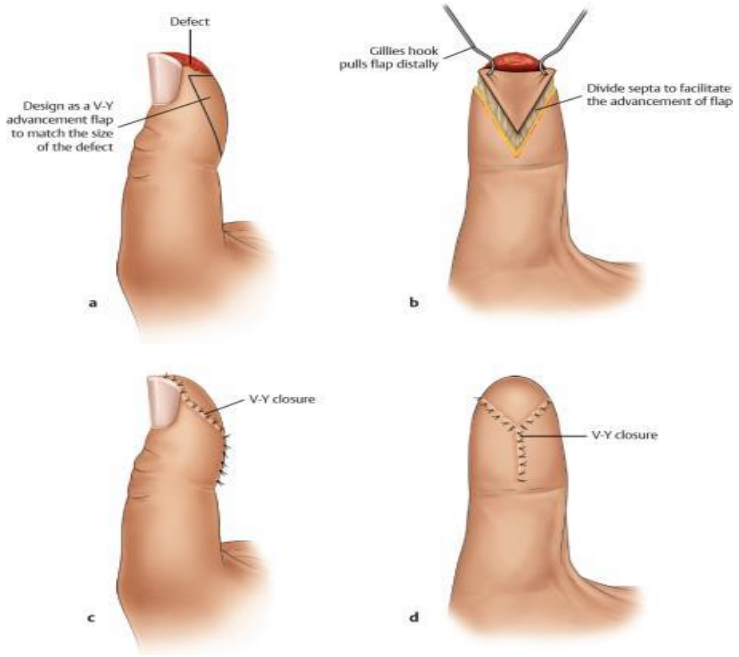

Figure (2): VY advancement flap for distal thumb reconstruction **(Hutton, 2024).**

Modifications and Variations:

- **Kutler's bilateral V-Y advancement flap (1947)** involves two lateral V-Y flaps advanced centrally, suitable for transverse fingertip defects.
- **Extended V-Y flap** designs allow greater advancement by undermining more proximally or including the distal interphalangeal flexion crease **(Rinker et al., 2018).**
- The **"triangular-pulp flap"** variant increases flap length while minimizing donor-site tension **(Agarwal et al., 2022).**

Complications and Management:

- **Flap congestion** due to excessive tension or inadequate undermining.
- **Cold intolerance**, reported in up to 20–25 % of cases.
- **Hook-nail deformity**, resulting from loss of bony support under the nail tip.
- **Hyposensitivity or paresthesia**, typically transient, improving with time and sensory retraining **(Agarwal et al., 2022).**

II- Moberg flap:

In the thumb, the palmar advancement flap first described by Moberg in 1964 holds special importance. This flap is an advancement flap based on proper neurovascular bundles, designed for coverage of palmar defects of the pulp. It is considered the standard flap for reconstructing medium defects that are 2 cm or smaller **(Malone, 2013).**

The procedure should be performed as soon as the patient's condition allows. Satisfactory results can be achieved even after several days of delay, provided that the wound is tidy and free of infection at the time of flap coverage **(Cortes,2023).**

Dissection should be dorsal to the neurovascular structures towards the flexor tendon sheath. The flap is elevated from distal to proximal. Sometimes the severed digital nerve branches may be divided sharply 5 mm proximal to the skin edge to avoid creating painful neuromas at the thumb tip. The flap is freed of all dorsal

attachments and mobilized proximally to the level of the metacarpophalangeal (MP) joint in order to maximize its distal advancement. Proper elevation of the flap should allow advancement of up to 2 cm, **(Fig.3) (Yassin et al., 2022).**

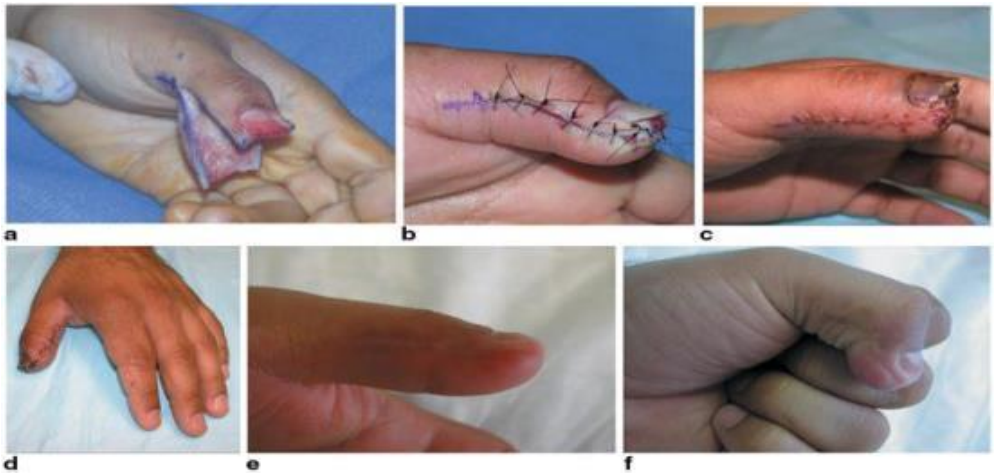

Figure (3): Moberg flap for distal thumb reconstruction **(Porembski et al., 2015).**

Modifications and variations:

While the classical Moberg flap remains effective, several modifications have emerged to extend the reach of the flap and mitigate complications. One such modification combines the Moberg flap with a proximal V-Y advancement component to increase length and avoid IP joint flexion contracture, **(Fig.4) (Díaz et al., 2023).**

Figure (4): The modified Moberg flap **(Suresh Rajendran, 2024).**

In 1968, O'Brien introduced a modification of this technique by converting the advancement flap into an island flap to cover larger defects. Germann later described that performing bilateral Z-plasties at the base of the flap and dividing the subcutaneous septa can avoid flexion contracture of the interphalangeal joint. In cases involving large defects with bone exposure, bone shortening may be considered, although this can result in reduced strength in pinch grip. Despite these challenges, the Moberg flap remains the reference standard for covering complex distal thumb pulp defects **(Ayad et al., 2019).**

Complications:

While flap viability is excellent (100% in some series), specific complications merit attention. Cold intolerance is reported in up to 30% of patients **(Barone et al., 2023)** and nail deformities may persist **(Datiashvili, 2023).** Flexion contracture of the IP joint is a known risk when the advancement is maximal and closure tension is high **(Monreal & Monreal, 2016).** However, in a large series of 36 patients, no permanent flexion contracture occurred and grip strength was preserved unless bone shortening was performed **(Baumeister et al., 2002).**

III-First dorsal metacarpal artery flap:

One of commonly employed procedures is the first dorsal metacarpal artery (FDMA) flap, also known as the Kite flap, described by **Foucher et al. in 1978.** This flap is based on the earlier work of **Holevich (1963) and Hilgenfeldt (1950).** It is based on the first dorso-metacarpal artery and usually includes the sensory branch of the radial nerve. Although the Kite flap was primarily intended for dorsal defects, it is frequently used to restore thumb sensibility in cases of pulp loss. The Kite flap provides immediate sensibility and is therefore especially indicated in older patients, in whom nerve coaptations do not yield satisfactory results. Secondary defect reconstruction is usually performed with full-thickness skin grafts **(Ghoraba et al., 2018).**

The major indication for the use of the FDMA flaps is the presence of deep soft tissue injuries around the thumb. The FDMA flaps have also been used to restore thumb sensibility and to treat cold intolerance. **Foucher and Braun in 1979** mention the use of this flap to treat venous congestion in replanted thumbs as well. Active thumb infections, trauma to the index finger affecting the traject of the artery, and an absence of a preoperative Doppler's signal are all contraindications for the use of these flaps **(Couceiro et al., 2018).**

The first dorsal metacarpal artery is a consistent branch of the radial artery, arising just distal to its origin from the second dorsal metacarpal artery. It runs over the first dorsal interosseous muscle, giving three terminal branches:

1. A radial branch to the thumb,
2. An intermediate branch to the first web space, and
3. An ulnar branch supplying the index finger, **(Fig.5) (Choudhary et al., 2022).**

This is the most frequent pattern (60–70%) and provides the most reliable anatomy for FDMA flap harvesting.

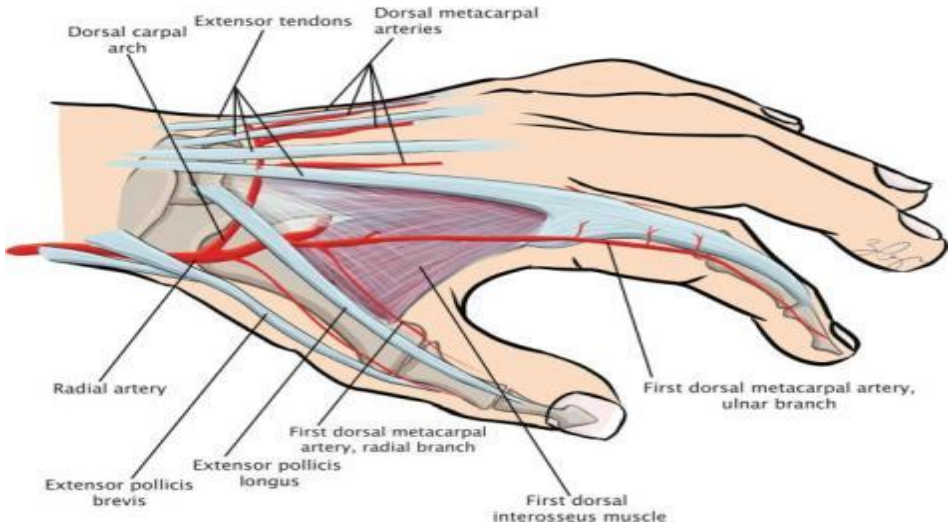

Figure (5): First dorsal metacarpal artery, **(Karamanos, 2021).**

There are other two patterns of FDMA which are bifurcation Pattern in which FDMA divides into two branches (radial to the thumb and a common trunk supplying the index finger and first web space **(Prasad et al., 2022).** Dominant Radial Branch is the third pattern in which the FDMA gives off a large radial branch to the thumb, while branches to the index finger and web space are hypoplastic or arise more proximally, **(Fig. 6) (Barone et al., 2023).**

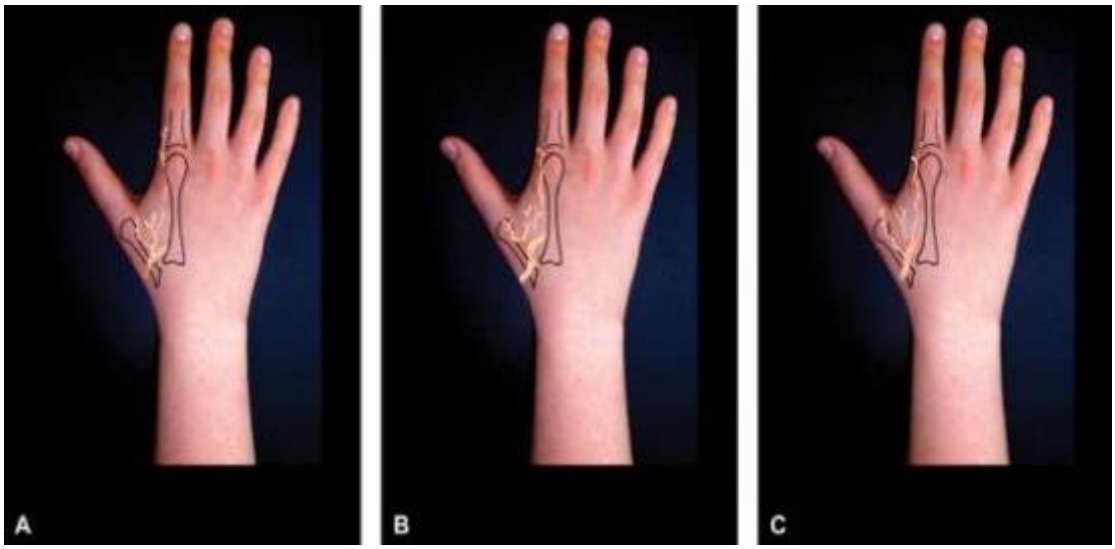

Figure (6): The three different patterns of the first dorsal metacarpal artery**(Couceiro et al., 2018)**

Most of the flaps on the FDMA family are based on the ulnar branch (FDMAu). This ulnar branch ends as a vascular plexus over the dorsal fascia of the index finger. It is important to note that a distal perforator is frequently present at the radial side of the index finger at the height of the metacarpophalangeal joint, this distal perforator connects the FDMAu to the second palmar metacarpal artery and must be generally either ligated or coagulated to perform the flap, **(Fig.7) (Couceiro et al., 2018).**

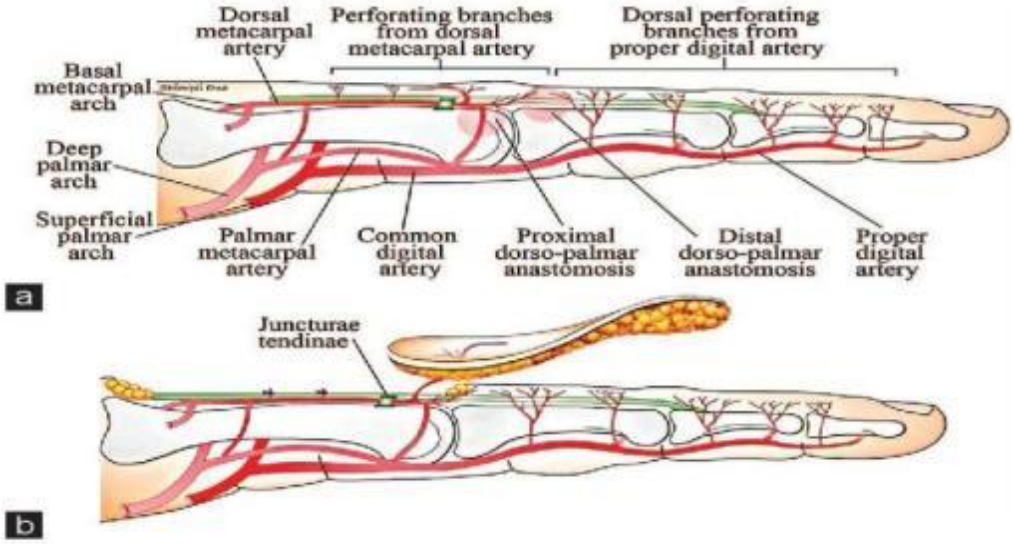

Figure (7): Perforators of ulnar branch of FDMA **(Chung, 2020).**

Modifications and Variations:

Several refinements have been developed to enhance FDMA flap outcomes:

1. **Foucher flap (classical design):** Sensate island flap based on the ulnar branch of FDMA, transferred as an island pedicle, **(Fig.15).**

2. **Extended FDMA flap:** Incorporates skin distal to the PIP joint to reach more distal thumb defects **(Li et al., 2020).**
3. **Reverse FDMA flap:** Used for dorsal defects of the thumb or index finger **(Kumar et al., 2021).**
4. **Chimeric FDMA flap:** Combines skin and bone (from second metacarpal base) for osteocutaneous reconstruction **(Bakhach et al., 2021). (Fig.8)**

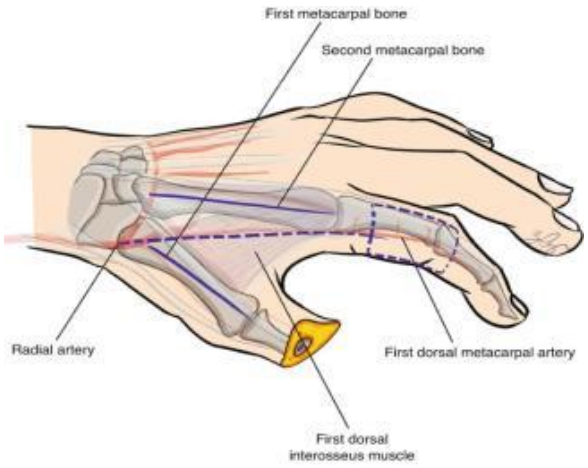

Figure (8): Classical design of FDMAF **(Julian , 2021).**

Complications and Management:

Despite its reliability, the FDMA flap may encounter specific complications:

- Venous congestion (most common), especially in island flaps with long pedicles.
- Partial necrosis at the distal flap tip due to inadequate dissection.
- Donor-site morbidity such as numbness of the index dorsum or graft pigmentation.
- Cold intolerance in up to 25–30 % of cases **(Kumar et al., 2021).**

IV- Other Techniques of Thumb Reconstruction:

a. Reversed flow radial homodigital pedicled flap:

The radial reversed flow pedicled flap was first described by **Moschella and Cordova in 2006**, The dorsoradial artery originates from the radial artery at the level of the anatomical snuffbox and passes under the extensor pollicis brevis tendon to the middle of the thumb proximal phalanx, which is the pivot point of the flap. The dorsoradial collateral artery communicates with the palmar network at the level of the middle third of the proximal phalanx **(Fig.9)** (**Ghoraba et al., 2018).**

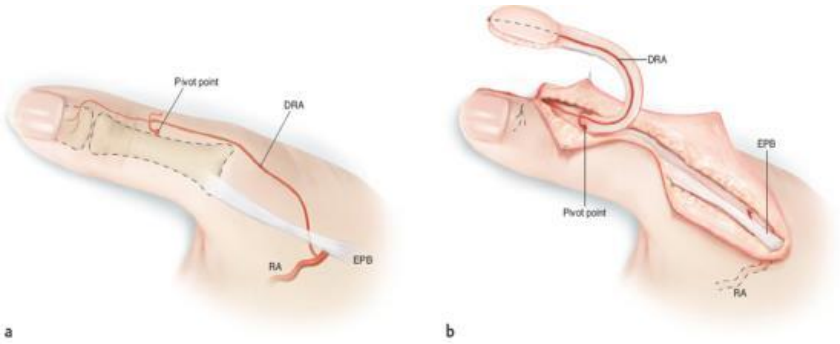

Figure (9): Reversed flow radial homodigital flap **(Hrabowski et al., 2010). (EPB**: Extensor pollicis brevis , **DRA :** Dorsoradial artery, **RA:** Radial artery).

Preoperatively, a Doppler examination helps to identify the course of the vessel and mark the pivot point. At no point during the surgical procedure must the pedicle be visualized, and a wide strip of subcutaneous tissue is included to ensure venous outflow and avoid kinking. Dissection of the flap should not be extended beyond the middle third of the proximal phalanx to protect communication with the palmar vessels. The arc of rotation of the flap allows coverage of the distal palmar or dorsal parts of the thumb as well as radial defects of the proximal and distal phalangeal areas **(Yassin et al., 2022).**

b. Reversed flow pedicled homodigital flap:

A reversed flow pedicled homodigital flap based on the dorsoulnar collateral artery was first described by **Brunelli in 1993**. The dorsoulnar collateral artery, which originates from the palmar arteries, runs superficially within the subcutaneous tissue, and the flap is centered over the dorsoulnar aspect of the first metacarpal. Flap dissection is similar to the technique of **Moschella et al.** This flap is suitable for covering small to medium defects of the dorsal and palmar sides of the thumb, **(Fig.10) (Mehanna et al., 2018).**

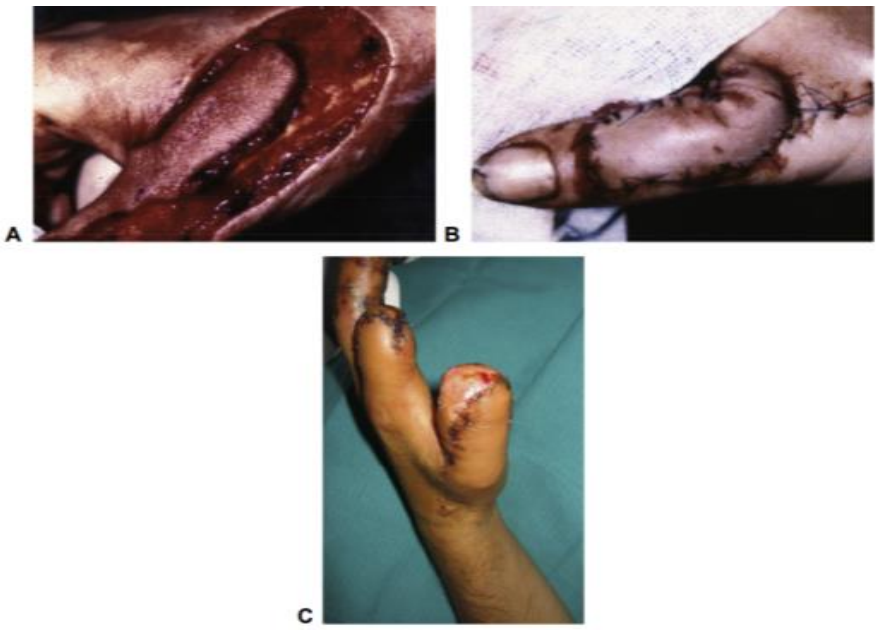

Figure (10): A) An ulnar reversed-flow homodigital island flap **(Brunelli flap)** is raised on the dorsal ulnar recurrent artery. B) A small dog ear is left in this case to protect the vascular pedicle. C) Another case in which the flap is used for tip reconstruction **(Germann et al., 2015).**

c. Cross-Finger Flap:

The cross finger flap is a time-tested technique in which dorsal skin from the adjacent index or middle finger is transposed to cover the thumb defect before later division. It provides reliable coverage for volar oblique or transverse thumb injuries, especially when glabrous donor tissue is unavailable **(Huang et al., 2019).**

Although dependable, a key drawback is the need for two stages, as well as donor-site morbidity requiring skin grafting. Sensory recovery is limited compared to homodigital or neurovascular flaps. Nonetheless, its reliability makes it useful in crush injuries or in contaminated defects where microsurgery is contraindicated , **(Fig.11) (Efanov et al., 2021).**

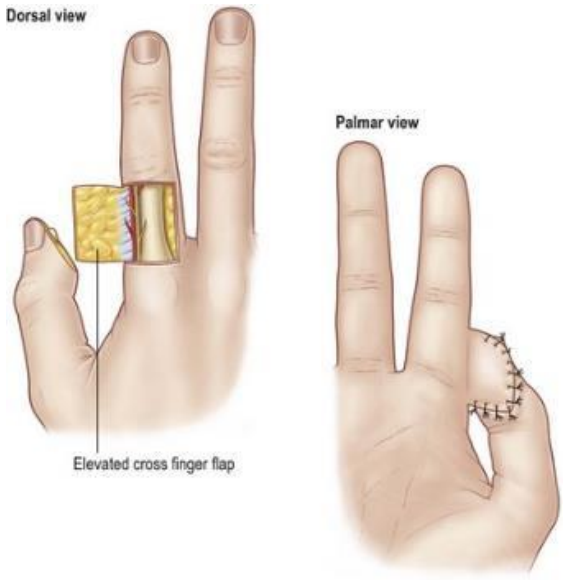

Figure (11): Elevated cross finger flap **(Jeffery B.Friedrich, 2016).**

d. Free Tissue Transfer (Microsurgical Free Flaps):

Free flaps are used for large or composite defects where local or regional flaps are insufficient. Options include the great toe pulp flap, medial plantar artery flap, and lateral toe pulp flap. These flaps offer highly durable, glabrous, sensate tissue closely resembling native thumb pulp, **(Fig.12) (Horta et al., 2020).**

The medial plantar flap is particularly valued for its thickness, texture, and sensory capacity comparable to the thumb, while the great toe pulp flap provides the most anatomically similar replacement. However, microsurgical skill is required, and donor-site morbidity on the foot may limit use **(Zhang et al., 2022).**

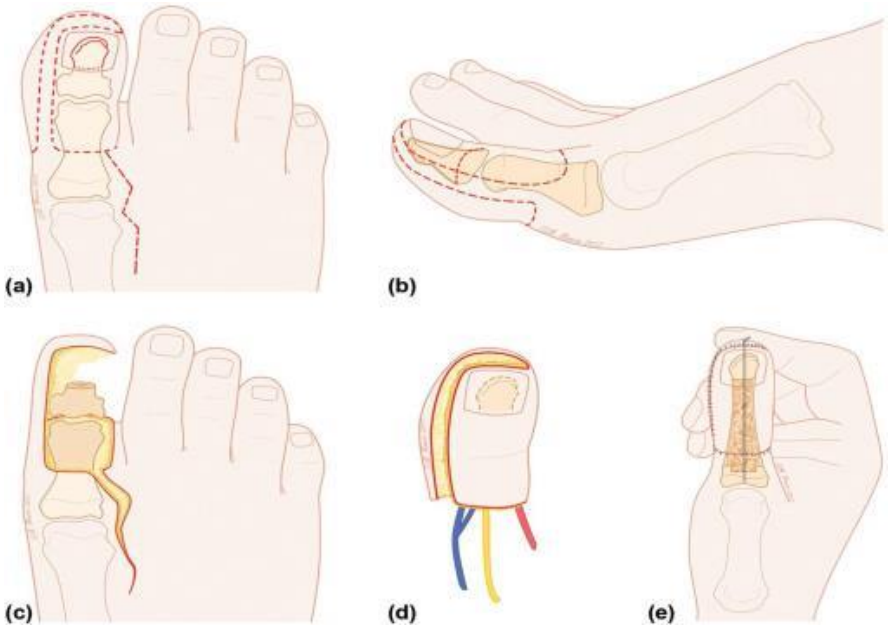

Figure (12): Great toe to thumb free flap **(Sang Hyun Woo, 2017).**

Second toe–to-thumb transfer remains a cornerstone of functional thumb reconstruction in suitably selected patients. Its evolution, including refined fixation methods and aesthetic planning, illustrates ongoing efforts to optimize both functional and cosmetic outcomes. The procedure involves harvest of the second toe

with its neurovascular bundle, tendons, and bone, followed by microsurgical anastomosis to vessels and nerves in the hand. It provides more refined appearance, less donor morbidity; indicated for distal or mid-level loss, **(Fig.13) (Ghosh et al., 2024).**

Figure (13): Second toe to thumb transfer **(Chung, 2013).**

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