Salvage of a Thumb Replant Using a Bilobed Dorsal Metacarpal Artery Island Flap: Case Report and Literature Review

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Abstract Amputations and degloving injuries of the hand are highly disabling, especially when they affect the thumb. Dorsal metacarpal artery (DMCA)-based flaps have been well-documented in the literature for use in extensive degloving injuries of both dorsal and palmar aspects of the thumb surface. Modifications on these flaps, such as the bilobed island flap, offer additional advantages when larger surface areas or more distal defects of the thumb are present. We present a review of the literature on the DMCA flap and describe its use to salvage a partial survival of a thumb amputation through the metacarpophalangeal joint.

Keywords Thumb amputation · Replant ·
Dorsal metacarpal artery flap · Salvage

Introduction

The thumb is essential to preserve pinch and grasp capacity. The ability to perform fine finger manipulation and power grip enables the execution of a wide variety of complex maneuvers ranging from the everyday routine to vocational activities and the performing arts. Complete or partial loss of the thumb results in significant permanent disability. Even the loss of sensation is disabling enough to affect hand function. Because of its relatively exposed position with respect to the other digits, the thumb is often prone to

injury, and when permanently injured can reduce dominant hand function by up to 40% [9].

Whereas initial success with digital replantation and revascularization procedures had a high failure rate, the current series for thumb replantation report successful results from 71% to 91% with sharp injuries nearing 100% [1, 12, 19]. However, in the face of severe crush injury, multisystem trauma, prolonged delay from time of injury, or unavailability of the amputated part, a microvascular repair may not be feasible and the use of alternative salvage techniques for the preservation of hand function becomes necessary [1, 18].

Distal tip amputations can be treated with primary closure or skin graft from the amputated piece as long as there is no bone or tendon exposed. For more extensive or proximal amputations with exposure of the deeper structures, various local flaps, regional flaps, and free tissue transfers have been developed. The sensate island flap, first described by Littler [14], was initially developed to restore pinch sensation, but was later expanded to include a larger skin paddle for resurfacing small defects of the thumb. For larger areas such as circumferential degloving injuries, the DMCA flap has become very useful. Originally based on the first dorsal metacarpal artery (FDMA), a second dorsal metacarpal artery (SDMA) flap, a reversed FDMA flap, and a bipedicle flap have been described [2, 7, 13, 24, 25]. A unilobed or a bilobed skin paddle is taken from the dorsum of the index and/or middle finger with dorsal cutaneous branches of the radial nerve providing sensation. In our patient, we used a bilobed DMCA flap that preserved both the first and second metacarpal artery to salvage a replanted thumb after partial survival of a complete amputation through the metacarpophalangeal (MCP) joint. A literature review on the use of DMCA flaps as a salvage technique for thumb replantation is discussed.

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Case Report

IB is a 55-year-old and right-hand-dominant man who sustained a complete amputation of his left thumb at the level of the MCP joint with a circular saw. He was taken to the nearest hospital before being transferred to our institution for replantation. His past medical and surgical history was remarkable for a 40-year 1.5-pack per day smoking history and Crohn's disease. He had been in remission for over 10 years, but had received treatment with prolonged steroids in the past for the Crohn's disease.

The patient arrived with the amputated thumb properly preserved. He had no other injuries and was taken immediately to the operating room for an uneventful replantation of his thumb and fusion of the MCP joint. Intraoperatively, the ulnar digital artery, which was the dominant vessel, measured approximately 0.8 to 0.9 mm in diameter. Six to seven 9-0 nylon interrupted sutures were placed across the vessel. The artery was unclamped to locate an appropriate dorsal vein. A single vein was found measuring between 0.4 and 0.5 mm in diameter; the vessel was repaired with four 10-0 nylon interrupted sutures.

Postoperatively, leech therapy was immediately initiated because of concerns with outflow, as the largest dorsal vein was half the diameter of the ulnar digital artery. The patient was also treated with aspirin (325 mg daily) to reduce platelet adhesion as per our institutional protocol. Leech therapy was discontinued 5 days postoperatively, and the patient was discharged home on the eighth postoperative day with a viable replanted thumb and with instructions to continue the aspirin. He was also given instructions for smoking cessation and for maintaining arm elevation until his outpatient follow-up. Two days after his discharge, IB returned to the emergency department with what appeared to be complete necrosis of the replanted digit.

IB was taken back to the operating room for debridement. The distal phalanx and its skin and subcutaneous tissue covering were completely necrotic. An amputation at the level of the interphalangeal (IP) joint was performed that included removal of the cartilaginous cap overlying the proximal phalanx. The skin and superficial portion of the soft tissue over the proximal phalanx was also necrotic and was thus debrided. However, the bone and some of the soft tissue on the volar aspect appeared viable and was retained. A bilobed neurovascular island flap based on the first and second dorsal metacarpal artery (Fig. 1) was then used to resurface the proximal phalangeal stump using the technique adapted from Yao et al. [25].

The flap was elevated from distal to proximal, taking care to preserve both neurovascular bundles (Fig. 2). The skin islands were harvested from the dorsum of the index and middle fingers, distally at the level of the proximal interphalangeal (PIP) joints and proximally at the MCP

Figure 1 Preoperative markings of the bilobe flap are shown. Three points are identified: 1 the radial styloid process, 2 the radial side of the second metacarpal head, and 3 a point between the heads of the first and second metacarpal heads. These three points form a triangle within which the FDMA and the SDMA run longitudinally. A lazy S incision is used to expose the pedicles. The skin paddle is designed over the distal one third of the metacarpal area up to a few millimeters proximal to the proximal interphalangeal joint level.

joint. A lazy S-shaped incision was made on the dorsum of the second metacarpal between the two long lines of the triangle defined earlier to expose the neurovascular pedicle. Upon reaching the MCP joint, the ulnar branch of the FDMA divides into a number of small vessels. These feed into a rich subdermal plexus supplying the skin overlying the dorsum of the proximal phalanx that will eventually become the skin islands for the bilobed flap. The SDMA usually runs in an oblique line between the anatomical snuff box and the second web space and serves as an additional blood supply. After the bilobed flap was elevated, the flap was tunneled through the first web space dorsally to reach the left thumb defect. (Fig. 3a and b) The donor site was then covered with a full-thickness skin graft taken from the thigh.

Results

The patient recovered well with a durable sensate flap covering the left residual thumb (Fig. 4). We proposed a first web space deepening procedure to improve grasp, however, the patient wanted to wait, citing his ability to perform most activities of daily living, such as satisfactorily gripping a comb or steering wheel. The patient continued to

Figure 2 The bilobed flap is raised on the first and second dorsal metacarpal artery and its venae comitantes. The dorsal cutaneous branches of the radial nerve provide sensation.

perceive sensation as originating from the dorsum of the left index finger despite sensory reeducation. Unfortunately, we could not obtain quantitative measures of grasp and pinch function as the patient was lost to follow-up.

Discussion

We believe that there were multifactorial contributors to our patient's failed thumb replant. The patient continued to smoke postoperatively, which likely caused arterial vasospasm. In addition, noncompliance with the prescribed arm

elevation in the face of a relatively small-caliber draining vein may have resulted in venous congestion. In the light of his long-standing history of peripheral vascular disease and noncompliance, alternate means of salvage had to be devised as he was not the ideal candidate for microvascular reconstruction.

Various reconstructive options exist for avulsion or degloving injury of the thumb. Local advancement flaps such as the Moberg flap or Atasoy flap exhibit limited range of mobility and as such are used only to cover small surface defects of the palmar tip [8]. The wraparound partial toe transfer technique, introduced by Morrison et al. [17], can cover a larger surface area, but is cumbersome to perform, requires creation of a small vessel anastomosis, and exhibits significant donor site morbidity. Littler's neurovascular island flap provides sensation for key pinch, but is limited in size as a technique for resurfacing the thumb [8, 18]. In addition, cold intolerance to the donor site is a major disadvantage. Gaul [10, 11] described a radially innervated cross-finger transposition flap. This technique, however, requires a staged approach and a considerable period of immobilization with subsequent risk of joint stiffness [18].

FDMA-based island flaps harvested from the dorsum of the proximal phalanx of the index finger, initially described by Colema in 1961 and Holevich in 1963, was modified by Foucher and Braun to include neural structures and renamed the "kite" flap [7, 24]. Since then, dorsal artery skin flaps based only on the SDMA have been reported [2, 13, 25]. In an extensive thumb defect, however, where circumferential length can reach 6 cm, a traditional single-digit DMCA flap may be inadequate thus necessitating the utilization of a bilobed flap.

Figure 3 a and b The bilobed DMCA flap is inset and a full-thickness skin graft placed on the donor site.

Figure 4 **a** Radiograph of the left hand demonstrating the amputated thumb at the MCP joint. **b** Radiograph of the same hand at 4 weeks after the DMCA flap coverage—note the salvaged proximal phalanx (**c, d**) The left hand at 9 months after DMCA flap coverage illustrating the patient's hand in a gripping position.

The idea of using a bilobed skin flap from the dorsum of the index and middle fingers was originated by Smith and Harrison [22]. They described a “seagull” flap that was based on a single pedicle and applied to the repair of syndactyly. Yao et al. [25] have since described a modification of this technique that includes both the FDMA and SDMA in the pedicle and incorporates more dorsal skin from the proximal phalanges. The FDMA and the SDMA run longitudinally within a triangular space between the radial styloid process, the radial side of the second metacarpal head, and a point between the first and second metacarpal heads (Fig. 1). The FDMA arises from the radial artery just distal to the tendon of the extensor pollicis longus and gives rise to the ulnar branch, which runs over the fascial layer of the radial

head of the first interosseous muscle in the musculo-osseous groove to supply the index finger [5, 20].

The presence of a second arterial supply can be beneficial in supporting viability and sensation in the bilobed flap. Of course, there are cases when the SDMA is too small or is injured during elevation. In Yao’s case series, the SDMA was injured in three patients and the bilobed flap survived on the FDMA alone. Karacalar et al. described two cases where a similar bilobed flap survived solely on the SDMA [13]. These experiences support the idea that a flap can survive provided its width is no greater than 80–100 times the diameter of its supplying artery [23].

FDMA-based flaps of the dorsal index finger can reach a length of up to 7 cm, giving it a wide enough arc of rotation to cover both proximal and distal pulp defects of the thumb.

Chang et al. [2] used FDMA-based dorsal skin from the index finger to resurface extensive pulp defects of the thumb in eight patients. Very few reports address SDMA flap coverage of distal thumbs. Earley was the first to report the use of the SDMA flap and applied it toward the reconstruction of first web space defects [6]. Subsequently, Small and Brennen reported that the SDMA flap's main difficulty in reaching the thumb tip was because of limitations by the extensor tendons of the index finger [21]. To bypass this hurdle, Karacalar et al. [13] took advantage of the interconnection between the SDMA and the palmar arch as described by Maruyama [15] to design a reverse flap with a wider rotational arc capable of reaching the distal thumb. Their dorsal index finger flap was based on the SDMA and contained two pivot points. The proximal pivot corresponded to the origin of the SDMA just distal to the wrist crease, and the distal pivot corresponded to the entry point of the recurrent cutaneous branch of the SDMA into the skin paddle just proximal to the MCP joint. Similarly, we encountered no difficulty in resurfacing the amputated proximal phalanx of the thumb with the bilobed flap based on Yao et al. [25]. In spite of its range, difficulty in resurfacing distal thumb defects using the DMCA flap has been reported in a few cases when the thumb was exceptionally long [8].

Moberg [16] expanded on the work of Erik Weber and suggested that, for useful tactile gnosis, static two-point discrimination (2PD) should be less than 6 mm. Dellon and Mackinnon later noted that moving 2PD correlated more closely with hand functionality as it accounted for quickly adapting A-fibers [3, 4]. Williams et al. [24] investigated retained moving 2PD in ten patients, eight of whom had FDMA and two that had SDMA-based flaps. They noted that comparable 2PD between flap and corresponding donor site on the normal hand was an all or nothing phenomenon. Of those with functional sensation, six had moving 2PD values less than or equal to 5 mm and one exhibited a moving 2PD less than 9 mm. It is interesting to note that when hand function was assessed using Moberg's pick-up test, all patients, when blindfolded, demonstrated a statistically significant increase in time to task completion using the operated hand versus the nonoperated hand.

In their series of 11 patients treated with the bilobed dorsal finger flap, Yao et al. [25] reported retained sensation in all patients with a mean 2PD of 11.2 mm. However, even with sensory training, only two patients were able to perceive sensation as originating from the thumb. Ege et al. [7] used the FDMA flap from the dorsum of the index finger in 21 cases and found a mean 2PD of 10.8 mm. All but one of the patients in their series was able to use the operated hand in daily activities although reported grip strength was 15% less than in the unaffected hand. Chang et al. [2] studied the use of the FDMA flap to reconstruct

pulp defects of the thumb. Static 2PD ranged from 6–14 mm and all patients continued to perceive flap sensation as originating from the dorsum of the index finger. Most of their patients adapted well, however, and exhibited functional tactile gnosis within 4–8 months of surgery.

The absence of sensation in some flaps may be attributed to technical factors such as traction or compression of the pedicle and ischemia or progressive fibrosis of the terminal nerve branches [8, 24]. For this reason, incorporation of a generous amount of subcutaneous tissue around the pedicle is advocated as a means to preserve sensory fibers. The paired venae comitantes are usually sufficient for venous drainage; however, if necessary, a dorsal vein may be anastomosed to a recipient vein in cases of severe congestion. A criticism of the DMCA flap is the use of dorsal skin for a glabrous surface; however, with persistent use, the dorsal skin begins to resemble the volar skin over time.

A bilobed island flap based on the DMCA is a feasible alternative when larger surface areas or more distal defects of the thumb are present. Functional sensibility is variable in most studies and, when retained, is generally perceived from the donor site. Through cortical reintegration, however, many patients are able to adjust and derive satisfactory utility from the repaired thumb. In conclusion, the bilobed DMCA flap is a relatively facile, single-stage procedure that can be applied toward resurfacing extensive thumb surface defects. This is especially useful in patients that are not candidates for microvascular procedures.

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