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Littler's flap revisited: An anatomic study, literature review, and clinical experience in the reconstruction of large thumb-pulp defects

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A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Summary

Background: An anatomic study and the authors' clinical experience with 15 flaps used for resurfacing sizable thumb defects are presented.

Material/Methods: Sixteen upper extremities from fresh cadavers were dissected to delineate the anatomy, vascular pattern, and reconstructive potential of the heterodigital island flap. Fifteen heterodigital island flaps were also performed between 1996 and 2004 in 15 patients (mean age: 41.2 years) suffering from a major trauma of the thumb. Flap and donor site skin quality, scar contractures, finger mobility expressed in terms of total active movement, sensibility evaluated by two-point discrimination and the Semmes-Weinstein (SW) monofilament tests, cold intolerance, double-sensibility phenomenon, and cosmetic results were assessed. All patients were reviewed over a postoperative follow-up period of 10–18 months.

Results: Good coverage with well-vascularized skin was obtained and donor-finger full-thickness skin grafting was successful in all cases. All flaps survived completely. Mild cold intolerance was seen in all donor fingers, but no flap had hyperesthesia 10 months postoperatively. Total active range of motion was rated as good or excellent in all patients for both the donor finger and the thumb. Sensation in the donor finger was reported as "slightly altered" and the double-sensibility phenomenon was present in all patients.

Conclusions: The heterodigital arterialized flap is a single-stage, thin, fairly mobile flap that produces an excellent cosmetic result, restores sensibility, and enables early mobilization of the hand. Morbidity in the donor finger is within acceptable limits and its usefulness in the reconstruction of thumb pulp defects is well documented.

key words: **Littler's flap • thumb • reconstruction**

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Background

The anatomy of the hand allows covering small skin defects with a great variety of local pedicle and island flaps. Extensive loss of the thumb pulp with or without bone exposure is a major problem for the patient and remains a challenge for hand surgery. Deep skin defects usually involve cosmetic and functional aspects. Surgical possibilities include regional, distant, and local flaps. Although there are many surgical procedures for the management of these severe injuries, a difficult surgical technique is often required and the functional or cosmetic results can be unsatisfactory. Use of the ipsilateral upper limb as a donor site has many advantages [1]. Both the donor and recipient sites are located within the same operative field, permitting the entire surgical procedure to be performed with the patient under a single regional block anesthesia, both flap and recipient sites being prepared synchronously in a bloodless field. In addition, donor site morbidity is restricted to a single extremity. Techniques such as the Moberg advancement flap [2] and the cross-finger flap [3] may require two-stage surgical procedures and have an increased rate of complications, such as joint stiffness, poor recovery of sensibility, or an unacceptable aesthetic outcome.

This article reviews the use of the neurovascular island flap, which was suggested by Moberg [4] and developed by Littler [5,6] and Tubiana and Duparc [7,8]. We present an anatomic study performed with the use of eight fresh cadavers (sixteen upper limbs) as well as our clinical experience with 15 flaps used for the resurfacing of sizable defects of the thumb. These are supported by a wide review of the relevant literature.

Material and Methods

Anatomic study and surgical technique

Cadaver management and preparation: Sixteen fresh cadaver upper extremities were dissected to delineate the anatomy, vascular pattern, and reconstructive potential of the flaps. Each subclavian artery was irrigated with 20 cc normal saline followed by injection with a silicone rubber compound (Microfil, Flow Tech Inc.) to enable determination of all vascular branches of each upper extremity. Microfil compounds fill and opacify microvascular and other spaces of non-surviving animals and post-mortem tissue under physiological injection pressure. Following injection, Microfil compounds cure to form a three-dimensional cast of the vasculature. Microfil compounds are available in five radiopaque colors as well as a clear version. The MV-series compounds require either an alcohol-methyl salicylate or glycerin clearing sequence, whereby the refractive index of the clearing solution is the same as that of the tissue. This allows for microscopic examination of a selected vascular bed.

The flap was usually lifted from the ulnar aspect of the middle finger, the radial side of the ring finger being a second option (Figure 1). Its distal point could be carried out up to the tip of the middle finger on to the radial aspect. A zigzag incision was performed from the distal margin of the flexor retinaculum in the palm to the finger web. The pedicle in the finger as far proximal as the bifurcation of the common digital artery was raised as a monobloc of fatty tissue. In the side of the finger, the palmar skin was raised off the subcutaneous tissue and this tissue was incised down to the tendon sheath until the skeleton. Blunt dissection separated the bloc from the bone and a vessel rubber loop was passed around it. Gentle traction displayed the nerve and vessel branches to the flexor tendons and joints which were divided. The branch of the common digital artery to the ring finger was ligated. The proper digital nerves of the third web space were separated from each other in a way to preserve their dorsal digital branches. This dissection advanced as far proximal as the superficial palmar arch. The tunnel to the defect was formed in the subcutaneous plane superficial to the palmar fascia, which was sometimes divided transversely. A Penrose drain was passed from the palmar wound to the defect and a hemostat was passed through it, emerging at its ulnar end.

A 4-0 nylon stay suture was placed through the tip of the island flap, which was then raised from its bed with a scalpel. The flap was carefully introduced in the drain and pulled out of the tunnel by applying traction on the suture. The drain was then discarded, as the flap was in place. The flap was secured with a stitch, the thumb was fully abducted and extended, and the pedicle was checked for any evidence of tension or kinking. After this test, the flap was sutured into position, prior to release of the tourniquet. A full-thickness graft was harvested for the secondary defect.

Case series

Between 1996 and 2004, 15 heterodigital island flaps were performed in 15 patients with a major trauma of the thumb. The average age was 41.2 years (range: 19–64 years). There were 9 men and 6 women. All the operations were performed by the same surgeon. In all cases the flap was used as a neurovascular flap for resurfacing pulp defects of the thumb.

All the defects were attributable to trauma except one, which was due to a neglected tendon sheath infection of the flexor pollicis longus resulting in loss of the tendon and the pulp with exposure of the bone (Figure 2). One third of the patients were severely injured, with multiple tissue involvement. Besides having soft-tissue defects, these patients had concomitant damage to joints, tendons, and/or ligaments.

Before surgery, the blood flow to the middle and ring fingers was always assessed by Doppler to ensure that both digital arteries were supplying both fingers adequately. Surgery was performed under tourniquet control, which was inflated with the arm elevated, but not completely exsanguinated. The donor finger was the middle finger in all cases. The flap was raised from the ulnar side of the middle finger (donor) with the nerve and the artery and was transferred to the recipient thumb via a subcutaneous tunnel to the palm to avoid another scar to the base of the reconstructed finger (Figures 3,4).

In all but one case, thumb resurfacing was performed within one week. The exception was the post-infection case that ended with an almost complete loss of the pulp and the FPL itself as well as septic arthritis of the interphalangeal joint. This was treated one month after the infection had commenced. The defect was covered and the joint was fused.

Figure 1. Heterodigital island flap designed to resurface a volar defect on the thumb in a cadaveric hand. The flap has been lifted from the radial side of the ring finger.

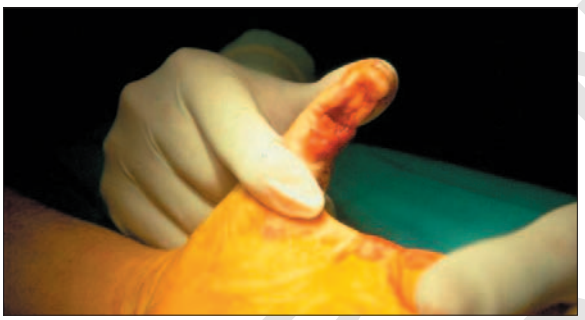

Figure 2. A 3.8×1.8 cm defect on the volar surface of the thumb after tendon sheath infection treated suboptimally. FPL is missing, bone is exposed, IP joint is destroyed.

Figure 3. The design of a 4×2 cm flap from the ulnar side of the adjacent middle finger.

Figure 4. The hand one week postoperatively showing the flap on the volar side of the thumb. Arthrodesis of the IP joint was done due to joint destruction.

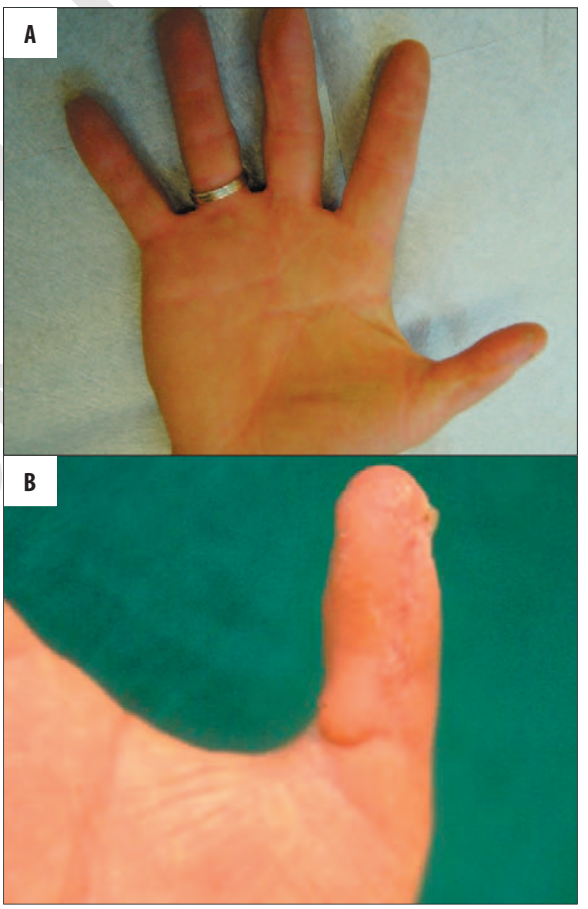

Figure 5AB. The thumb flap and the full-thickness skin graft on the middle finger three months postoperatively. Excellent cosmetic result which enables early mobilization.

The average flap dimensions were 3.4 cm in the longitudinal axis (range: 1.9–4.6 cm) and 1.9 cm in the transverse axis (range: 0.9–2.5 cm). Rehabilitation commenced on the second postoperative day, but can be delayed if circumstances dictate. Active range-of-motion exercises were instituted for both the recipient and donor digits. Therapy was intensified after removal of the full-thickness skin-graft tie-over one week later.

Postoperatively, all patients were reviewed at regular intervals, the total follow-up period being between 10 and 18 months (average follow-up period: 14.4 months). The

Table 1. Results of the parameters assessed.

A/a	Age years	Sex	Thumb (TAM) sum degrees	Donor (TAM) sum degrees	Donor 2Pd mm	Thumb 2Pd mm	SW test	Cosmetic	F-U months
1	32	M	110	260	13	6	1	EXCEL	15
2	19	M	140	270	12	9	2	EXCEL	18
3	56	M	115	250	12	9	1	GOOD	18
4	43	F	150	210	7	8	2	GOOD	16
5	24	M	150	255	6	6	2	EXCEL	18
6	64	F	110	205	7	7	2	GOOD	10
7	38	F	115	260	6	8	1	EXCEL	12
8*	42	M	–	270	7	6	1	GOOD	14
9	27	M	140	270	7	6	2	GOOD	13
10	55	F	150	190	9	7	2	GOOD	15
11	61	M	105	255	12	7	2	GOOD	10
12	39	F	110	270	8	9	1	EXCEL	18
13	34	M	150	200	9	7	1	EXCEL	14
14	58	M	150	210	10	8	2	GOOD	13
15	26	F	150	255	11	7	2	GOOD	12
AVE	41.2	–	131.7	242.6	9.06	7.33	–	–	14.4

TAM – total active motion (MCP+PIP+DIP-extension deficit); 2PD – two-point discrimination; SW – Semmes-Weinstein monofilament test (1: normal sensation, 2: diminished light touch sensation); * IP joint arthrodesis.

following parameters were assessed: flap and donor site skin quality, scar contractures, finger mobility expressed in terms of total active movement (TAM) of the MP and IP joints of the involved fingers compared with the normal hand, sensibility evaluated by the two-point discrimination (2PD) test and the Semmes-Weinstein (SW) monofilament test, cold intolerance, presence of Tinel's sign in the palm as an indication of pedicle compression, the double-sensibility phenomenon, and the examiner's subjective opinion of the cosmetic results, graded as "excellent", "good", "fair", or "poor".

Results

Good coverage with supple and well-vascularized skin was obtained in each patient. Donor-finger full-thickness skin grafting was successful in all cases. No major scar contractures were recorded in any patient (Figure 5A,B). Despite the large size of many of the flaps, early postoperative flap congestion rarely occurred in our series. All flaps survived completely. Mild cold intolerance was seen in all donor fingers. None of the hands developed reflex sympathetic dystrophy and none of them had hyperesthesia by the tenth postoperative month. A positive Tinel's sign was noticed in the palm in six of the cases.

Donor-finger morbidity was assessed in all patients. Total active range of motion for the donor finger assessed according to the grading system recommended by the American Society for Surgery of the Hand [9] for flexor tendon result was rated as excellent in 70% (10 cases) and good in 30% (5 cases) of the patients. The average total active range of motion of the 15 donor fingers was 242.6 degrees (normal maximum: 280 degrees). Nine thumbs (60%) were graded as excellent and six (40%) as good. The average total active range of motion for the reconstructed thumbs was 131.7 degrees (normal maximum: 155 degrees). One thumb was not counted because of IP joint arthrodesis. Sensation in the donor finger was reported as "slightly altered", with two-point discrimination of 6–13 mm. The average two-point discrimination of all 15 donor fingers and reconstructed thumbs was 9.06 mm and 7.33 mm, respectively. By the SW test, six patients were shown to have normal sensation, nine patients had diminished light touch sensation, and no patient had diminished protective sensation. The double-sensibility phenomenon was present in all patients. The results are summarized in Table 1.

Discussion

The use of island flaps from the finger began with the neurovascular flap and its developments. These flaps are suitable for resurfacing distal digital pulp defects, where obtaining sensation is critical or when we are dealing with irreparable damage to the nerves of the finger [10]. Although, these

flaps were revolutionary in finger reconstruction, they have many limitations. Direct homodigital neurovascular island flaps can cover limited defects. In the heterodigital reverse-flow neurovascular island flap (midpalmar or dorsolateral from the middle phalanx), the common digital artery of the second space is sacrificed, with a subsequent decrease in arterial flow. The free flaps are not an easy option, either, because the recipient vessels may be unhealthy due to surrounding infection or trauma.

Despite the fact that the Littler neurovascular island is fraught with many problems, it is suitable for large finger defects where return of sensation is critical, such as injuries to the thumb's pulp. The flap can be extended to include the entire half of the digital skin, as rationalized by Hueston [11], and not only the half pulp as initially introduced. The middle finger was his proposal, where a flap measuring 6 cm × 3 cm is possible. Of course, donor-finger morbidity was high because half of the sensate finger pulp was lost, in addition to the cosmetic morbidity with the loss of contour of the fingertip.

Hyperpigmentation, contour deformity, and joint stiffness were cited by Paterson et al. [12] as other aspects of donor-finger morbidity. In all our cases, a full-thickness skin graft with a meticulous tie-over gave a satisfactory contour to the donor finger and minimized scarring and contracture. This also enables early postoperative mobilization and prevents the development of finger stiffness. Contrary to the previous report, there was minimal morbidity of our donor fingers with full-thickness skin grafting. This could be because of earlier and better rehabilitation. The donor-finger range of motion was excellent or good in all of our cases.

The average donor-digit two-point discrimination result in our series was 9.06 mm, outside the normal range, which can be explained by the dissection of the digital nerve of its bed. Dissection of the digital artery with the digital nerve is performed meticulously and under loupe magnification. These results disagree with those of Rose's series [13,14]. The average static two-point discrimination of the donor finger in his series was 4.3 mm, but he preserved the nerve in its bed.

The timing of the reconstruction is dependent on the abnormality. For traumatic conditions, resurfacing is usually performed within one week, as in our series. For amputation or ring avulsion injuries, where microvascular anastomoses are performed, resurfacing should be performed between 10 and 15 days, when re-endothelialization of the anastomosis is complete [15]. There was only one delayed reconstruction in our series in the post-infection case and that because of delayed referral of the patient. He was treated one month after the infection had commenced, the defect was covered, and the joint was fused.

Flap venous congestion is a commonly reported problem [16–19]. Moss et al. [20] conducted studies on the venous anatomy of the digit and found that its venous drainage consists of dorsal and palmar systems. The dorsal system consists of a series of arches, one over each phalanx. These arches are connected to each other by longitudinal veins. The palmar system is subdivided into a superficial and a deep system. The dorsal and palmar systems are connected by oblique communicating veins. The level of the metacarpal heads is the point at which most of the palmar venous blood joins the dorsal system by intercapitular veins. They also found a system of valves, present in all veins as far distal as the pulp, which were arranged so as to direct the flow from distal to proximal, from palmar to dorsal, and from radial to ulnar in the hand.

In Rose's series [13,14], all of his flaps suffered early postoperative venous congestion, but eventually survived. This could have been because of the dissection of the digital artery and its venae comitantes from the digital nerve. Because of the proximity of all the structures in the finger and the delicacy of the venae comitantes, even with loupe magnification and meticulous technique some damage inevitably occurs to the venae comitantes during the above dissection. Only two of the 15 flaps in our series experienced early postoperative venous congestion.

The results in sensory reconstruction have not been perfect for the neurovascular island flap [21–26]. Most of the neurovascular island flap's problems can be attributed to the digital nerve. Many articles have reported progressive deterioration of sensibility, "double-sensibility," cold intolerance, hyperesthesia, and other problems, especially with the conventional island flap. This is probably related to unsatisfactory cortical reorientation following flap transfer.

Many authors have attempted various modifications, but without much success. In an effort to minimize these side effects [25–28], digital nerve division and coaptation to the thumb (ulnar) digital nerve and free pulp transfer are proposed as alternatives. Nevertheless, both fail to restore sensation as completely as the pedicled neurovascular flap. Adani et al. [25] state that the nerve reconnection technique solves the "double sensibility" phenomenon (41.1% in the original technique), but two-point discrimination is less than that achieved by the Littler technique.

Rose [13,14] modified the Littler neurovascular island flap to include only the digital artery and venae comitantes at its pedicle, preserving the digital nerve in the donor digit. Microsurgical separation of the digital artery from the digital nerve minimized sensory loss of the donor digit and cortical reeducation at the recipient site was unnecessary. The heterodigital arterialized flap as proposed by Rose minimized donor-finger morbidity in terms of function and cosmesis. The donor finger retained a cosmetic fingertip and a functional sensate pulp. This flap can obviously be very useful for other digits, but not equally for the thumb, where restoration of sensibility is of paramount importance.

The results of the donor and reconstructed fingers regarding range of motion showed that all patients achieved excellent or good results. This is based on the American Society for Surgery of the Hand [9] criteria for flexor tendon result according to the percentage of return of motion at the metacarpophalangeal and proximal and distal interphalangeal joints. Many of these recipient fingers did not have good range of motion to begin with, as one third of the patients were severely injured, with multiple tissue involvement as mentioned above. All of the flaps

healed primarily without necrosis or ischemia to provide supple skin coverage to the hand.

Conclusions

Attention has recently returned to the classic Littler's flap for correction of thumb tip defects [29]. This article was devoted to an update on the heterodigital arterialized flap and illustrates its reconstructive potential, but also its handicaps. We have studied and applied this flap for more than ten years. It is a single-stage, heterodigital, pedicled flap that is thin, fairly mobile, sensate, and hemodynamically stable. Coverage by this thin flap produces an excellent cosmetic result and enables early mobilization of the hand. Morbidity in the donor finger is within acceptable limits. Aside from the technical expertise of the surgeon, the indication depends on the size and the location of substance loss. It can be used to resurface defects in the hand when other flaps are not indicated or when their drawbacks preclude their use. The double-sensibility phenomenon has been a constant problem in our series, but two-point discrimination was satisfactory. In our opinion the original Littler's flap, if properly done, is superior to its modifications and has proved to be an extremely valuable tool for the reconstruction of thumb pulp defects.

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