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Reverse Radial Forearm Flap to Provide Arterial Inflow to a Toe Transfer

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Abstract

Background: Toe-to-thumb transfer has become the gold standard for thumb reconstruction, but in badly mutilated hands, additional soft tissue coverage may be required or a suitable recipient artery may not be available. There are only 3 case reports describing the successful use of a reverse radial forearm flap for coverage of a soft tissue defect around the thumb as well as providing arterial inflow for a toe transfer, performed either simultaneously or secondarily. **Methods:** A single surgeon's experience of all toe-to-hand transfers performed in conjunction with a reverse radial forearm flap between 1995 and 2014 was reviewed, including patient demographics, type of toe transfer and vascular pedicle, whether immediate or secondary, follow-up, and complications. **Results:** Eight toe-to-hand transfers were performed in 7 patients—3 children (age range, 3-15 years) and 4 adults (age range, 19-39 years). Three patients underwent primary toe-to-thumb transfer simultaneously with a reverse radial forearm flap, and 5 patients underwent secondary toe-to-hand transfer between 4 months and 2½ years after an initial reverse radial forearm flap. All toe transfers survived completely. Average follow-up was 5.1 years. All patients were satisfied with the function and appearance of their reconstructed thumb. **Conclusion:** The reverse radial forearm flap is a very reliable procedure as a "Sister" or "Siamese" flap to provide immediate arterial inflow to a simultaneous toe-to-thumb transfer, or to provide primary soft tissue coverage on the radial aspect of the hand and subsequently provide a recipient arterial inflow for a secondary toe transfer.

Keywords: toe-to-hand transfer, reverse radial forearm flap, "Siamese" flap, "Sister" flap, toe transfer

Introduction

The radial forearm flap has been widely used as a pedicled or free flap for reconstruction of the hand and upper extremity.[4] We have already reported a series of reverse radial forearm flaps for coverage of palmar and dorsal defects of the hand and wrist.[6] The majority of reverse radial forearm flaps have been performed for immediate or delayed reconstruction after trauma, burns, infection, or tumor resection, but the flap is indicated after release of thumb–index finger web space contractures and for coverage of an unreplantable amputated thumb. Furthermore, a reverse radial forearm flap can be used to provide a recipient arterial pedicle as well as soft tissue coverage of the metatarsal bone of a toe transfer. Mahoney and Naiberg first reported a successful toe-to-thumb transfer into a reverse radial forearm flap.[10] However, Culp et al reported difficulties associated with a secondary toe-to-thumb transfer after an initial reverse radial forearm flap reconstruction.[3]

When considering a toe-to-thumb transfer in a badly mutilated hand, several problems may be encountered, such as absence of a suitable recipient artery, an associated soft tissue defect around the radial aspect of the hand and wrist, or a secondary first web space contracture. In such situations, a reverse radial forearm flap may become an option to facilitate a toe transfer. We describe 8 cases of a reverse radial forearm flap used to provide arterial inflow into a toe-to-hand transfer, which, to our knowledge, is the only series describing this procedure in both adults and children.

Methods

Seven patients, 5 males and 2 females, ranging in age from 3 to 39 years, underwent 8 toe transfers utilizing an anastomosis of either the dorsalis pedis—first dorsal metatarsal artery system (5)—or the first plantar metatarsal artery (2) to the proximal stump of the radial artery of a reverse radial forearm flap. Four patients were adults (age range, 19-39

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Table 1. Patient Demographics.

Patient	Gender	Age	Reconstruction type	Reconstructed digit	Donor site	Anastomosis	Follow-up, y
1	Male	31	Immediate	L thumb	R 2nd toe	FDMA–dorsalis pedis ETE → radial artery	1
2	Female	10	Immediate	R thumb	L 2nd toe	FPMA ETE → radial artery	9
3	Male	3	Immediate	R thumb	L 2nd toe	FPMA ETE → radial artery	14
3	Male	3	Secondary	R small finger	R 2nd toe	FDMA–dorsalis pedis ETS → radial artery	14
4	Female	15	Secondary	L thumb	R 2nd toe	FDMA–dorsalis pedis ETE → radial artery	6
5	Male	19	Secondary	R thumb	R "trimmed" great toe	FDMA–dorsalis pedis ETE → radial artery	2
6	Male	38	Secondary (after distraction)	R thumb	R "trimmed" great toe	FDMA–dorsalis pedis ETE → radial artery	1
7	Male	39	Secondary (after distraction)	L thumb	L "trimmed" great toe	FDMA–dorsalis pedis ETE → radial artery	3
							Average: 5.1

Note. FPMA = first plantar metatarsal artery; ETE = end-to-end; FDMA = first dorsal metatarsal artery; ETS = end-to-side.

years) and 3 patients were children (age range, 3-15 years). Three patients underwent immediate second toe-to-thumb transfer simultaneously with the reverse radial forearm flap. Five patients underwent a secondary toe-to-hand transfer (4 toe-to-thumb transfers and 1 toe-to-small finger transfer) between 4 months and 2½ years after initial reverse radial forearm flap coverage. There were no technical differences between adults and children.

Secondary reconstruction of performing a toe transfer into an already performed reverse radial forearm flap is more difficult than a primary simultaneous reconstruction. However, preoperative angiograms of either the donor foot or the recipient hand were not performed. In secondary toe transfers, the radial artery in the reverse radial forearm flap was localized using a hand-held 8-mHz Doppler probe. The flap was elevated from the distal inset margin in the hand and the ligated stump of the radial artery identified in all 5 secondary cases. The tourniquet was then deflated and the radial artery was serially sectioned until there was a positive "spurt test" from the radial artery. Either the dorsalis pedis artery or the first plantar metatarsal artery was anastomosed to the proximal stump of the radial artery in the reverse radial forearm flap using standard microsurgical techniques. Seven of the anastomoses were end-to-end, but one was end-to-side (case 1). All the venous anastomoses were performed end-to-end to a dorsal vein, not to the vena comitans of the reverse radial forearm flap.

Five second toes and 3 "trimmed" great toes were transferred to reconstruct 4 dominant right thumbs, 3 left thumbs, and 1 small finger. Both second toe transfers and "trimmed" great toe transfers were harvested on the dorsalis pedis—first dorsal metatarsal artery pedicle in 6 cases—and 2 second toe immediate transfers were harvested on the first plantar metatarsal artery (Table 1).

Case 1: Immediate Reconstruction in a Child

A 3-year-10-month-old right-handed boy presented after traumatic amputation of all 5 digits of his right hand from an explosion 9 months previously (Figures 1 and 2). He had undergone debridement and primary wound closure with skin grafting in another hospital. It was decided to transfer the left second toe to reconstruct the right thumb and the right second toe to reconstruct an ulnar digit to provide pinch and grasp. However, dissection of the thumb stump failed to reveal any suitable recipient artery. Therefore, a reverse radial forearm flap was used to provide soft tissue coverage and the proximal stump of the radial artery within the flap provided arterial inflow for an immediate simultaneous second toe-to-thumb transfer (Figure 3). The first plantar metatarsal artery of the toe transfer was anastomosed end-to-end to the radial artery in the flap, and the saphenous vein was anastomosed end-to-end to a dorsal forearm vein. Split thickness skin graft was used to cover the radial forearm flap donor site. One week after the operation, he developed a superficial infection around the flap, which resolved with intravenous antibiotics for several days. Four months later, the right second toe was transferred to reconstruct an ulnar digit (Figure 4). The dorsalis pedis—first dorsal metatarsal artery of the right second toe transfer—was anastomosed end-to-side to the radial artery of the previously placed reverse radial forearm flap, because the superficial palmar arch and distal ulnar artery were not deemed suitable as a recipient artery. Fourteen years postoperatively, the patient is extremely satisfied with the result and has regained everyday function of his hand including picking up a paper clip, tying shoelaces, and holding a large object such as a cup (Figure 5). His Disabilities of the Arm, Shoulder and Hand (DASH) score is 35, and his Southampton Hand Assessment Procedure score is 81/100.

Figure 1. This 3-year-old boy sustained amputation of all 5 digits of his right hand due to an explosion.

Figure 2. Radiograph of the hand prior to reconstruction.

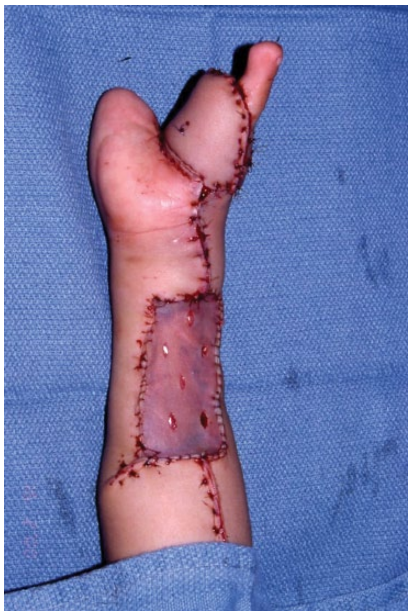

Figure 3. He underwent a reverse radial forearm flap to provide both soft tissue coverage and arterial inflow to a simultaneous left second toe-to-thumb transfer. The first plantar metatarsal artery was anastomosed end-to-end to the proximal stump of the radial artery within the reverse radial forearm flap.

Figure 4. Four months later, he underwent a right second toe transfer into the small finger position to create an opposable digit, with anastomosis of the first dorsal metatarsal artery end-to-side into the radial artery within the reverse radial forearm flap.

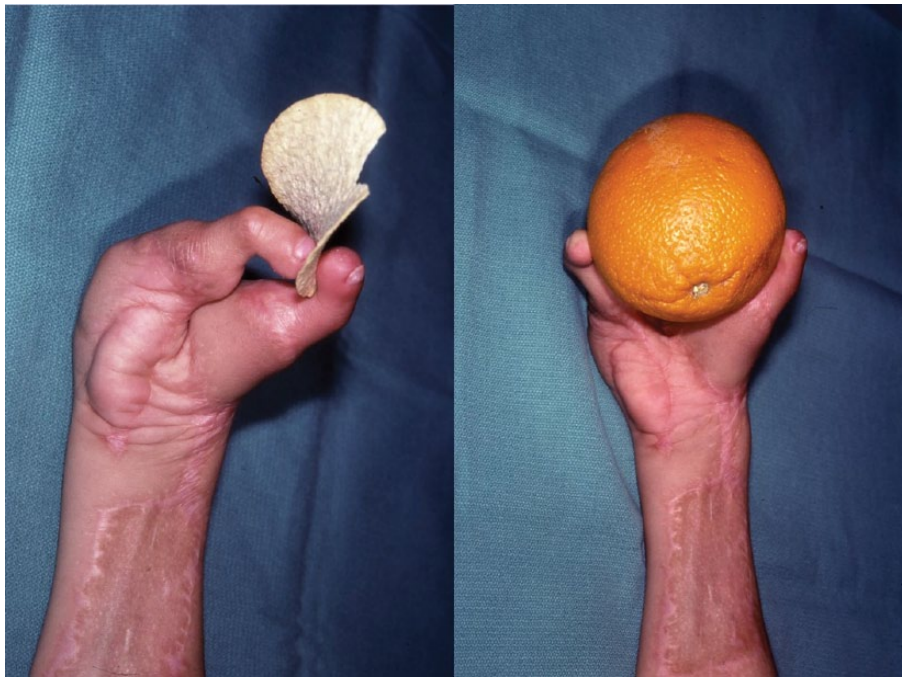

Figure 5. Fourteen years postoperatively, he has excellent pinch and grasp between the two second toe transfers.

Case 2: Secondary Reconstruction in an Adult

This 38-year-old right-handed man sustained an amputation of his right thumb through the metacarpophalangeal joint. Attempted replantation of the thumb unfortunately failed. He subsequently underwent coverage of the amputation stump with a reverse radial forearm flap, followed by distraction lengthening of the thumb metacarpal and a 4-flap Z-plasty of the thumb–index finger web space at another hospital (Figure 6). He was left with excruciating pain related to the palmar aspect of the head of the thumb metacarpal.

Examination revealed the right thumb metacarpal was held adducted with contracture of the thumb–index finger web space and radial subluxation of the base of the thumb metacarpal with respect to the trapezium. He was extremely hypersensitive over the palmar aspect of the head of the metacarpal due to neuromas of the radial and ulnar digital nerves of the amputated thumb.

Two and a half years following the amputation, he underwent a "trimmed" right great toe transfer to his right thumb (Figure 7). The dorsalis pedis artery was anastomosed end-to-end to the proximal stump of the radial artery within the reverse radial forearm flap. The reverse radial forearm flap was reelevated and advanced distally and ulnarly to release the contracture of the thumb–index finger web space (Figure 8). The flap was debulked and the skin was used as a full thickness skin graft to further thin the flap.

One year postoperatively, he has had complete relief of his previous symptoms of severe pain due to the neuromas of the radial and ulnar digital nerves and is using the thumb for pinch and grasp (Figure 9).

Results

All 3 immediate reverse radial forearm flaps were successful, and secondary elevation of the other 5 flaps did not result in any partial flap loss. One secondary toe-to-thumb transfer required reexploration for venous thrombosis, but all 8 toe transfers survived completely. The only other complication was a superficial infection around a reverse radial forearm flap, which resolved with intravenous antibiotics. There was complete "take" of the split thickness skin grafts for coverage of the forearm donor site. Mean follow-up was 5.1 years, ranging from 1 to 14 years. All patients were satisfied with the functional result and appearance of their toe-to-thumb transfers, as well as the appearance of the forearm donor sites.

Discussion

The radial forearm flap was first described as a free flap by Song et al and Yang et al for resurfacing the neck after radical release of burn scar contractures.[12,14] The versatility of the free radial forearm flap was extended to soft tissue

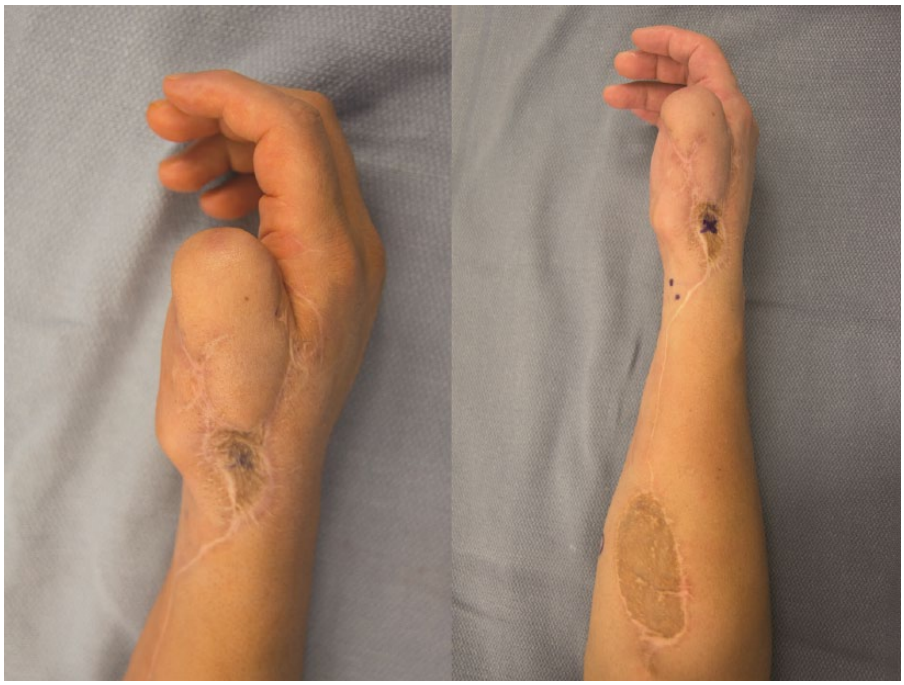

Figure 6. This 38-year-old man sustained an amputation of his right dominant thumb at the metacarpophalangeal joint level. Unfortunately, replantation was unsuccessful and he subsequently underwent coverage with a reverse radial forearm flap and distraction lengthening of the thumb metacarpal.

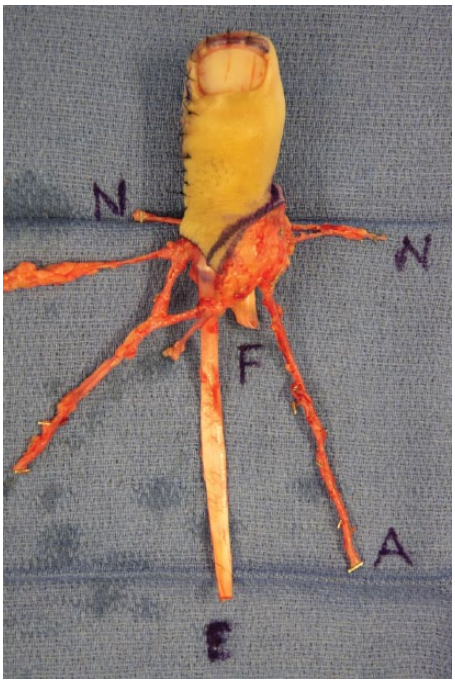

Figure 7. Two and a half years after the amputation, he underwent a right "trimmed" great toe transfer to reconstruct the right thumb.

Figure 8. The dorsalis pedis artery was anastomosed end-to-end to the proximal stump of the radial artery within the reverse radial forearm flap. The flap was elevated and advanced distally and ulnarly to release the contracture of the thumb–index finger web space.

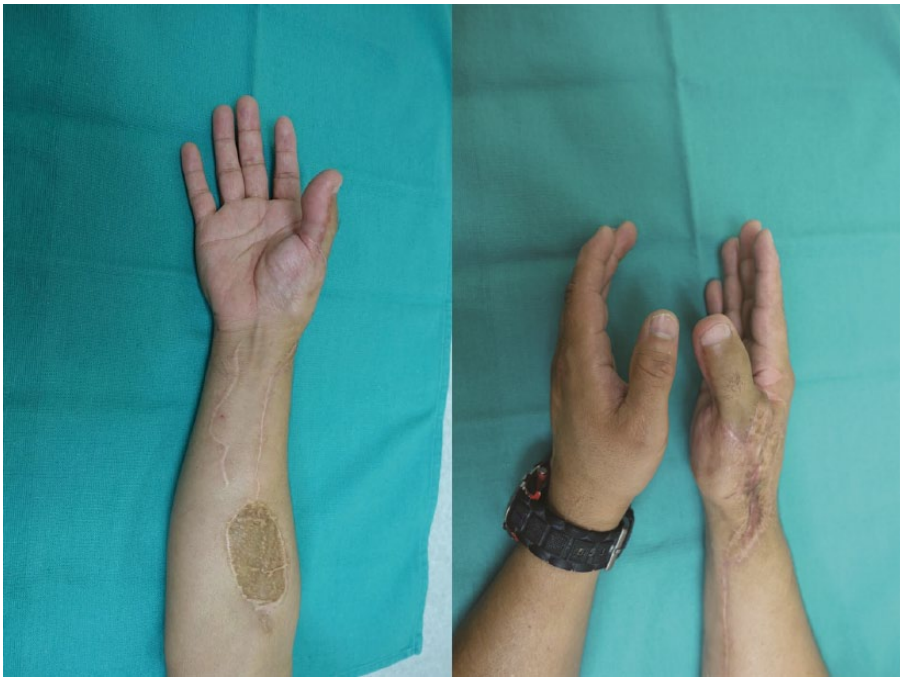

Figure 9. One year postoperatively, he had complete relief of his previous symptoms of severe pain due to the neuromas of the digital nerves of the amputated thumb and is using the reconstructed thumb for pinch and grasp activities.

coverage of both the upper and lower extremities as well as intraoral reconstruction.[11-13] Lu et al subsequently reported the reverse radial forearm pedicled flap, based on retrograde flow in the radial artery from the ulnar artery through the palmar arches, to provide coverage of soft tissue defects of the hand and wrist.[9] A short segment of radius bone may be incorporated in a reverse radial forearm flap for thumb reconstruction.[1] The palmaris longus tendon may also be incorporated as a vascularized tendon. Critics of the radial forearm flap cite the need for skin grafting of the donor site and sacrifice of the radial artery. However, the adipofascial variant allows primary closure of the donor site skin and preservation of cutaneous nerves.[8] Furthermore, the ulnar artery provides the main arterial supply to the superficial palmar arch and the hand,[2] and in rare situations where the ulnar artery is compromised, the radial artery can easily be reconstructed with a vein graft.[4]

A great toe or second toe transfer is the most sophisticated option for thumb reconstruction. However, in a severely mutilated hand, associated challenges include a significant soft tissue defect on the radial side of the hand, a first web space contracture or lack of a suitable recipient artery. The reverse radial forearm flap may circumvent these challenges by providing soft tissue coverage of a toe transfer as well as providing arterial inflow to the toe transfer through the proximal stump of the radial artery within the flap. Only 3 case reports have described a toe transfer powered by a reverse radial forearm flap,[3,5,8,10] but to our knowledge, this is the only case series describing this procedure and the only one to have been performed in both adults and children.

Lack of suitable recipient vessels in the vicinity of a defect can usually be overcome by using a vein graft in microsurgery. However, if the injured hand also has an associated soft tissue defect, a flap may be required. Karacalar et al described using a reverse radial forearm flap to cover a soft tissue defect of the first web space and thenar eminence, while simultaneously providing arterial inflow to a devascularized thumb.[7] The radial digital artery of the thumb was anastomosed end-to-end and the ulnar digital artery of the thumb was anastomosed end-to-side to the radial artery in the reverse radial forearm flap. Both Song et al and Foucher et al have described a "Sister" or "Siamese" flap, in which the vascular pedicle of one free flap can provide perfusion to a second free flap.[4,12] The reverse radial forearm flap, by providing a suitable recipient artery, can facilitate successful revascularization of a toe-to-thumb transfer and is an example of such a "Sister" or "Siamese" flap.[5,7,8,10]

There are only 2 case reports in the literature describing a secondary toe transfer after an initial reverse radial forearm flap reconstruction[3,10] and only 2 case reports describing a toe transfer performed simultaneously with

a reverse radial forearm flap.[5,8] Mahoney and Naiberg were the first to describe a reverse radial forearm flap to cover a degloved hand followed 9 months later by a second toe-to-thumb transfer.[10] Initially, the cephalic vein in the reverse radial forearm flap was anastomosed to a dorsal hand vein to improve venous drainage of the flap. During the subsequent toe transfer, the digital artery and vein of the second toe were anastomosed to the radial artery and its vena comitans in the reverse radial forearm flap.[10] However, in a second case report, Culp et al reported that difficulties can arise from using an initial reverse radial forearm flap in a patient who may subsequently need reconstruction with a toe-to-thumb transfer.[3] They described a patient who underwent coverage of a thumb avulsion with a reverse radial forearm flap, who subsequently decided to undergo thumb reconstruction with a toe transfer. However, a Doppler pulse could not be heard in the distal radial artery, and angiography revealed no inflow from the palmar arches into the distal radial artery in the reverse radial forearm flap, precluding its use as an arterial inflow pedicle for a toe-to-thumb transfer. Consequently, a reversed saphenous vein graft was used to elongate the stump of the radial artery in the proximal forearm down to the anatomical snuffbox, and a great toe-to-thumb transfer was successfully anastomosed end-to-side into this vein graft at a second-stage procedure 2 months later. The authors concluded that a preliminary reverse radial forearm flap imposes higher risks to an already complicated toe-to-thumb procedure and should be discouraged.[3] However, our series of 5 successful secondary toe transfers into a reverse radial forearm flap contradict their more pessimistic conclusion.

Güçer et al reported the first successful single-stage reconstruction using a reverse radial forearm flap and a simultaneous second toe-to-thumb transfer.[5] The first dorsal metatarsal artery of the second toe was anastomosed to the radial artery, and the dorsal vein of the toe transfer was anastomosed to a vena comitans of the radial vascular pedicle. The reverse radial forearm flap served a dual purpose—providing both arterial inflow for the toe transfer as well as coverage of the metatarsal bone of the toe transfer. Keramidas and Miller also described a single-stage reconstruction using an adipofascial variant of the reverse radial forearm flap to provide both soft tissue coverage and an arterial pedicle for a great toe-to-thumb transfer.[8] The first plantar metatarsal artery of the great toe was anastomosed end-to-side to the radial artery in the reverse radial forearm flap, and the dorsal vein of the toe transfer was anastomosed end-to-end to a dorsal forearm vein. The adipofascial variant was proposed to reduce donor site morbidity, by allowing direct closure of the forearm skin.

Based on our series of 5 patients who underwent secondary toe-to-hand transfers and 3 patients who underwent simultaneous toe-to-thumb transfers into reverse radial forearm flaps, the use of the proximal radial artery pedicle in a reverse radial forearm flap is a safe and reliable procedure, which can also address the challenges associated with traumatic loss of the thumb—such as significant soft tissue loss on the radial side of the hand in the acute situation, secondary contracture of the first web space, and an inadequate recipient artery for a toe-to-thumb transfer. The procedure has been equally successful in children and adults.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Informed consent was obtained from all individual participants included in the study.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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