Alternatives to Thumb Replantation

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Learning objectives: After studying this article, the participant should: 1. Have a variety of options for thumb reconstruction. 2. Know the advantages and disadvantages of the nonmicrosurgical and microsurgical techniques for thumb reconstruction. 3. Understand the decision making from the variety of thumb reconstruction techniques based on patient needs. 4. Have a basic understanding of the various thumb reconstruction techniques discussed.

The traumatic amputation of the thumb is an absolute indication for attempted replantation. The profound disability of the hand resulting from absence of the thumb, with loss of pinch and grasp, obliges the surgeon to make every attempt to replant the amputated thumb and preserve hand function. However, not all attempts at replantation result in survival of the amputated portion, and unreconstructable damage to or complete loss of the amputated part may preclude attempted replantation. In such situations, the surgeon must have alternative methods of dealing with the sequelae of thumb loss. This article will discuss nonmicrosurgical and microsurgical techniques for thumb reconstruction. (Plast. Reconstr. Surg. 110: 1492, 2002.)

HISTORICAL PERSPECTIVES

One of the first procedures to be attempted for restoration of function after thumb amputation, and still in use today, is phalangization of the thumb metacarpal, described by Huguer1 in 1874. The first reported toe-to-thumb procedure was performed in 1897, by Nicola-doni,2 in Vienna. Performed as a staged procedure, it required attachment of the hand to the foot for at least 3 weeks. In 1949 Gosset3 used the pollicization of the index finger on its neurovascular pedicle to replace the thumb. However, it was the advent of microsurgical techniques for hand surgery that allowed procedures for thumb reconstruction to achieve their maximum potential in terms of function, predictability, and acceptance in the medical community. In 1966 Buncke et al.4 reported successful great toe-to-thumb transfers in rhesus monkeys. This breakthrough was quickly followed by successful application to a human, as reported by Cobbett5 in 1969. Microsurgery also enhanced primary thumb replantation. Much has been written on this topic elsewhere, and our purpose here is not to add to this body of literature. However, it is important for the surgeon and the patient to have realistic expectations with regard to the outcome of replantation. Survival rates from 46 to 91 percent have been quoted, with the highest viability in laceration injuries and the lowest in avulsion injuries.6,7 Most patients report satisfaction with the results of successful replantation.8 In unsalvageable cases or in the event of a replantation failure, various methods for thumb reconstruction are given that can be quite functional.9,10

PATIENT SELECTION

It is generally accepted that any thumb amputation is an indication for an attempt at replantation.11 It has been suggested that in certain types of amputations, completion of amputation and replantation result in similar costs, and functional outcome is equal or better in those patients who have undergone successful replantation.8 Therefore, patients in whom alternatives to thumb replantation are considered are those in whom replantation cannot be performed because of severe mangle or complete loss of the amputated portion. The requirements for thumb reconstructions are a sensate and nontender thumb tip, stability at the interphalangeal and metacarpo-
phalangeal joints with mobility if possible, strength adequate to resist the forces of the fingers, correct stance and positioning of the thumb with a wide webspace, and mobility of the carpometacarpal joint with intrinsic muscles to provide thumb prehension. A possible algorithm for thumb reconstruction is oriented to the level of amputation. Distal and tip amputations may require resurfacing with sensitive flaps. Amputations of intermediate length may be reconstructed with a combination of “phalangization” (web deepening) and distraction lengthening. A level of amputation close to the metacarpophalangeal joint is the perfect indication for toe-to-hand transfer. It requires only two motors—flexor and extensor. The closer the amputation is to the basal joint, the less thumb motion that can be restored by any procedure other than pollicization. Indeed, if the metacarpal base is absent, pollicization (if a digit is available) is almost mandatory. Other factors influencing decisions are the patient’s age, health, occupation, and functional demands, and the condition of the remaining hand. An athlete may be ill-advised to surrender a toe. A woman may be dissatisfied by the appearance of an osteoplastastic thumb reconstruction. The presence of multiple amputations is a relative contraindication for pollicization; on the other hand, a damaged finger can be pollicized with good results. Low functional demand on the part of the patient may result in phalangization being the procedure of choice. A toe-to-thumb transfer may best treat a proximal amputation in a patient with high functional demands. The following discussion will cover the considerations with regard to which nonmicrosurgical or microsurgical technique may be used for thumb reconstruction (Fig. 1).

**NONMICROSURGICAL TECHNIQUES**

**Revision Amputation**

Revision of an amputation is undertaken when the amputated part is unsalvageable. Whether this is the final procedure or the first step in a more complicated reconstruction often is determined by the length of the residual thumb. Very distal amputations involving minimal bone loss can be treated with soft-tissue coverage, including such techniques as palmar advancement flaps and neurovascular island pedicle flaps from the ring finger or the first dorsal metacarpal artery flap. The indication for the palmar advancement flap is a distal, midpalmar defect of the thumb (Fig. 2). This flap has the advantage of bringing well-innervated palmar thumb skin distally to resurface the defect, thereby restoring nearly normal sensory perception with durable

Fig. 1. (Left) An unsalvageable thumb avulsion. (Right) After thumb amputation and wound closure with a groin flap. This result was quite functional for the patient, who declined further treatment.
skin and subcutaneous tissue. To gain maximum length, Z-plasties, Burow triangles, or a proximal releasing incision at the base of the flap can be performed, but if greater than 2 cm of coverage is needed, other techniques are preferred. A defect of the entire palmar surface of the distal phalanx of the thumb can be covered with a conventional cross finger-to-thumb flap. This flap is reliable, but being a random pattern flap, it requires the attachment of the index finger to the thumb for 3 weeks with possible joint stiffness and thumb web contracture. An alternative method is the first dorsal metacarpal artery flap. This flap incorporates the same donor site as the conventional cross finger flap, but through dissecting the first dorsal metacarpal artery to its origin, it is changed to an axial pattern flap. The sensate component is a terminal branch of the superficial radial nerve. The preoperative Doppler examination for presence of the vessels is mandatory. It should be noted that intraoperatively the vessels tend to be more radial than presumed. The paratenon above the extensor hood should be preserved to allow a perfect skin graft take for the donor site closure. The dissection of the pedicle includes parts of the interosseous muscle fascia. It is not advisable to isolate the vascular pedicle, and one should leave approximately 0.5 to 1 cm of fascial tissue around the artery. The pedicle can be followed to its origin from the radial artery, which allows a generous arc of rotation. The inset of the flap can be accomplished by passing the flap through a skin tunnel to the recipient site or by direct skin opening to the recipient site. The neurovascular island flap from the ring finger is rarely used currently because it requires a very tedious dissection to bring the neurovascular island from the lateral aspect of the ring finger to the thumb defect. Although certainly other intrinsic flaps are available for use in distal thumb defects, the palmar advancement flap and the first dorsal

Fig. 2. Drawing of a palmar advancement flap for the thumb (from Germann, G., Sherman, R., and Levin, L. S. Decision Making in Reconstructive Surgery: Upper Extremity, 1st Ed. New York: Springer, 2000; used with permission).
metacarpal artery flap are practicable and will afford coverage for most defects.

**Phalangization**

More proximal amputations involving the middle third of the thumb ray can be treated with any of the various methods described for phalangization. Simple Z-plasty and deepening of the web space can greatly enhance grasping ability. More frequently, a double opposing type of right angle Z-plasty is needed to provide the required web deepening and apparent functional thumb lengthening. Release of part of the first interosseous muscle and proximal transfer of the insertion of the adductor pollicis can be added for additional length. Phalangization as the only treatment is rare; it is frequently used as an adjunct to another technique for thumb reconstruction.

**Distraction Lengthening**

Distraction lengthening of the thumb metacarpal, as described by Matev, can be used to distract bone and soft tissue to an appropriate length for functional restoration. The osteotomy site is usually at the base of the first metacarpal. If any portion of the proximal phalanx is present, the metacarpal phalangeal joint should be pinned to prevent future flexion deformity. The distraction apparatus is applied with the proximal and distal bony segments in contact. Gradual lengthening can start several days after osteotomy, and the metacarpal may be lengthened 1 to 1.5 mm daily. Once adequate length is achieved, corticocancellous bone grafting and internal fixation of the distracted gap are performed to provide more rapid healing, more stabilization, and quicker mobilization. In young children, spontaneous regenerate may form, obviating the need for grafting. Lengthening of up to 4 cm has been described. After distraction is completed, a Z-plasty of the first web space is normally required, because the apex of the web skin gets dragged out distally with the lengthening (Fig. 5). Most complications in-
volve pin migration, loosening, or infection.\textsuperscript{28,30} Further complications are distal skin necrosis and bony nonunion. The patient must be committed to the requirements and inconveniences of the lengthening procedure. A close follow-up is mandatory to prevent minor complications from becoming problematic.

\textit{Osteoplastic Thumb Reconstruction}

Osteoplastic thumb reconstruction was one of the preferred methods of reconstruction in the 1950s and 1960s, before microtechniques became popular. Osteoplastic thumb lengthening, which involves placement of a corticocancellous graft and coverage with a tubed pedicle flap (most often the groin or abdominal flap), can be used for very proximal amputations.\textsuperscript{12} The type of coverage should not jeopardize any potential recipient vessels, neural structures, or joints, which may be of value in a later elective thumb reconstruction. Typically, a corticocancellous bone graft from the iliac crest is fixed to the end of the metacarpal.

The length required for hand function should be equal to the length of the interphalangeal joint of the normal thumb.\textsuperscript{13} A standard groin flap, based on the superficial circumflex iliac artery, is raised.\textsuperscript{31} The flap should be 7.5 cm wide and at least 12 cm long and is tubed for most of its length. The initial bulkiness of the reconstructions may have to be addressed later by defatting to improve fit and cosmesis, depending on the amount of subcutaneous fat present. The donor site is closed before insertion of the bone graft into the tube, which should be positioned such that the longitudinal suture line is palmar. Flap maturation time of 4 weeks should be allowed because of the limited contact between the flap and vascularized tissue. Immobilization should be continued until there is radiographic evidence of bony union. The inconvenience of setting the remnant thumb for several weeks into the groin should be weighted against the alternative procedures. Further possible disadvantages include distal bone graft resorption and lack of sensation of the reconstructed thumb. For sensation, a neurovascular island flap can be added.\textsuperscript{21,32-34}

\textit{Prosthetic Replacement}

Prosthetic replacement of the thumb can be satisfactory in patients who have at least 1.5 cm of residual thumb (Fig. 5, below, right).\textsuperscript{35} Modern prosthetic designs provide excellent cosmesis and can be fabricated such that a stable post for light grasping is created (Fig. 6). Nevertheless, most series demonstrate that approximately one-third of patients fitted with prostheses fail to wear them.\textsuperscript{35} Patients usually remove prostheses for more vigorous activities, including instrumental music, gardening, swimming, knitting, and cooking, and often express concern that the prosthesis will fall off in public. In patients who might be candidates for prosthetic fitting, care should be taken to bury nerve endings to prevent neuroma and provide stable skin coverage. As with all prostheses, realistic goals, careful fitting and fabrication, and consistent follow-up are necessary for success.\textsuperscript{36} The development of the osseointegrated digital prosthesis has advanced prosthesis design and function.\textsuperscript{37,38} The prosthesis attaches securely by means of an osseointegrated socket placed within the intramedullary canal of the residual bone of the amputated thumb. The prosthesis can deliver some tactile sensation because of its intimate association with the bone of the residual digit.
Before the development of microvascular techniques, pollicization was a hazardous undertaking with mixed results.\(^{39,40}\) The results improved in terms of both function and cosmesis with the introduction of microvascular techniques. Pollicization is a one-stage procedure that restores length, provides motion, and results in near-normal sensation, with acceptable deficits in function or appearance of the remainder of the hand (Figs. 7 and 8).\(^{15,41,42}\) The technical details of the pollicization are beyond the scope of this article but are described in detail by Kleinman and Strickland.\(^{15}\) Pollicization can be performed in a number of ways, depending on the condition of the rest of the injured hand. If no other rays are injured, either index or ring finger pollicization can provide good results.\(^{10,41,43-45}\) In the post–World War II era, there was a controversy as to which digit was best transferred.\(^{66}\) The French, represented by Gosset, transferred the index finger.
finger or the ring finger," the German school (Hilgenfeldt) favored the transfer of the middle finger, and the United States predominantly used pollicization of the index finger. The current preference is to transpose the adjacent index finger, which is technically easier to transfer to the thumb position. If other rays are injured, a “spare parts” approach can be used. An injured digit can be used in the acute setting for immediate reconstruction of the thumb, or it can be “banked” for delayed reconstruction.

Composite Free-Tissue Transfer

A multitude of options are available when free-tissue transfer with microsurgical technique is considered. Tissue from various sites has been described for use in thumb reconstruction with good results, such as the first dorsal metacarpal artery island flap or the osteocutaneous radial forearm flap. The method of choice is the toe-to-thumb transfer. The possible options in that particular field are second toe transfer, twisted two toe transfer, and variations of the great toe transfer such as entire great toe transfer, trimmed toe, and wraparound toe flap. The surgeon should be aware of the position of the first metatarsal artery (the terminal branch of the dorsalis pedis artery), which runs plantar to the metatarsal in up to 50 percent of patients and shows a highly variable anatomy. The great toe-to-thumb transfer fairly consistently provides good function and sensibility. The transplanted toe remains somewhat larger than the normal thumb but provides strong pinch and good motion. The great toe wraparound flap is ideal for the reconstruction of thumb amputations, which are just distal to midproximal phalanx level.

The great toe is degloved except for a strip along the medial and distal aspect of the toe that is retained for donor-defect closure. The entire rest of the distal phalanx of the toe is then transferred to the amputation site. In addition, an intercalated bone graft segment is needed between the proximal phalanx of the thumb and the distal phalanx of the toe. The wraparound flap provides excellent cosmetic results but no motion at the former interphalangeal joint. In 1988 Upton and Mutimer (modified toe) and Wei et al. (trimmed toe) used the same surgical approach to provide both acceptable cosmesis and joint motion. In this approach, the bone, nail plate, nail matrix, and soft-tissue pulp of the great toe are reviewed from the medial aspect of the toe to achieve an appropriate circumference of the reconstructed thumb (Fig. 9). Wei et al. reported reasonable return of motion in a series of trimmed toes. Second toe transfer is performed less often (Fig. 10). The transferred second toe is less satisfactory in appearance than the great toe or the wraparound procedure, provides
less strength, and is more difficult in terms of harvest. The twisted two toe transfer, as originally described by Foucher, combines a partial transfer from the great toe (pulp, vascularized bone, and nail) and a compound joint from the second toe (bone, joint, and extensor mechanism) based on the same vascular bundle. This technique combines joint motion and excellent cosmesis of both the donor and recipient sites. The patient should be aware that the failure risk for free toe transfer has been quoted as high as 10 percent. Donor-site morbidity varies

Fig. 7. (Above, left) An avascular thumb after crush injury. (Above, right) A groin flap is applied as a first step in a staged procedure to gain soft tissue. (Below, left) The left hand after division and inset of the groin flap. (Below, right) After phalangization of the index finger.
Fig. 8. The final result for the patient in Figure 7, showing function and aesthetic appearance.

Fig. 9. (Above, left) A right hand after traumatic thumb amputation at the middle of the proximal phalanx. (Above, center) The design for a trimmed toe transfer. (Above, right) The donor site. (Below) The result after the trimmed toe transfer.
according to the different techniques in toe transfer. Most authors agree that the gait after toe transfer is satisfactory. However, the great toe techniques can affect balance during gait. From the patient’s point of view, the sacrifice of a toe in favor of thumb reconstruction is generally accepted. A major disadvantage is the complexity of these procedures, which in practice restricts free toe transfer operations to experienced centers.

CONCLUSIONS

This has been a brief overview of nonmicrosurgical and microsurgical methods of thumb reconstruction. Results of all procedures vary according to the level of amputation and concomitant injuries. Distal amputations treated with revision of amputation have been shown to provide results comparable to those of replantation. For more proximal amputations, it has been demonstrated that the great toe transfer provides excellent mobility and strength of grip, whereas pollicization results in improved pinch accuracy. Comparison of great toe transfer with second toe transfer has demonstrated better cosmetic results and stronger grasp with great toe transfer, but with a more significant donor defect. The donor defect can be diminished in selected cases by use of the great toe wraparound flap.

It should be noted the decision-making process should be directed by the patient’s need rather than the surgeon’s ability to perform certain operations.

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REFERENCES


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**Self-Assessment Examination follows on the next page.**
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1. WHILE EACH IS DESIRABLE, WHICH OF THE FOLLOWING POINTS FOR THUMB RECONSTRUCTION IS LEAST IMPORTANT?
   A) Sensate, nontender pulp
   B) Correct orientation of the pulp relative to the digits
   C) Length of the reconstructed thumb to be at the level of the middle phalanx
   D) Ability to oppose the thumb to the digits
   E) Stability of the carpometacarpal joint

2. WHICH OF THE FOLLOWING PROCEDURES IS INDICATED IN UNSALVAGEABLE THUMB AMPUTATIONS CLOSE TO THE METACARPOPHALANGEAL JOINT TO ACHIEVE THE BEST POSSIBLE FUNCTIONAL OUTCOME?
   A) Toe-to-thumb transfer
   B) Osteoplastic thumb reconstruction
   C) Pollicization
   D) Phalangization
   E) Distraction lengthening

3. WHEN COMPARED WITH GREAT TOE TRANSFER FOR THUMB RECONSTRUCTION, WHICH OF THE FOLLOWING IS THE MAJOR ADVANTAGE OF SECOND TOE TRANSFER?
   A) Stronger pinch
   B) Better motion
   C) Better sensibility
   D) Better cosmetic result
   E) Lower donor-site morbidity

4. WHICH OF THE FOLLOWING IS THE MOST IMPORTANT FACTOR FOR SUCCESSFUL PROSTHETIC THUMB RECONSTRUCTION?
   A) Length of the thumb stump
   B) Dominant versus nondominant hand
   C) Quality of skin coverage
   D) Patient motivation
   E) Quality of the prosthesis

5. THE PRIMARY DISADVANTAGE OF THE FIRST METACARPAL ARTERY FLAP IS:
   A) Poor vascularity
   B) Poor sensation
   C) Necessity to sacrifice extensor tendons
   D) Need for skin graft at donor site
   E) Sacrifice of the first dorsal interosseous muscle

6. WHEN PERFORMING DISTRACTION OSTEOGENESIS FOR THUMB RECONSTRUCTION, THE BEST SITE FOR THE OSTEOTOMY IS:
   A) Carpal metacarpal joint
   B) Base of the first metacarpal
   C) Midshaft of the first metacarpal
   D) Distal first metacarpal
   E) Through the remnant of the proximal phalanx, if adequate
7. WHEN PERFORMING DISTRACTION OSTEOGENESIS FOR THUMB RECONSTRUCTION, ANY REMNANT OF THE PROXIMAL PHALANX SHOULD BE:
   A) Removed
   B) Included in the distraction device
   C) Pinned through the metacarpal phalangeal joint
   D) Removed and banked for future bone graft
   E) Left alone

8. WHICH OF THE FOLLOWING HAS IMPROVED THE SUCCESS OF POLLICIZATION FOR THUMB RECONSTRUCTION?
   A) Reserving it for congenital absence only
   B) Use of microsurgical technique
   C) Delaying the transferred digit in a multistage procedure
   D) Using only in the nondominant hand
   E) Using only when no other digits have been injured

To complete the examination for CME credit, turn to page 1623 for instructions and the response form.