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Toe Transfers in Mutilated Hands: Technical Considerations To Get Good Outcomes

Shanmuganathan Raja Sabapathy, MCh, FRCS, * Hari Venkatramani, MS, MCh, *
Praveen Bhardwaj, MS, FNB, * Monusha Mohan, MS, FNB, * Vigneshwaran Varadharajan, MS, FNB *

* Department of Plastic, Hand, and Reconstructive Microsurgery, Ganga Hospital, Coimbatore, Tamil Nadu, India

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In severe mutilating injuries of the hand, microvascular toe transfers can help gain prehension. Radical debridement and primary wound healing, with or without a flap cover, are the prerequisites for a successful toe transfer. A pedicled groin flap is our preferred method of soft tissue cover. A primary toe transfer can be performed in cases of isolated thumb loss. The metacarpophalangeal joint should be preserved whenever possible. The first web space should be maintained to obtain optimal results. In cases where two toe transfers are required, the authors prefer to do them in two sittings; the thumb is reconstructed first, followed by finger reconstruction. A great toe is used for thumb reconstruction in patients where a part of the palm and multiple fingers are lost. Proper positioning of the thumb and high quality of tendon and nerve repair followed by adequate hand therapy will lead to ideal outcomes.

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Mutilated hands, by definition, have experienced loss of tissue, and hence, they lack the capacity for prehension.¹ This definition helps define the goal of management, which is to gain prehension. When there are digital losses, toe transfers are one of the best methods to regain prehension. The technique of performing toe transfers has been well documented, and the procedure was well accepted.² Decades of experience have helped refine the indications. In this article, we intend to detail the technical considerations that influence achieving a good outcome.

Patient Details

Over the past 24 years, we have performed 135 toe transfers, with 2 failures. Sixteen were great toe transfers (performed in 14 adults and 2 children). Twelve great toe transfers were performed directly, and four required prior groin flap procedure. There were 119 second toe transfers. Of them, 39 were performed in children below 16 years of age. Of them, 25 were in post-trauma situations,

and 14 were for congenital differences. In 121 trauma patients, the toe transfer was performed as part of the primary procedure in 56 patients, and the rest were after a primary groin flap. Two patients had two toe transfers performed, but they were performed in separate sittings. Ninety-two toe transfers were performed for thumb reconstruction, and 43 were performed for finger reconstruction.

Primary Wound Healing: The First Criteria for Achieving Good Outcomes

The ability to perform toe transfers has increased our capability to obtain functional hands even in devastating injuries (Fig. 1). Mutilating hand injuries are characterized by extensive crushes or avulsion trauma. Radical debridement and primary wound healing are important to reduce the extent of fibrosis in the existing tissues.

Achieving primary wound healing in a mutilated hand most often would involve procedures for soft tissue cover either by skin grafting or a flap. The saying “Begin with the end in mind” is relevant while choosing the type of soft tissue cover in mutilating hand injuries. The type of skin cover must be decided based on the entire plan and not just aim at primary wound healing.

Most of the time when it is believed that toe transfers are needed and a prior soft tissue cover is essential, we use the groin flap as the soft tissue cover of choice (Fig. 2; Video S2, available online on the

Corresponding author: Dr Shanmuganathan Raja Sabapathy, MCh, FRCS, Chairman, Division of Plastic Surgery, Hand Surgery, Reconstructive Microsurgery, and Burns, Ganga Hospital, 313, Mettupalayam Road, Coimbatore, Tamil Nadu, India 641043.

E-mail address: rajahand@gmail.com (S.R. Sabapathy).

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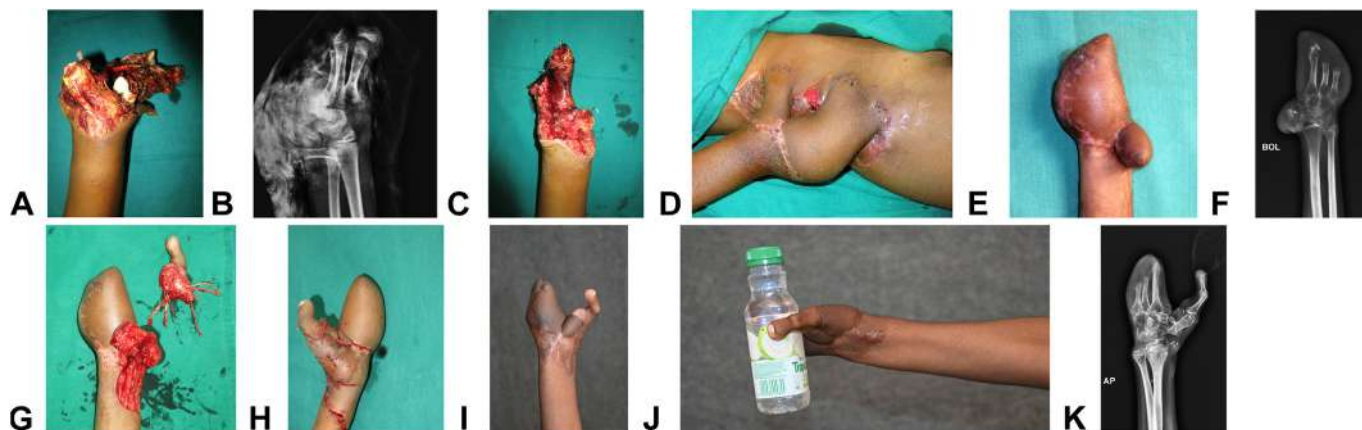


Figure 1. Loss of thumb at the carpometacarpal joint. **A** mutilated hand because of cracker blast injury. **B** The radiograph showing loss of thumb at the carpometacarpal joint level with extensive disorganization of the skeleton, **C** postdebridement picture, **D** two separate abdominal flaps performed one along the thumb ray and the other to cover the metacarpal stumps, **E** the hand after division of the flaps—note the flap in the position of the thumb to accommodate the metatarsal of the second toe—**F** the radiograph postflap cover, **G** second toe harvest with the metatarsal, **H** immediate postoperative picture, and **I, J,** and **K** outcome after 3 years.

Journal's website at <https://www.jhsgo.org>). It helps preserve the recipient vessels for further microsurgical procedures. Although it is technically possible to use the flap vessels or the vessels of the reverse radial forearm flap as recipient vessels, planning is so much easier when working on a previously unoperated territory while doing toe transfers.³ The planned groin flap must be inset in such a way that the flap is directed in the line of the thumb.⁴ This makes it easier to adjust soft tissues and create a web during toe transfer.

In thumb amputations at the level of the base of the metacarpal or at the carpometacarpal joint, pollicization is conventionally considered the ideal reconstructive option.⁵ However, in mutilated hand injuries, the other fingers also might have experienced severe damage, and pollicization may not be feasible. In those patients, second toe transfer is the only option. The second toe would need to be harvested with the metatarsal to gain length. The bare metatarsal would need a soft tissue cover. The flap planned for wound healing must be sufficient to provide cover to the bare metacarpal in the subsequent stage of toe transfer.⁴ If the flap provided is inadequate and just serves for primary healing of the wound, another flap may be needed to obtain a good web space at the time of toe transfer, adding complexity to the procedure.

Timing of Toe Transfers

In isolated thumb losses, we have performed primary toe transfers. Good outcomes have been reported.⁶ In a mutilated hand, opportunities for doing primary transfers, although possible, are seldom performed. It is better to obtain optimal healing of all the other structures and get the injured structures to their maximal functional levels before embarking on toe transfers. For example, if there are fractures and tendon injuries in the fingers, it is better to wait to obtain the maximal range of motion in the fingers or perform secondary procedures, if necessary, before performing toe transfer. It will help decide the length, position, and tension in the tendons of the transferred toe.

Toe Transfers for Reconstruction of Metacarpal Hand

If the digital amputations are at the level of the base of the proximal phalanges, and the stumps need soft tissue cover, it is important to preserve the base of the proximal phalanx by providing flap cover. The temptation to further shorten the stumps to avoid a flap cover is to be avoided. Preserved

metacarpophalangeal (MCP) joints and skeletal length add considerably to functional outcomes after toe transfer.⁷

In a total metacarpal hand, there is a tendency of the first metacarpal to develop an adduction contracture. If not splinted, the first metacarpal will deviate to lie in the plane of the other metacarpals. If toes are transferred, there will not be adequate first web space, and pulp-to-pulp pinch will not be possible. In total metacarpal hands, the first web is kept open by a V-shaped or a transverse K-wire spacer between the first and second metacarpal during soft tissue reconstruction. The wire is retained till thumb reconstruction is performed.⁷

Combined loss of thumb and all digits would need at least two toe transfers: one for the thumb and the other for the ulnar post. The ultimate outcome would depend upon the positioning of the two toes in such a way that the transferred toes can make a pulp-to-pulp pinch, with a good web space.

Sequencing and Positioning of the Toes During Transfer in a Metacarpal Hand

The choice is between performing toe transfers for the thumb and finger reconstruction at the same stage or in two stages. Although both are possible, the authors prefer performing the procedure in two stages. The thumb is first reconstructed. We prefer a great toe for this. After full rehabilitation of the thumb, its movement arc is determined. Finger reconstruction is then performed with the second toe from the other foot and positioned in such a way that it will meet the thumb.

Conventionally, in reconstruction of the total metacarpal hand, the fifth metacarpal is the position of choice for the second toe transfer. It was surmised that it would help provide a wider grip span. The authors' team also practiced this sequence, but in the last decade when hand usage in mobile phones and digital platforms increased, the authors found that the patients were more comfortable with the transferred toe positioned in the index position or over the third metacarpal. We find that with the toe in the index position, adequate span is still available for large object grasp (Fig. 3).

Choice of metacarpal positioning with correct rotation is the key to getting good functional outcomes in multiple toe transfers. As Littler said, "It is not the full length of the thumb, nor its great strength and movement, but rather its strategic position relative to the fingers and the integrity of the specialised terminal pulp tissue

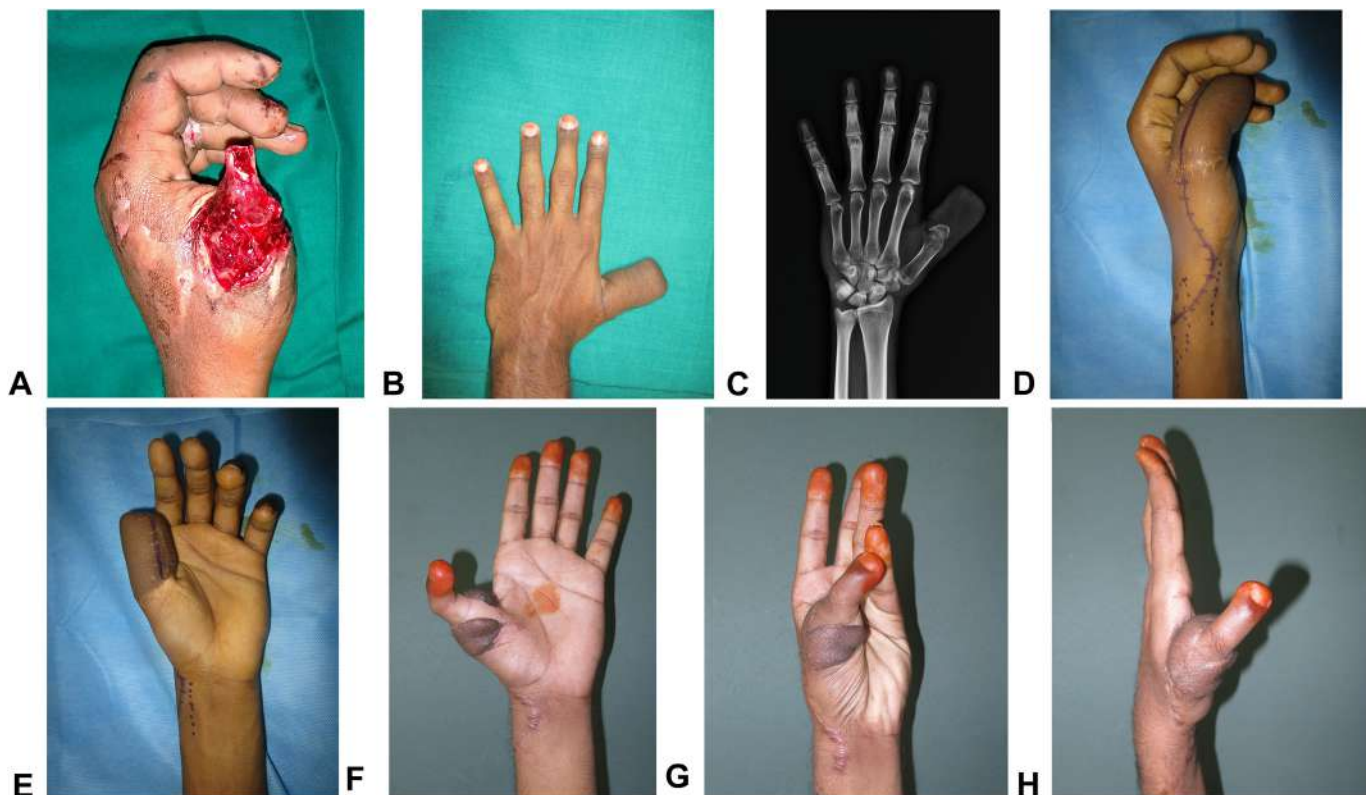


Figure 2. Loss of thumb with skin loss. **A** Total amputation of the thumb through the proximal phalanx, **B** after flap cover, **C** retaining the base of the proximal phalanx, and **D** and **E** exposure for toe inset and access to vessels. Flap spitting gives good access. The excess flap can be thinned and trimmed to suit the needs. **F, G, and H** One-year postoperative result.

which determines its prehensile status.”⁸ Unless correctly placed, there may be scissoring of the digits on an attempted pinch, or the thumb tip may not reach the tip of the transferred toe. This is a real risk in the reconstruction of a total metacarpal hand. Although coarse grip will still be possible, fine pinch requires precision placement of the toes in correct alignment and rotation. In our hands, good outcomes are achieved when we space the toe transfer for thumb reconstruction and the digits separately. We first perform the toe transfer for the thumb and fully rehabilitate the patient. By 6 months, we will have a fair idea of the extent and the arc of movement of the thumb. Second toe transfer for digit reconstruction is then performed positioning it to meet the thumb.

Combined second and third toe transfers have been performed to provide a tripod pinch in total digital loss, and good results have been demonstrated.⁹ Currently it is favored to perform two separate second toe transfers in cases of total digital loss. The positioning and function are much better than with combined second and third toe transfers.^{10,11}

Choice of Great Toe Versus Second Toe in Reconstruction of Mutilated Hands

For thumb reconstruction in a mutilated hand, a great toe is preferred when there is a considerable loss of the palm and fingers (Fig. 4). In such instances, power and strength provided by the great toe are valuable. For the same reason, a full great toe is preferred over modifications like the trimmed toe transfer or wrap-around flap.^{12,13} In the wrap-around flap, there is no interphalangeal (IP) joint. The power of pinch then totally depends upon the thenar musculature. In a mutilated hand, thenar musculature might also be affected, leaving the indication of wrap-around flap limited for isolated thumb losses at or distal to the MCP joints.¹² Trimmed toe

transfer has the advantage of retaining the interphalangeal joint and the power of the long flexor and was designed to compensate for the difference in the size of the thumb and the great toe.¹³ Although it is acceptable in isolated thumb reconstruction, in mutilated hands, reconstruction of great toes make great thumbs. It has less scarring and better sensory recovery. The great toe is wider than the thumb. After 1 year, the thumb decreases by 20% in size and matches the thumb well.¹⁴ Hence, we prefer great toe for thumb reconstruction in mutilated hands with loss of other digits. In children, we prefer the second toe over the great toe. The metacarpals and phalanges of children undergo hypertrophy over the growth period.

Toe Transfers in Degloving Injuries

A wrap-around flap of the great toe is the best form of reconstruction for degloving injuries of the thumb if replantation is not possible. Second toe wrap-around flaps have also been performed for the reconstruction of degloving injuries of the digits.^{15,16} Donor site morbidity is reduced by performing cross-toe flaps. In degloving of the digits and thumb, the nail bed may be retained with the germinal matrix. In such cases, the germinal matrix and nail bed must be ablated before performing a wrap-around flap.

Technical Considerations

Preoperative planning

The examination of the donor foot, feeling for the dorsalis pedis pulses, evidence of any previous injuries, and an X-ray of the foot are the preoperative work-up. Angiograms are not performed routinely, and in the presence of a palpable dorsalis pedis, no

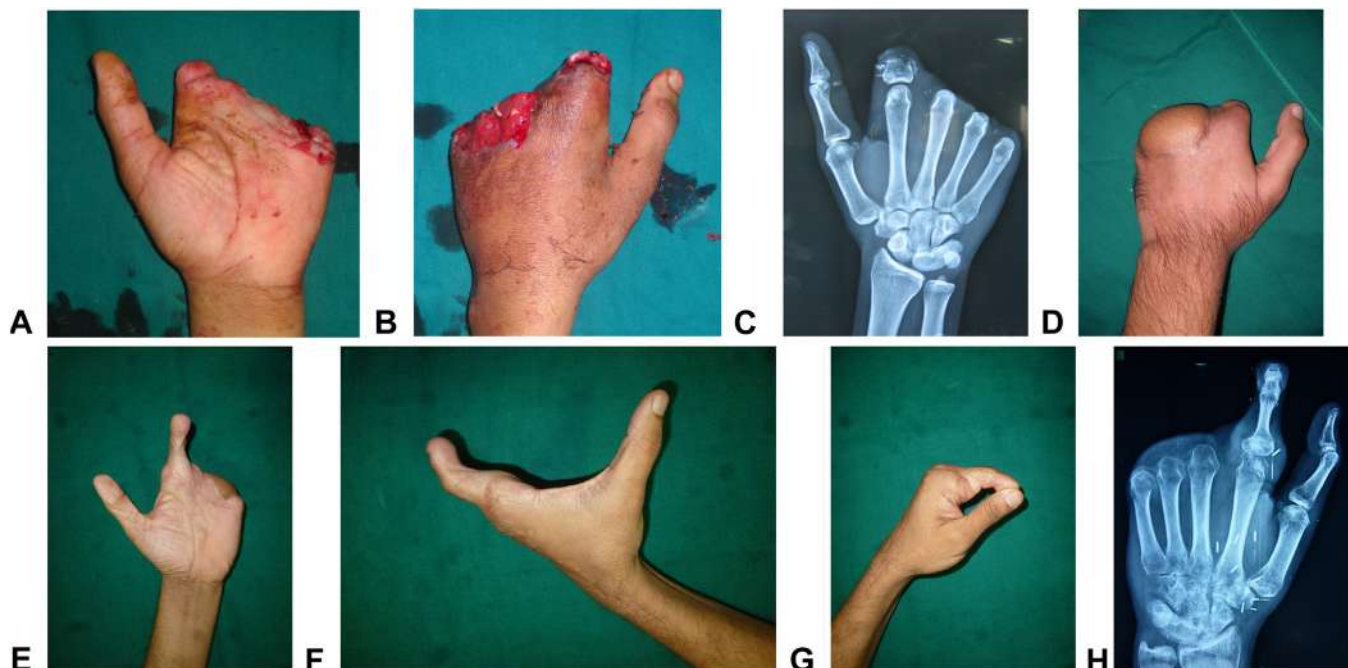


Figure 3. Traumatic loss of all the fingers of the hand. **A** and **B** A machine cut injury with loss of all four fingers, **C** the amputation is through the base of the proximal phalanx of the index and through the metacarpophalangeal joint of other fingers, and **D** available skin used to cover the index-finger stump and a groin flap used to cover the rest of the finger stumps. **E**, **F**, and **G** Second toe transfer performed on the index stump. Note the good first web space and flexion at the MCP joint; **H** the second toe proximal phalanx on the remnant of the base of proximal phalanx. The presence of the joint adds so much to function.

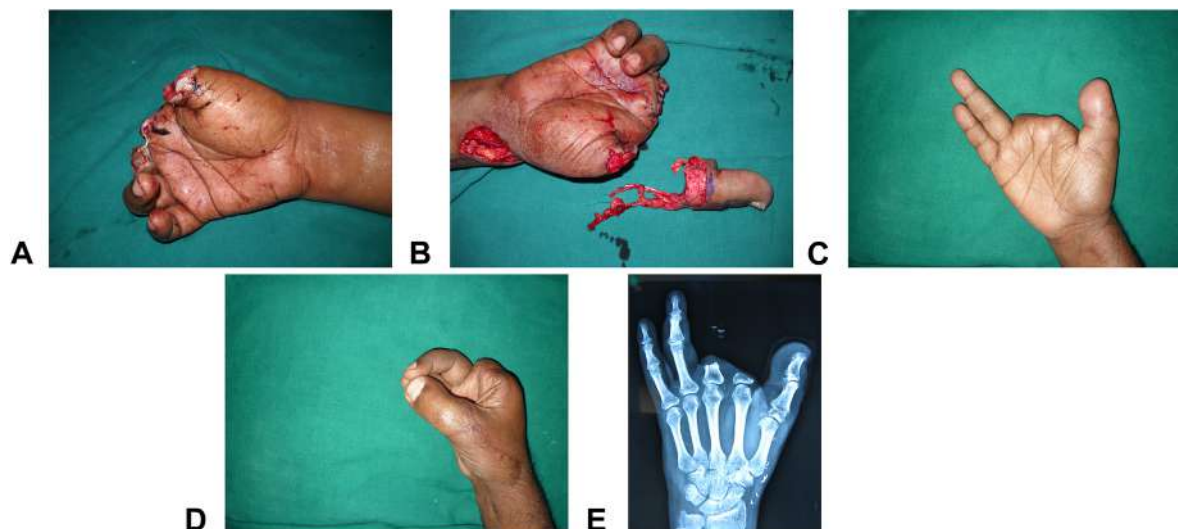


Figure 4. Great toe transfer. **A** Total amputation of thumb, index, and middle fingers. **B** Primary reconstruction of thumb performed with great toe. The stumps of the index and middle fingers are closed. **C** and **D** Long-term result. Great toe in a compromised hand helps provide good grip and pinch strength. **E** Retaining of even a small base of the proximal phalanx is of good functional value.

further investigation is necessary.^{14,17} The anatomical pattern of the first dorsal metatarsal artery can be revealed using ultrasonography.

Woo et al¹⁷ suggested that preoperative angiography should be performed in patients over the age of 50 years, those with evidence of cardiac disease, or those with lower limb peripheral occlusive vascular disease. Lee et al¹⁴ reported that in almost all the cases, the Doppler signals correlated to the arteriogram and surgical findings. Although angiograms can report the dominance of the first dorsal metatarsal artery, vascular spasms of the vessels can obscure the

images. An angiogram is not routinely performed even in children with congenital hand differences.¹¹ The authors use a handheld Doppler probe to map the dorsal and plantar arterial system in the foot before surgery and do not prescribe an angiogram. Only on one occasion did we have to abandon the toe harvest dissection in the presence of a palpable dorsalis pedis pulse. This was in a patient with major electrical burns to both upper limbs for whom we planned a toe transfer for a metacarpal hand. In this patient, we had a palpable dorsalis pedis artery, but on exploration, there were no usable veins. The veins on the dorsum of the foot had been

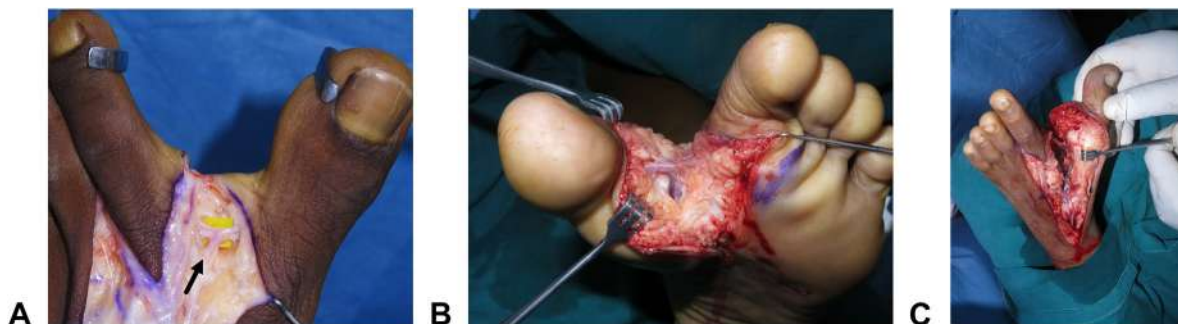


Figure 5. **A** Isolating the T junction formed at the division of the first metatarsal artery. Presence of the T junction dorsal to the deep transverse ligament denotes a dorsal dominant system and **B** plantar dominant system. **C** Dissection to the dorsalis pedis would involve major dissection in the intermetatarsal space.

extensively used as a source of venous access during the resuscitation and subsequent multiple surgeries for resurfacing of the major burns that most veins had thrombosed, and there was total absence of saturable veins on the dorsum of the foot. The other foot was used as the donor. This fact has to be kept in mind during the reconstruction of major injuries where toe transfer would be part of the reconstruction strategy. From the initial stages, the veins of the dorsum of the foot could be preserved at least on one side. Barring this example, there has not been a single instance of abandonment of toe harvest dissection.

Sequence of dissection

We start with the racquet-shaped incision extended dorsally to access the dorsalis pedis artery. After isolating the veins to the toe, the main veins are dissected proximally to suit the needs of the hand. Attention is then turned to the web space to identify the T junction formed by the branching of the first dorsal metatarsal artery and look at its position in relation to the deep transverse metatarsal ligament. A superficial position confirms the dominant dorsal system, and a deep position points to the plantar artery dominance (Fig. 5). In our series of 135 toe transfers, this has always been accurate in prediction. This distal to proximal dissection of the arterial pedicle after identification of the T junction has quickened the harvest.¹⁸ A dorsal dominant system is easy to dissect, and it is extended to the dorsalis pedis artery. Plantar dominant system is difficult to dissect, and we have used two options. One is to dissect on the plantar side as much as it is comfortable and then use a vein graft. The other alternative is to perform a tedious dissection through the intermetatarsal space and trace it to the dorsalis pedis artery. Authors prefer a vein graft if longer lengths of vessels are needed at the recipient site.

Skeletal fixation

Osteosynthesis with plate and screws and K-wires with box type of suturing with stainless-steel wires, double K-wires, or single K-wire have all been used as methods of fixation of the toe. The preferred method of fixation by the authors is to use a single K-wire. It is simple, quick, and easy to use. The downside is the possible rotation that can happen. We circumvent this by taking a couple of 4-0 Prolene sutures of the soft tissues on either side of fixation of the toe. With a single K-wire and two more sutures, no rotation is possible. This helps avoid the use of two K-wires or stainless-steel wire box fixation. We do not use plate and screw fixation.

The most common level of toe transfer is around the MCP level. Even a short base of the proximal phalanx, if present in the hand, is retained to gain the joint. If the fixation is at the joint level, arthrodesis of the joint in neutral or in 10 degrees of flexion is

recommended. Second toe fixed in hyperextended position at the MCP joint is not advantageous for function. This factor has to be taken care of since secondary correction of the toe fixed in hyperextension has the inherent risk of injuring the veins or the dorsal digital nerves. One simpler method to correct minor levels of hyperextension deformity at the MCP joint is to excise an ellipse of skin on the volar side at the MCP joint level and resuture the wound. The dermodesis effect can correct hyperextension deformity of up to 30 degrees.

Tendon and nerve repairs

The function of the transferred toe depends upon the availability of the musculotendinous units for repair and the quality of tendon and nerve repairs. The toes, particularly the second and smaller toes, are basically flexed in their normal position. If they are fixed in the same position, during an attempted pinch, a tip-to-tip pinch occurs. Ideally, the power depends upon the surface area of contact, and for this, pulp-to-pulp contact is ideal. Since the interphalangeal joints of the toes are basically flexion joints, the extensor tendons have to be sutured in good tension to maintain the IP joints in a neutral position. A 1.4 mm K-wire fixation of the toe is also performed with the IP joints in extension. During harvest, measured lengths of the tendons and nerves are taken for adequate suturing. Falling short in length of the nerves or tendons by a few centimeters and use of graft compromise function. If grafts are needed, which might be in cases of major mutilated injuries, palmaris longus or fascia lata are the two common sources of graft that are used.

Good nerve repair is essential for function. Apart from the plantar digital nerves, dorsal digital nerves are also harvested and repaired. Dorsal sensation is also highly appreciated by patients. Tendon or nerve grafts, if required, are attached to the harvested toe, and then, skeletal fixation is performed. On average, our toe transfer patients have achieved 8–10 mm of two-point discrimination when examined at 1 year of follow-up, and in the long term, they can reach 6 mm. None of the patients has developed trophic ulcers in the long term.

Rehabilitation

The K-wires are removed at 4 weeks, and mobilization of the transferred toe is performed. Other forms of skeletal fixation would render early mobilization possible but, in our opinion, have not mattered on the long term. The patients must be cautioned on the use of the toe to prevent trophic ulcers till they regain sensation.

Toe transfers performed primarily or secondarily have helped us obtain good functional outcomes in reconstruction of mutilated hand injuries. Adequate soft tissue covers, prior to toe transfer and maintenance of good first web space, are important. Appropriate

positioning of the transferred toe, tensioning of the tendon repairs, and good nerve repair followed by good rehabilitation help us get good outcomes.

Conflicts of Interest

No benefits in any form have been received or will be received related directly to this article.

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