MINI-SYMPOSIUM: HAND TRAUMA

(i) Skin cover in hand injuries

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Summary
Prompt coverage of skin loss associated with major hand injuries ensures primary healing, protects the reconstruction of the underlying structures and facilitates early rehabilitation. Radical debridement prior to the provision of skin cover is important. Flap cover is chosen according to the functional requirements of the site to be covered, need for access for further procedures and donor site morbidity. Combined defects can be reconstructed with composite flaps. Coverage of large defects can be made simpler by providing flap cover only to critical areas which definitely need flap cover and the rest with skin grafts. With the wide choice of flaps available to cover a particular defect, the surgeon’s experience with the particular flap and donor site morbidity, on which depends the long-term satisfaction of the patient, become the main considerations in the choice of the flap.

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Introduction
Most major hand injuries have skin loss as one of the injury components. With the technical advances and refinements in reconstruction that have been made in the past few decades, many mutilated hands can be saved to provide useful function. However good are the techniques of skeletal fixation, tendon or nerve reconstruction, unless the overlying skin heals primarily or the skin loss is made good in time we cannot expect primary healing of the underlying structures. In addition, the skin cover that we provide must allow the hand to meet the functional demands of the individual. In this review, the guiding principles in providing skin cover are first outlined, then the later half details the coverage considerations of specific areas and technical considerations of some commonly used flaps.

General principles
Debride adequately before providing skin cover

The wound must be debrided adequately before providing skin cover. This is important irrespective of the site of injury or the type of skin cover chosen. If this point is missed, infection sets in and the reconstruction may end in failure. Debridement must be done under anaesthesia, with good lighting and tourniquet to ensure adequate debridement and prevent inadvertent injury to vital structures. A three-dimensional excision of the wound must be performed,\textsuperscript{1} but taking care to retain the longitudinal structures such as...
tendons and nerves. Identify important nerves and vessels before wound excision to prevent inadvertent injury. The longitudinal structures are then carefully skeletonized and all contaminants removed. The hand has got many pockets where contaminants can become lodged, and time spent on debridement is time well spent (Fig. 1). Even a well-vascularized free flap cannot compensate for poor debridement.

Provide skin cover as early as possible

If the wound has been well debrided, it can be covered primarily. To delay skin cover is to invite disaster. Early skin cover alleviates pain, prevents infection and reduces the number of surgical procedures and the cost of treatment. If bone, tendons and nerves are exposed without cover and are allowed to dry they die. If tendons and nerves loose their sheen before skin cover is provided, the chances of them sloughing out and wound infection setting in are high. Infected tendons are one of the common causes for persistent infection under the flap and sinus formation at the flap margins. If, for any reason, primary cover is not possible, the wound may be temporarily covered with collagen sheets to keep the structures moist. It is only a temporizing measure and collagen sheets must be used only after good debridement.

Sometimes the associated injuries or co-morbid factors may not permit early skin cover. The management of life threatening injuries and co-morbid conditions take precedence. Though primary skin cover may not be possible on such occasions, debridement of the wound and skeletal fixation must be done on day one. Good, and early, skeletal fixation is particularly important if pedicle flaps are used. Loose fixation causes pain and delays rehabilitation.

Think of future needs when you choose the type of skin cover

In a major injury, make the whole plan and not just a tactic for the day. The skin cover provided must allow for future reconstructive needs. If at a later time, access would be needed for bone grafts, tendon grafts or tenolysis, it is better to provide a skin flap than a fascial flap covered with skin graft. Skin flaps are better if tendon grafts have to be tunneled through, since the subcutaneous fat allows easy passage during surgery and facilitates rehabilitation.

When a flap is provided, the size and the orientation of the flap must facilitate the next stage. This is particularly important in planning thumb reconstruction. The flap should be oriented in the direction of the thumb (Fig. 2). If a flap is pointing in the wrong direction, changing the orientation of

Figure 1  (a) Dorsal combined loss due to road traffic accident with heavy contamination. (b) After radical debridement. (c) Well-healed flap without any infection, which is possible only due to radical debridement.
the flap secondarily will be difficult and will result in poor utilization of the transferred tissues.

**To graft or to flap?**

If the raw area exposes bare bone, bare cartilage, bare tendon or nerve, or there is an open joint, it has to be covered with a flap. On other occasions a split skin graft will do. The decision to choose a flap or skin graft is based on the nature of the bed and not on the size of the defect. Even if the raw area is small, if structures like flexor tendon are exposed, a flap must be chosen in order not to compromise function. The decision about the type of cover needed is made at the end of debridement. If, at the end of debridement, it appears that a particular area would need flap cover, it will almost always need flap cover. Waiting does not change the demands of the area. A flap is preferred to a graft in areas like the first web space, where there is a need to fill in volume in addition to providing cover.

When there is a large raw area to be covered, it can be divided into *critical* and *non-critical* areas. By ‘critical’ is meant areas which need a flap and ‘non-critical’ where a skin graft would do. The plan should be to graft the non-critical areas and flap only the critical areas (Fig. 3). In this way, the technical demands in the provision of skin cover will become simpler. This protocol will involve the inset of the flap to raw areas but it has not affected the outcome. If a pedicle flap is planned there need not be any change in the timing of the delay and division protocol.

**Skin cover in composite defects**

If skin loss is part of a composite defect, it is possible to reconstruct all components in one stage by a composite flap. An example would be an osteocutaneous free fibula to reconstruct a combined defect of metacarpals and the dorsal skin. Very often the geometry of the loss of the various components in the defect may not make it convenient to design a composite flap. In such instances, the defects of the various components can be individually addressed by the best possible means and a skin flap provided (Fig. 4). The functional outcome in both types of reconstruction appears to be the same. Primary reconstructions of deeper structures can also be combined with pedicle flaps safely. Debridement has to be radical and an inset of more than 80% must be planned if pedicle flaps are combined with primary bone, tendon or nerve grafting. The ultimate functional outcome depends upon the quality of debridement rather than on the type of the flap cover chosen. Though microsurgical free flaps have obvious advantages over skin grafts, it is not possible to obtain a well vascularized flap from the donor site in all types of defects.
advantages, pedicled flaps will continue to be used. A hand surgeon has to become well versed in all techniques.\textsuperscript{5}

**Act early when complications occur**

A complication of skin cover is flap necrosis, which may be partial or complete. In the rare event of complete necrosis of the flap, one has to resort to back-up options early. A common situation is a small area of flap necrosis exposing a vital structure like bone or tendon. Even in such a situation, early debridement of the area has to be done and an additional flap has to be provided to salvage the exposed structure. If not done early, even if most of the flap survives, the exposed critical structure will dry and die, and in many instances the reconstructive goal will not be reached or suboptimal functional results will be achieved.

**Skin cover in degloving injuries**

The thin envelope of skin and the differential quality of the skin on the dorsal and volar aspect of the fingers and hand are challenging to replace when they are totally lost in a degloving injury. Single finger degloving commonly occurs in ring avulsion injuries. The best way of covering them is by replantation of the avulsed skin.\textsuperscript{6} Other alternatives for the cover of single finger degloving injuries often result in bulky fingers, needing repeated thinning of the flap. When all or multiple fingers are involved, a large flap is required. In addition, if the palm and dorsum are also degloved, very few options exist.

Cover of a circumferential defect in a single finger requires a flap of 70–100 cm\textsuperscript{2} and if all four fingers are covered with a single flap after syndactalizing, then the flap requirement will be about 300 cm\textsuperscript{2}. That necessarily makes it very bulky. While providing flap cover to a degloved finger, it is advisable to nibble the terminal phalanx to the base. This reduces the size of the flap to be provided while retaining the attachment of the extensors and flexors. Flap cover of a single finger may result in a long and Bulky finger which will be functionally disabling and cosmetically not acceptable. When we have a patient with a four finger degloving injury, our protocol is to amputate the index finger at its base and transfer the first dorsal interosseus to the middle finger. This gives the patient a good first web space and the reconstruction is less demanding. The three fingers are individually covered with tube flaps from the lower abdomen if the individual is slim. Such tube flaps must always be delayed before division. If individual tube flaps are not possible, a single big free or pedicle flap is raised. The fingers are later separated. Until the fingers are separated functional levels and patient satisfaction are poor. Multiple free flaps including tissue transfers from the foot, have been done to primarily reconstruct these devastating injuries.\textsuperscript{7} If such technically demanding procedures are not possible, staged reconstructions are resorted to.

If degloving of the fingers is associated with palmar or dorsal degloving injuries, skin grafts are used where possible and the rest of the area is covered with flap.

**Skin cover in neglected hand injuries**

In neglected hand injuries, in addition to the loss suffered due to the injury, further loss occurs due to infection and desiccation of vital structures. Hence, debridement has to be more radical in neglected injuries than in an acute injury before providing soft tissue cover. The defect always becomes wider after debridement. After debridement,
Skin cover provision is on the same principles as are followed in acute injury. Infection is associated with oedema and oedema leads on to fibrosis. The fibrosis runs along the perivascular tissue planes. This makes vessel dissection difficult and vessel walls in such areas are friable and rupture easily. Such vessels are also more prone to spasm. When choosing recipient vessels for free flaps in neglected hand injuries, one has to move well away from the zone of trauma. In the site chosen for anastomosis, vessel dissection must be easy with a smooth surrounding plane of dissection.

Regional coverage considerations

Fingers

Finger-tip amputations are the commonest form of tissue loss in the hand. The best form of cover is replantation when possible. For distal injuries healing by secondary intention, resuturing the amputated part as a composite graft, advancement flaps and cross finger flaps are some of the frequently used options. If the defect does not expose bone and is less than 1.5 cm the wound can be allowed to heal by secondary intention. Composite grafts take well in children. The less the ischaemia time, the better is the take of the graft.8 Hence, when using composite grafts it is better to act as early as possible, as when performing a replant. With advancement flaps it is important to dissect and mobilize the flaps well prior to suturing. Tight suturing due to poor mobilization is the commonest cause of post-operative flap problems.

In finger injuries, it is important not to discard any tissue until one is sure that it is not needed. Specialized tissues like nail bed and volar skin, can be used as a graft. When multiple fingers are injured viable skin from non-salvageable fingers that are being amputated can be used to salvage adjacent or non-adjacent injured fingers.9,10 Thinking of the possibility during initial assessment is important. In skin loss in the proximal fingers cross finger flaps and kite flaps from the adjacent fingers are commonly used.

Thumb

Sensation is important in restoring cover for volar thumb defects. The Moberg advancement flaps, first dorsal metacarpal artery flap,11 Littler island flap and free toe pulp transfers have all been used. The Littler island flap has a bad reputation for retaining cortical orientation and division of the nerve and resuturing it to the nerve of the thumb has been advised. That would have the disadvantage of a blind period of no sensation. Our experience with Littler island

Figure 4 (a) Gun shot injury causing skin loss with segmental loss of third metacarpal and extensor to the middle finger, reconstructed with iliac crest bone graft, palmaris longus tendon graft and a reverse posterior interosseous pedicle flap. (b) Long-term post-operative result. (c) Pre- and post-operative radiographs.
Dorsum of the hand

A variety of options exist for the coverage of the dorsum. If the paratenon over the extensors is intact, skin graft is a good option. In the hand, full take of the graft has to be aimed at. It is advisable to regraft small areas of skin loss rather than allow secondary healing. Secondarily healed areas cause fibrosis and stiffness and, in dark skinned people, hypopigmentaton. The hand is an exposed part of the body, and we must aim to achieve aesthetic satisfaction in all that we do.

A variety of free flaps and pedicle skin flaps from the lower abdomen can be used to cover the dorsum of the hand. This area is also amenable to be covered by local pedicle flaps like the radial and the posterior interosseous flaps. It is imperative that a hand surgeon is conversant in performing both these flaps.

The reverse radial forearm flap is a fasciocutaneous flap which allows a large area of volar forearm skin to be raised and turned over. Large defects can be covered (Fig. 5). The pivot point lies 1–2 cm proximal to the radial styloid. A flap less than 5 cm allows primary closure of the donor area.

Figure 5  (a) A composite loss in the dorsum of the hand, re-reconstructed with iliac crest bone graft, palmaris longus tendon graft and a reverse posterior interosseous forearm flap. (b) Reverse radial artery forearm flap marked and raised to cover the defect. (c) Metacarpal reconstruction with iliac crest bone graft and flap inset. (d) Radio graph showing bone union and long-term function.
When bigger flaps are used care must be taken to ensure full take of skin graft on the donor area. Sacrificing a major vessel to the hand and donor site morbidity are the two main disadvantages of this flap. Performing a fascia-only flap and basing the flap on the branches and perforators, without sacrificing the major vessel, are the refinements to reduce donor site morbidity. This flap can also be raised with bone as a composite flap, but due to the donor site morbidity and the availability of better options, presently this is not the preferred composite flap for hand defects.

The reverse posterior interosseous artery flap does not have the disadvantage of sacrificing a major artery and a flap of 12–15 cm in length and 8–10 cm in width can safely be raised from the middle third of the dorsal aspect of the forearm. The flap vessel lies in the septa between the extensor carpi ulnaris and extensor digiti minimi muscles and the key perforator lies at 1 cm distal to the distal mid point of the line from the lateral epicondyle to the distal radio-ulnar joint\(^\text{14}\) (Fig. 6). Once in the correct plane it is a fairly easy flap to raise and care must be taken to keep the important perforators. The pivot point lies at 2 cm proximal to the distal radio-ulnar joint. It is easier to raise a bigger flap than a smaller flap, since one has to ensure the inclusion of the key perforator vessels. Positioning the forearm is important while marking and raising the flap. The arm is kept by the side of the patient with the forearm pronated. The flap could be raised by identifying the vessels distally or proximally. The senior author prefers the proximal to distal approach. The flap can cover the whole of the dorsum and most of the palm and is an excellent choice for first web cover and for covering exposed vessels after trans-meta-carpal replantation and revascularizations.

The pedicle of these local flaps can be tunnelled subcutaneously. If done, care has to be exercised not to produce compression due to the inevitable swelling that occurs in the post-operative period. This is the commonest cause for venous congestion and flap morbidity. A safe technique to use is to take a thin strip of skin along the pedicle and inset it by making an incision from the pivot point to the defect (Fig. 4).

The palm

It is difficult to replace the palmar skin with like skin. The palmar skin is thicker and less prone to injury so the need to cover the palm is much less frequent compared to the dorsum of the hand. Avulsion injuries of the palm have been salvaged by arteriovenous shunting.\(^\text{15}\) If the bed would accept a graft, it is better to put in a full thickness graft. The degloved palmar skin has also been utilized. To enhance the take of the palmar skin it has to be thinned. The best way is to reverse the skin and shave the subcutaneous fat until the avulsed palmar skin is converted into a deep dermal thickness graft, then reapply it as a graft.

To replace palm skin with a like skin, a medial plantar artery free flap can been done,\(^\text{16}\) but due to the donor site morbidity it has not become popular. Whatever flap cover is chosen for the palm, it needs to be thin or thinned secondarily. A bulky flap in the palm is like having something in the hand. Object holding is difficult. A radial artery fascial flap covered with skin graft is a good option for coverage of palmar defects.

Conclusion

For any defect in the hand, there will be quite a few good options for cover. One need not be doing every possible flap all the time. It is better to do what one is comfortable with, refine it and get the best possible results out of it. Repetition is the mother of skill. Having said that, it is also pertinent to point out that each flap, however well done, will have its limitations. Realization of that point and willingness to opt for alternatives at an appropriate time is the hallmark of a good surgeon.

The immediate satisfaction of the patient is in the coverage of the raw area, but long-term satisfaction
depends upon donor site morbidity. Long-term follow-up can convert many happy patients to demanding individuals. A classic example would be the use of the pedicle flaps from the forearm to cover hand defects. Though they may provide excellent cover, some patients do not like additional scarring in the same injured limb. Such patients would have been happier with a free flap or a distant pedicle flap. With time, patients forget the nature of injury they had and concentrate on the donor site problems. Hence, it is important to involve the patient in the decision-making process.

**Practice points**

1. Debride adequately before providing skin cover
2. Aim to achieve skin cover early
3. Think of future needs when you choose the type of skin cover
4. Large defects can be divided into critical and non-critical areas when deciding on flap cover
5. Act early when complications occur
6. Immediate patient satisfaction depends on wound healing, but long-term satisfaction depends upon donor site morbidity
7. Involve the patient in the decision-making process

**References**