Management of Penetrating Soft Tissue Injuries

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The management of soft tissue injuries are an important consideration in penetrating trauma. Numerous options are available to close any wound, so the challenge is to use the optimal method. In penetrating trauma, the surgeon should take into account a multitude of interrelated factors. These include the mode of injury, the site and extent of injury to the soft tissue and the underlying structures.

Most soft tissue injuries are due to gunshot, stabbing or contact with inanimate objects. Most gunshot wounds in a civilian setting are due to low-energy missiles. They create a minimal zone of injury confined to the tract and are characterised usually by a small entry and exit wound. The missile tends to separate the soft tissue rather than destroy it. In the limbs this could result in a fracture if bone is involved; however there is minimal necrosis of soft tissue and the associated fracture tends to be relatively simple. Low-energy injuries require local surgical debridement.

High-energy injuries are quite different from their low-energy counterparts. There is a tremendous amount of energy delivered to the tissues. The entry wound may be relatively confined, but the exit wound is usually larger and the tissue in the path of the projectile is usually severely damaged by the expanding shock wave caused by the transmitted high energy. Tissue some distance from the path of the missile is invariably damaged. Associated fractures are usually comminuted, and the bone may be missing. The fractured bone fragments may themselves become secondary missiles and cause further damage to the surrounding tissue. Operative debridement is mandatory and must include exploration of the entire path of injury, including the entry and exit wound. Soft tissue exploration needs to be extended in some distance from the projectile path and all devitalised tissue debrided.

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68.1 Patients with Multiple Injuries

Patients with multiple injuries present a particular problem or set of problems to the treating team. When planning soft tissue closure, the surgeon should be aware of how the various injuries affect both the medical and the surgical management of the patient. Since certain injuries may at times have to be prioritised, it is not always possible for the surgeon to perform the surgical treatment that will provide both ideal form and function. For example, in these cases, a split-thickness skin graft (STSG) may be required in order to close the defect and allow earlier recovery of the patient, even though a more complex procedure would provide a better overall result. This can be seen in gunshot wounds involving the lower leg or forearm with an associated fracture which requires a fasciotomy. The fasciotomy defect would be closed a few days later either primarily or more commonly by a skin graft. The grafted area, although unsightly, can be corrected by serial excision or by the insertion of a tissue expander. This will allow for the complete excision of the skin graft and the return of the normal tissue in the area. It is therefore necessary that the trauma surgeon be experienced in plastic surgery techniques or preferably has access to a plastic surgeon. In complex wounds, the expertise of a plastic surgeon is of paramount importance.

Another point that the surgeon has to take into account is the age of the patient. Although advanced age is not a contraindication per se to complex reconstructive surgery, older patients often have coexisting medical conditions that may preclude a long anaesthetic, necessitating the use of the quickest and simplest method at the expense of form and function.

The surgeon should liaise with other specialists, for example, neurosurgeon or orthopaedic surgeon when planning complex reconstructive procedures. As an example, a compound fracture of the lower leg may be best covered by a local or regional flap, but when a free flap is considered as may be necessary in the lower third of the tibia, a free rectus abdominis flap may be preferable to a latissimus dorsi flap

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since this patient may need a strong shoulder girdle in order to use crutches during his recovery.

The timing of the reconstruction depends on the defect. In life-threatening defects, such as exposed viscera, joints and vessels, wound cover is indicated as early as safely possible. The wound may have to be further assessed, debrided to bleeding bone and tissue and covered ideally within 72 h of injury. Byrd et al. (1985) suggested that compound fractures of the tibia should be debrided radically, including debridement of the bone until bleeding is noted, and flap covered within 5 to 6 days after injury. He advocated that should cover not be achieved in that time, the wound becomes subacute within increasing risk of chronic osteitis. In support of Byrd's view, Godina (1986) and Yaremchuk (1986) showed independently excellent results when soft tissue cover was performed within 72 h of injury. These results emphasise the need for early stable cover of soft tissue wounds.

68.2 Wound Assessment

The wound should not be assessed in isolation, but the general condition of the patient should be determined and treatment prioritised. The wound size, location and tissue components have to be assessed and the need for replacement determined. The components may comprise of the skin, fascia, muscle, nerves, vessels, tendons, bone, joints, cartilage and mucosa. The presence of comorbid conditions should be noted. The need of replacing some or all these components has to be determined by the surgeon.

68.3 Fasciotomies

One cannot overstress the importance of not missing an acute compartment syndrome. The treatment of acute compartment syndrome involves urgent surgical decompression by fasciotomy. There should be a high level of suspicion, especially when there is pain out of proportion to the clinical situation. The presence of peripheral pulses does not exclude the presence of acute compartment syndrome since muscle and nerve ischaemia can occur in pressure below the diastolic pressure.

68.4 Nerve Injuries

In penetrating trauma, nerve injuries should be suspected if the injury is at or near the site of major nerves and any physical sign of neurological deficit is present.

Stab wound needs to be assessed and explored at initial surgery and the transected nerves repaired at the same time. An endoneural fascicular repair gives the best results, and a useful tip is to use the vasa nervosa to help align the transected ends. Early repair provides the best chance of recovery, since delay, especially if more than 7–10 days may make end-to-end neurorrhaphy difficult. This is because the nerve ends tend to retract, making tension-free repair impossible. Nerve grafts may then have to be used, resulting in a less favourable outcome than a primary repair. If the nerve is severely contused but macroscopically intact, a neurolysis (longitudinal splitting of the neural sheath) is indicated to release the endoneural pressure.

Gunshot wounds involving the peripheral nerves do not necessarily need immediate exploration. An expectant approach is usually employed since the nerve tends to have a neuropraxia from the shock wave and should show recovery within three months. Electrophysiological studies can often guide the surgeon towards making a diagnosis of the extent of injury and the need for late exploration.

68.5 Goals

The primary goals of reconstructive surgery are preservation of life and limb and restoration of form and function. Composite defect reconstruction can allow restoration of form and function and an improvement in the quality of life. Although these goals are not always attainable, one should nevertheless strive to achieve them.

There have been many advances in reconstructive surgery over the last 30 years with the introduction and establishment of muscle and musculocutaneous flaps, fascial and fasciocutaneous flaps, microvascular free tissue transfer and the use of tissue expansion. This has given the reconstructive surgeon many more options allowing one to customise the reconstruction and replace like tissue with like tissue.

The *reconstructive ladder* describes surgical options ranging from the simple to the more complex as one ascends the rungs (Fig. 68.1). Direct closure represents the simplest method, but if this is not possible usually due to the size of the defect, a more complex method of wound closure, such as a skin graft, would be needed. Skin grafting permits early wound closure but cannot be used over exposed bone, tendon and joints, and hardware or viscera. These complicated wounds would require a more sophisticated method of closure such as a local or regional flap, although local flaps may not be an option if they fall within the zone of injury (damaged adjacent tissue which is still viable). In such cases, a microvascular free flap may be required. Although the reconstructive ladder serves as a guide, the surgeon does not need to ascend the rungs when choosing an option for wound closure since the simpler methods do not necessarily provide the best functional and aesthetic result. The use of free flaps does not have more complications than the simpler methods. Free flaps have allowed superior restoration of form and

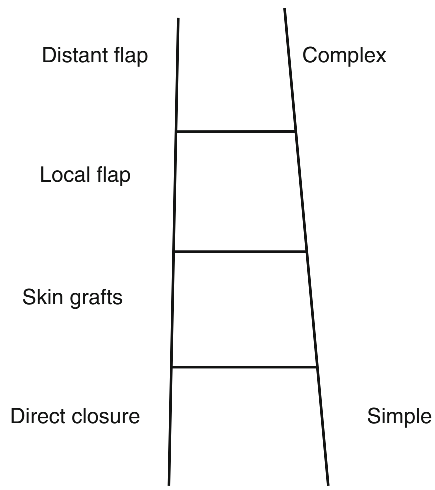

Fig. 68.1 Reconstructive ladder

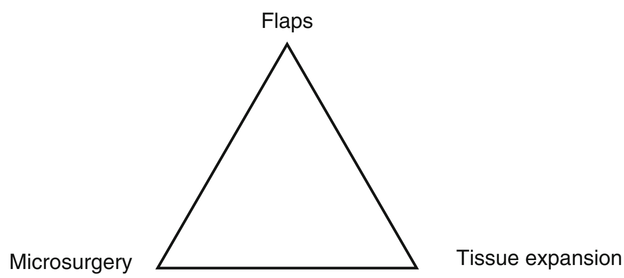

Fig. 68.2 Reconstructive triangle

function in many instances, the main disadvantage being that free flap failure can have disastrous consequences.

These recent advances in reconstructive surgery have led to the idea of the *reconstructive triangle*, which is more inclusive and practical (Fig. 68.2). This allows the surgeon to choose the optimal method of reconstruction with the least donor site morbidity. The best treatment can be chosen, be it flaps, microsurgical free flaps or tissue expansion.

68.6 Methods of Soft Tissue Cover

68.6.1 Direct Closure

This is best achieved in clean, uncontaminated wounds with free tissue bleeding following debridement. Closure should be performed in layers under no tension. Sometime surgeons tend to push the limit as to how much tension is permissible, and although we may get away with it in a younger, healthy patient, we may not be so fortunate in an older patient. It is important therefore to perform tension-free closure, if it is not possible to close the defect with a skin graft or flap.

In cases where there is extensive soft tissue damage, closure is usually delayed. In other words, after initial wound debridement, the wound is reassessed 36–48 h later at which time further debridement may be necessary prior to providing cover. This gives the tissue enough time to declare its viability.

68.6.2 Skin Grafts

Split-thickness skin grafts (STSGs) are thinner and therefore can survive on a recipient bed that has less vascularity than that needed by full-thickness skin grafts (FTSGs). An important advantage of STSGs is that they can cover a large area. A disadvantage of STSGs is that they are usually a poor colour and texture match with the surrounding normal tissue and they tend to contract. This contracture can be a particular problem in growing children since, unlike FTSGs, they do not grow with the child. STSGs are also less durable and should be avoided over pressure points if possible. Full-thickness skin grafts (FTSGs) are used for small defects, especially in the hands or face where quality and colour match are important. Most FTSGs are harvested in an elliptical fashion so that the donor site can be closed primarily, usually after some undermining of the edges.

A distinct disadvantage of skin grafts, in general, is that they cannot be used to cover exposed bone, tendon or joint as there is no direct blood supply to the overlying skin graft. These wounds can only be adequately covered by flaps.

68.6.3 Flaps

A flap is a unit of tissue that can be mobilised based on its blood supply. Since the transferred tissue depends on a blood supply, it is imperative that flap design incorporates a reliable vascular supply. Initially a *random pattern flap* was developed which involved raising a skin flap with a 1.5:1 or even 2:1 length to width ratio (Fig. 68.3). The flap could be rotated into the adjacent defect. The survival of such flaps depends on the circulation in the random subdermal plexus and a zone of injury confined to the defect. Random pattern flaps because of their relatively poor blood supply are not reliable in contaminated or infected wounds. Better understanding of the blood supply of the skin led to the introduction of *axial pattern flaps*. These flaps are based on an underlying longitudinal vascular network, resulting in a flap design not limited by the length to width ratio but by the length of the underlying vessels (Fig. 68.4). These flaps are more robust and resistant to infection. Examples of axial pattern flaps include the deltopectoral (internal thoracic vessels), lateral forehead (superficial temporal artery), dorsum of foot (dorsalis pedis artery) and superficial groin flaps based on the superficial circumflex iliac artery.

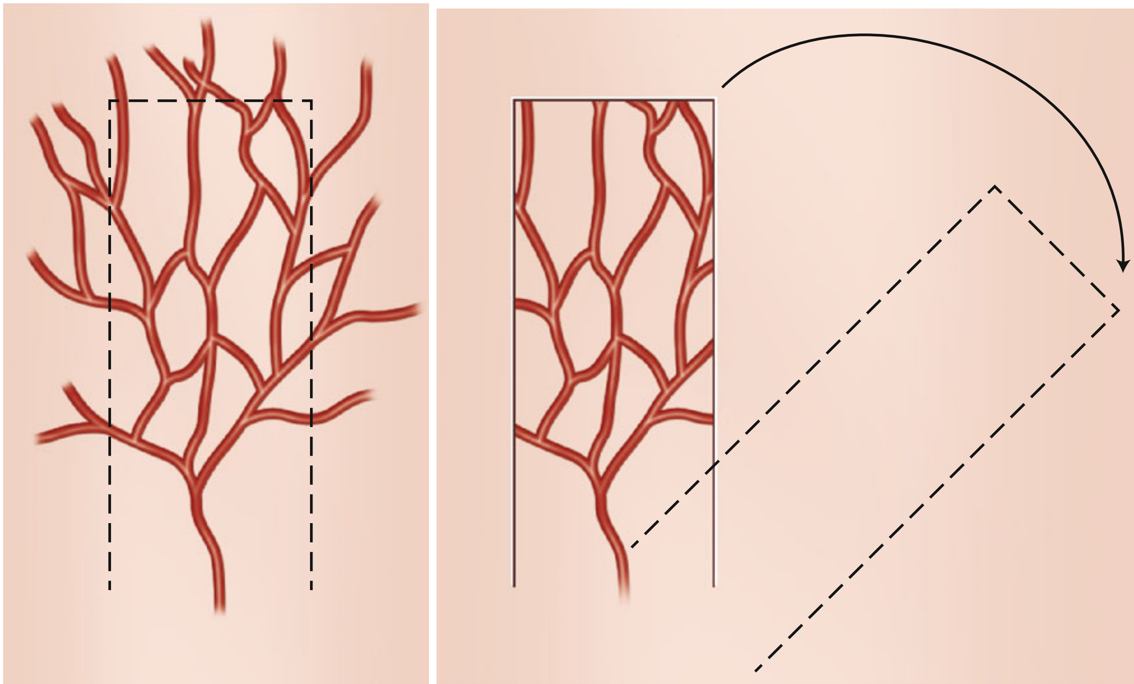

Fig. 68.3 Random pattern flap

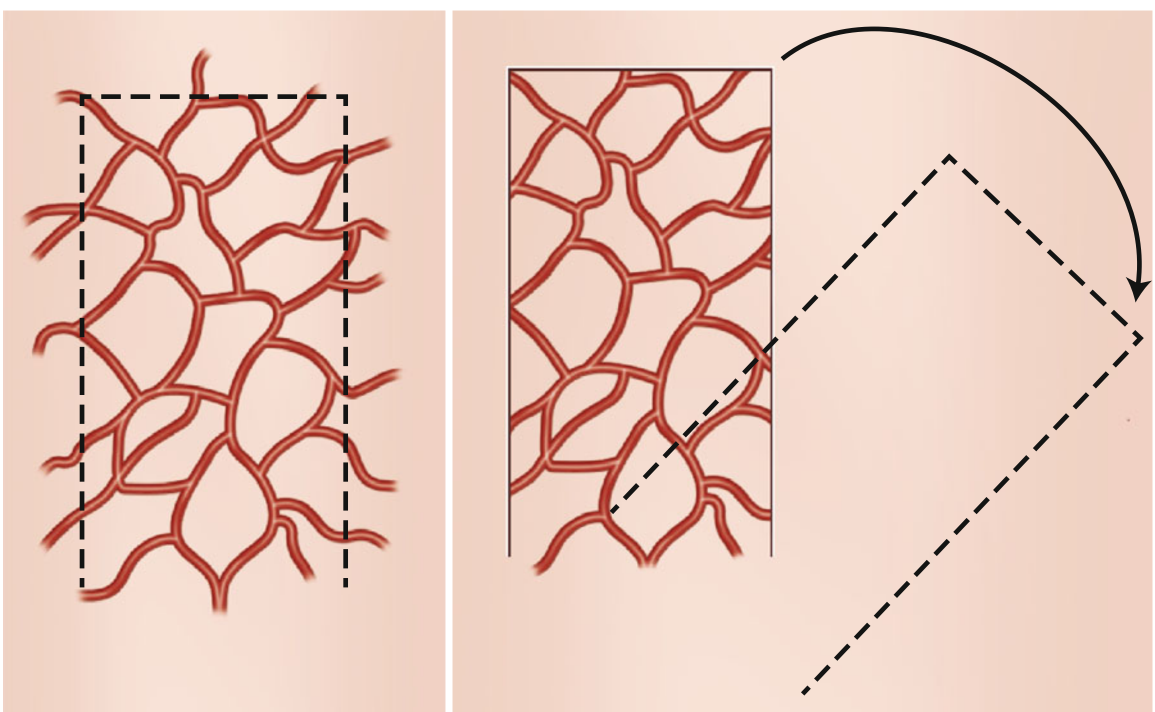

Fig. 68.4 Axial pattern flap

68.6.3.1 Muscle and Musculocutaneous Flaps

Anatomical and vascular studies led Mathes and Nahai to describe muscle flaps based on their blood supply. The muscles, with or without the overlying skin, can be transposed as a flap based on the vascular pedicle. The dimension of the flap is then potentially those of the underlying muscle. By dividing the origin and insertion of the muscle, the flap can be rotated on its vascular pedicle allowing even great

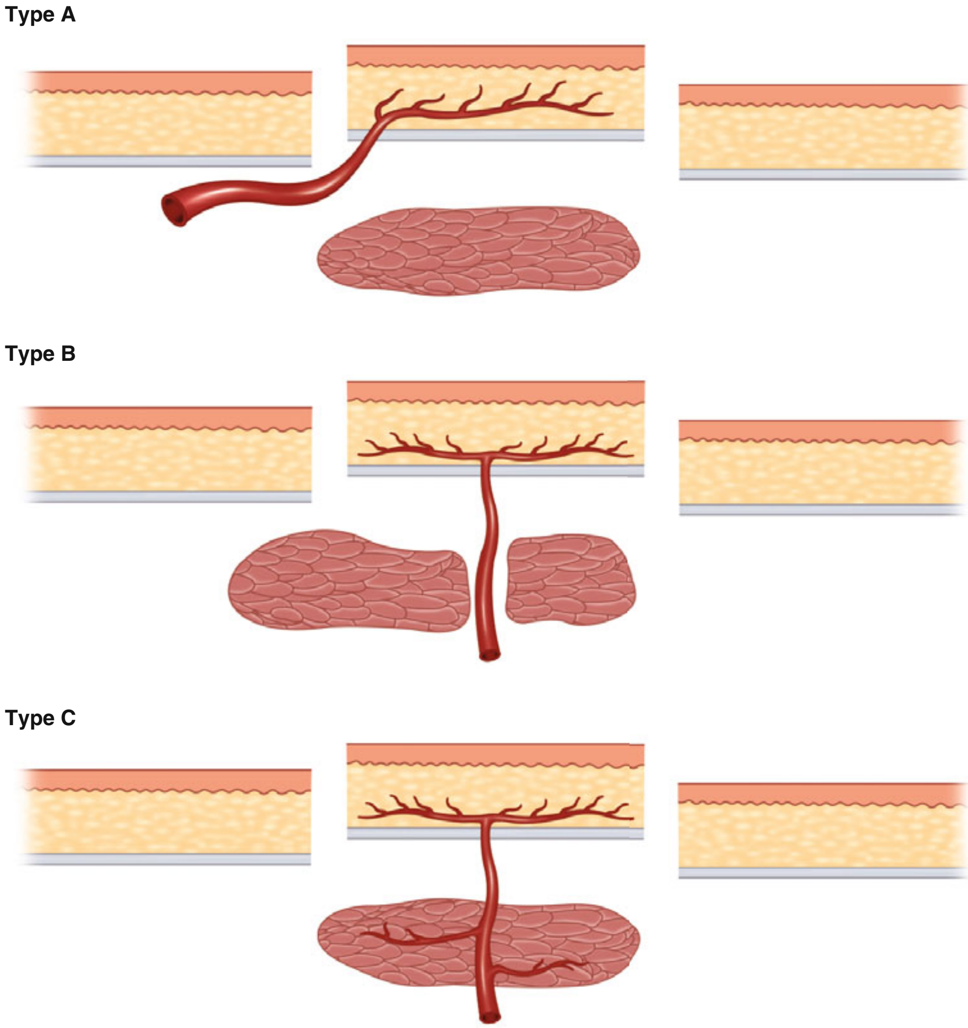

Fig. 68.5 Mathes and Nahai's classification of fascial and fasciocutaneous flaps

mobility of this flap. Examples of such flaps include the pectoralis major and the latissimus dorsi muscle flaps.

68.6.3.2 Fascial and Fasciocutaneous Flaps

Further surgical and anatomical studies led to the identification of vascular pedicles emerging between muscles and entering the deep fascia (Fig. 68.5). A flap could now comprise of the skin and its underlying fascia. A fascial flap consists of fascia transposed to another location without the overlying skin and fat; it forms a thin, pliable and delicate flap. A fasciocutaneous flap is in essence an axial pattern flap and includes skin subcutaneous fat and underlying fascia. The fascia may be separate from the fascia covering the muscle. Mathes and Nahai classified fascial and fasciocutaneous flaps as types A, B and C. The fasciocutaneous system consists of perforating vessels arising from the original arteries which travel in the fibrous septa between muscle bellies or compartments.

Type A fasciocutaneous flaps are also referred to as axial flaps. The vessel emerges from the original source and courses initially deep to the fascia before continuing into and then superficial to the fascia to supply the overlying skin territory. Examples of such flaps are the groin flap, the sural flap and the temporoparietal fascia flap (Fig. 68.5).

Type B fasciocutaneous flaps have a septocutaneous pedicle between major muscle groups in the intermuscular septa or between adjacent muscles. These pedicles are fairly constant in location and can be raised without the underlying muscle. Examples of such flaps include the dorsalis pedis flap, scapular flap and radial forearm flap.

Type C fasciocutaneous flaps have their supplying vessels passing through the underlying muscle. When raising these flaps, the dissection must follow the vessels through the muscle to the original source or incorporate part of that muscle in the flap design.

Type C flaps are commonly used as free flaps. The deltopectoral and anterior thigh flaps fall into this category.

68.6.3.3 Perforator Flaps

Perforator flaps are indicative of further refinement in flap design. These flaps have evolved from musculocutaneous and fasciocutaneous flaps without the muscle or fascial carrier, since neither the muscle nor the fascia is crucial to flap survival. These flaps do however require meticulous dissection to isolate the perforator vessels. An important advantage is that the muscle is spared with less functional deficit and the donor site tends to be small and can be closed primarily. These factors lead to a quicker postoperative recovery.

68.6.3.4 Free Flaps

Plastic surgeons are most commonly asked to cover soft tissue defects in the lower leg, ankle and foot. The use of free flaps is now commonplace in plastic surgery. Microvascular techniques have allowed the transfer of complex units of tissue comprising of the skin, fascia, muscle and even bone to cover complex defects. The advantage of free flaps is that large defects can be covered regardless of the site of the defect.

Many free flaps are available, but in the trauma setting, a number of points should be noted. The initial trauma can cause widespread damage, and therefore the relatively long pedicles of the free flaps commonly used in lower leg reconstruction allow the anastomosis to take place outside the zone of injury. Sometimes a vein graft may be required to gain adequate pedicle length. The status of the local vascular pedicles is best assessed at the time of initial debridement, since one of the main causes of free flap failure is poor recipient vessels.

Composite free flaps allow the en bloc reconstruction of complex multidimensional defects. For example, in a gunshot wound to the face where the defect is complex, a scapular composite free flap would allow the skin, bone and muscle to be used to provide for oral lining and restoration of the missing maxilla or mandible and cheek and all this can be performed with a single free flap. The fibula free flap in mandibular reconstruction is a further example of a complex free flap.

Flap prefabrication is a further advance where, for example, in a case of traumatic loss of the nose, a radial forearm fasciocutaneous flap is raised and a cartilage framework with a skin graft to provide mucosal lining allows for a nose to be reconstructed within the flap. A few weeks later the prefabricated flap comprising a lining for the mucosal surface, a cartilaginous framework and the skin can be raised as the prefabricated radial forearm flap and microanastomosed to the facial artery to reconstruct a nose.

68.6.4 Tissue Expansion

The skin and soft tissue adjacent to the defect offer the best cosmetic result since the colour, texture, contour and thickness are the same. Often the size of the defect and the associated zone of injury prevent the immediate use of adjacent tissue reconstruction. A solution to this problem is to use a tissue expander. Tissue expanders can be used once the initial injury has been covered, usually by a skin graft. The tissue expander is inserted adjacent to the closed defect, and after a few weeks, it is gradually and serially inflated with normal saline allowing an increase in the dimensions of the expanded skin and recruitment of surrounded tissue (Fig. 68.6). Once enough tissue has been expanded, the expander is removed, the defect excised and the expanded skin advanced to cover the defect. Tissue expanders are used routinely in breast and scalp reconstruction and in burn scar rehabilitation.

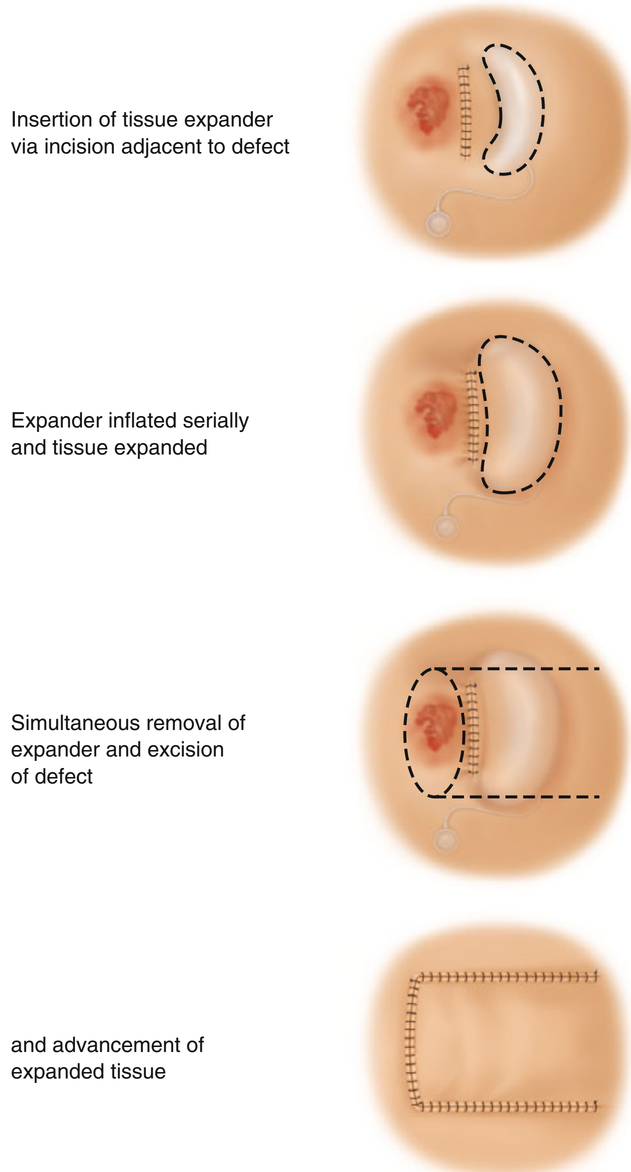

Fig. 68.6 Tissue expansion

68.7 Summary

In summary, soft tissue injuries range from the minor to the devastating and life threatening. Management involves full and careful assessment both preoperatively and during initial surgery. The best result will offer a successful reconstruction and restores both form and function. Choosing the best treatment involves a thorough knowledge of the various methods of soft tissue cover and reconstruction.

Important Points

- Careful assessment of the patient is critical.
- Prioritise treatment.
- Rule out or treat acute compartment syndrome.
- Communicate with other specialists.
- Simplest is not always best, especially in the long term.
- Be aware of other injuries and treat appropriately.

Recommended Reading

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