

Management of Post-Traumatic Composite Bone and Soft Tissue Defect of Leg

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Abstract

Management of composite defects of leg following trauma requires a planned ortho-plastic approach right from the outset. Timely, planned intervention results in reduced amputation rates and improved limb salvage and function. Right from the time of presentation of the patient to the emergency with such injury, the process of decision making in terms of salvage or amputation, local flap cover/ free flap cover, bone reconstruction first or soft tissue or both combined, come into play. Guidelines on management are unclear for such defects, a literature search yielding various methods being used by different authors.

This article is a review of current literature on management of composite leg defects.

A summary of the literature search in terms of various management options given by various authors including the rationale, advantages and disadvantages of each strategy has been provided in this article. The management protocol and method followed by the author in his institute for management of such composite defects have been described in detail. The article seeks to provide readers with an understanding of the management strategies so that appropriate method could be chosen to provide best result.

Keywords

- ▶ bone defect
- ▶ composite defect
- ▶ leg trauma
- ▶ lower limb trauma
- ▶ free fibula
- ▶ free flap
- ▶ distraction
- ▶ Ilizarov

Introduction

Road traffic accidents are a major cause of disability throughout the world,¹ and are projected to be the third largest contributor to global disease burden by 2020.²

Management of complex acute lower limb trauma requires an orthoplastic approach to prevent amputation and provide the best possible functional outcome.³ The mechanism of injury, the type of injury, age of the patient, general condition of the patient at presentation, other comorbidities, and the time delay from injury to presentation,⁴ all play a part in deciding which management pathway to take.

Many authors have described many different techniques of wound cover and varying order of reconstruction. We provide an organized summary of current literature and also author's preferred methods in such defects. This article should provide the reader with an overview of available management options and help make decision on providing appropriate wound cover.

Methods

A PubMed search was made for current literature on the management of composite lower extremity defects. Search words used were “free flap, lower extremity trauma, bone defect, distraction, reconstruction, muscle flap, fasciocutaneous flap, bone reconstruction of lower extremity, composite defect.” Currently available meta-analysis, systematic reviews, and CME articles were reviewed. Author's choice of treatment in each situation mentioned with reasons for choosing the same. This article is a literature review, and is not a systematic review.

Classification of Defects of Leg Trauma

Compound fractures have been classified by Gustilo-Anderson⁵ and is the most commonly used classification despite its limitations. It does not tell us about the bone loss and its extent when present. As the management options would differ depending on the size of bone defect, this classification system



is less useful in composite defects for decision making. All the wounds with composite defects would be either IIIB or IIIC depending on intact or absent vascularity, respectively.

Thus, for composite defects involving bone loss and soft tissue loss, in terms of reconstructive options, Swartz and Mears proposed another classification system.⁶ This classification is specific for composite defects and helps in making appropriate plan for reconstruction.

- Group 1: Soft tissue defects
- Group 2: Soft tissue and bone loss less than 8 cm
- Group 3A: Massive soft tissue and bone loss greater than 8 cm
- Group 3B: Contaminated wound
- Group 4: Bone defect only

We further classify Group 2 into 2A which has bone loss less than 3 cm and 2B with loss more than 3 cm but less than 8 cm. This is because the treatment differs for each of these groups.

Types of Bone Loss

Based on our observation we classify the bone loss in trauma as primary or secondary.

Bone loss occurring as a direct result of trauma or after immediate debridement is termed as primary bone loss. Primary loss can be a result of high velocity injuries like blast injury, gunshot injury or as a result of debridement following trauma (►Fig. 1A). Loose bone fragments are removed during debridement which could result in significant bone loss (►Fig. 1B).

Secondary bone loss occurs as a result of prolonged exposure of the bone to environment. This happens in neglected cases of trauma, or when early cover is not possible due to medical reasons. Exposed bone is prone for necrosis. If not covered early, this bone becomes nonviable (►Fig. 2A). In such cases, nonviable bone needs to be excised and the resultant bone gap managed (►Fig. 2B).

Initial Evaluation

First the patient has to be evaluated as a whole. Resuscitation and management of all associated life-threatening injuries take precedence over limb injuries. In these cases, treatment of extremity injury has to be limited only to stabilization of extremity and control of bleeding.

Following this, the field dressing should be removed and any significant bleeding should be immediately controlled



Fig. 1 (A) Contaminated compound fracture of both bones of leg. (B) Post-debridement status with external fixator in place and bone loss. (C) X-ray of same patient showing bone loss. (D) Latissimus dorsi free flap done. (E) Ilizarov fixator applied after 1 month of free flap. (F) X-ray showing good consolidation of regenerate. (G) Healed wounds with no limb length discrepancy.



Fig. 2 (A) Nonviable tibia, due to prolonged exposure. (B) Post-debridement bone loss as seen on X-ray. (C) Defect covered with latissimus dorsi + serratus anterior free flap in first stage. (D) Ilizarov fixator applied after 1 month of free flap and patient can ambulate immediately. (E) X-ray showing good consolidation of the regenerate. (F) Healed wound with no limb length discrepancy.

with direct pressure, tourniquet, a compressive dressing, or proximal clamping (in that order of preference).⁷

The limb is then examined to look for vascularity and the extent of soft tissue and bony loss, if possible. Vascularity is assessed by looking for capillary refill and blood flow on pin prick to the toes. Dorsalis pedis/anterior tibial and posterior tibial vessels are also palpated. When not palpable, hand-held Doppler probe is used. Neurological examination is then performed. Most of the time, accurate wound assessment is only possible under anesthesia in the operating room.

Salvage versus Amputation: Decision Making at First Examination

In extensive limb injury, amputation may be a simpler, more economically feasible option with reduced hospital stay.⁸ However, limb salvage is shown to be more psychologically acceptable,⁸ and hence whenever possible, salvage of injured limb has to be attempted. The aim in lower limb reconstruction is to achieve stable skeletal fixation and soft tissue cover which would give the best results in terms of bony union, sensory, and motor function.⁹

Systemic factors, extent of local injury, socioeconomic factors, and age of the patient all play an important role

in ultimate decision of whether to salvage the limb or to amputate. Tibial nerve disruption has been considered an indication for amputation by some.¹⁰ Most studies, though, point out that loss of plantar sensation alone does not necessarily indicate nerve disruption and is not an appropriate indication for amputation.^{7,11}

Several lower extremity injury severity scores have been described—mangled extremity severity score,¹² predictive salvage index,¹² injury severity score,¹³ new injury severity score,¹³ Ganga Hospital Score¹⁴ though clinical utility of none has been established.¹⁵ These scores are predictors of amputation. They can at best be used as a guideline, though decision of salvageability has to be individualized in every patient. Further decision on salvageability can be made after the debridement under anesthesia. Debridement has been described in the following section on management.

Management of Salvageable Lower Limb in Complex Trauma

The basic principles in the management of acute lower limb trauma include early radical debridement, re-establishment of vascularity of limb, skeletal stabilization with external fixator or plating, early wound cover with well-vascularized tissue, and bony reconstruction.^{16,17}

The cornerstone in the management of such defects is early, radical debridement under tourniquet control which permits early wound cover and minimizes chances of infective complications.¹⁸ Bony fragments with no or minimal soft tissue attachment should be removed. Vascularity of the tissues left behind is confirmed after tourniquet deflation. A knowledge of normal appearance of various structures is essential in deciding the extent of debridement.¹⁹ Debridement around intact nerves is done conservatively, making every attempt to preserve the nerve.

Copious irrigation of the wound should be done with normal saline. Some advocate pulse lavage, and studies have shown it to reduce bacterial count in chronic wounds,^{20,21} though its role in acute mangled extremity has not been studied extensively. There is some concern that pulse lavage can be damaging to the tissues by driving wound contaminants deeper. The author's practice is to use sharp surgical debridement under tourniquet control and loupe magnification in all cases followed by copious wound irrigation with saline. The end point of debridement is completely healthy tissue with good bright red bleed. Sequential debridement may be needed in cases of severe crush injuries. It is a prerequisite that the wound is undoubtedly clean before soft tissue coverage.

Options for the Management of Composite Lower Limb Traumatic Defects

Primary bone shortening with later distraction,^{22,23} free fibula flap,^{24,25} and reconstruction of soft tissue first followed later by bony reconstruction^{26,27} are all options available. The decision on the order of reconstruction and methods needs to be tailored depending on the size of bone loss and extent of soft tissue damage. The options available are as follows:

- Acute bone shortening and primary closure with or without later distraction.
- Early soft tissue cover followed by distraction osteogenesis.
- Vascularized osteocutaneous flaps.
- Soft tissue cover and nonvascularized bone grafting.
- Allografting after soft tissue reconstruction.

Acute Bone Shortening and Primary Closure with Later Distraction

Shortening and primary closure are possible in small bony defects with minimal soft tissue loss and when there is no wound contamination. In bone loss of more than 1.5 cm initial shortening and wound closure are followed later on by distraction with Ilizarov or other methods.^{22,28} Theoretically, there is no limit to the amount of lengthening that can be achieved with distraction osteogenesis.²⁶ In practice different authors have reported varying lengths of bone gap bridged by acute shortening and later distraction, ranging from 19 cm²² to under 10 cm²³ and to not more than 25% shortening²⁹ compared with normal leg. Some authors have recommended using the peripheral pulse as a guide to decide on the amount of shortening,^{30,31,32} as excessive shortening can cause vascular kinking and distal ischemia.

In our opinion primary shortening and soft tissue closure are not the ideal method for defects exceeding 3 cm bone loss.

In such cases, shortening results in soft tissue bunching making closure difficult and under some tension.

Another limitation of acute shortening is the need to shorten the fibula in the absence of fibular bone loss.²³ This would take away the stabilizing effect that an intact fibula would have provided. It requires more soft tissue dissection and increases possibility of vascular injury.²³

Early Soft Tissue Cover Followed by Bony Reconstruction

This is a staged procedure where the initial management is early radical wound debridement, use of external fixator for bony stabilization, and soft tissue cover with a free flap. The choice between muscle and fasciocutaneous flap is dependent on defect characteristics. Muscle flaps have generally been considered better than fasciocutaneous flaps in open lower extremity wounds.^{33,34} But recent studies show that functional outcome and limb salvage rates are similar whether muscle or fasciocutaneous flaps were used.^{24,35,36} Latissimus dorsi muscle flap is preferable when large pliable tissue is required. In cases where secondary procedures are needed, use of fasciocutaneous flap is preferred.³⁶ When secondary procedure are required, fasciocutaneous flap is preferred like the anterolateral thigh flap and when large pliable flap is needed, latissimus dorsi is used. If a large fasciocutaneous flap is harvested, like an anterolateral thigh flap, donor site needs to be skin grafted,³⁷ whereas latissimus dorsi muscle flap donor site is always primarily closed.

This is followed later by either distraction osteogenesis or use of free fibula flap. Among the two options, distraction osteogenesis is preferred as use of a second free flap in the same region is technically challenging. Recipient vessel availability may be a problem in such situations. A combination of distraction osteogenesis along with free tissue transfer has been shown to be the better reconstructive option in composite defects.^{26,27}

With regard to the timing of free flap reconstruction of traumatic defects, several earlier studies had shown better flap survival and outcome following reconstruction within 1 week compared with reconstruction after 1 week.^{16,38} Recent studies however suggest that because of better trauma and surgical management, no such time interval affects flap survival or infection rate.^{39,40} Authors prefer early cover, however in late presentation, it is our practice to apply vacuum assisted closure dressing till the time patient is fit for flap surgery.

After initial debridement, external fixation of bone and soft tissue coverage in the form of local or free flap is performed. The type of soft tissue coverage depends on the size of the defect and the condition of surrounding muscles and skin.

In smaller wounds with healthy surrounding tissue, upper one-third of leg wounds can be managed with either medial or lateral gastrocnemius flaps or distally based anterolateral thigh flap. In middle one-third leg wounds, soleus flap proximally or distally based fasciocutaneous flaps may be used. In distal one-third leg wounds, reverse sural flap, propeller flaps, or distally based perforator flaps are good options.

However, in high energy trauma, the size of wound is large and surrounding tissues are traumatized and cannot

be used as flaps. In such situations, free flaps are the only option. Latissimus dorsi is our workhorse flap in cases of lower limb reconstruction due to the large size of the muscle, pliability, large diameter of vessels, and long vascular pedicle (~8–10 cm). The muscle covers the defect and fills in any wound cavities. Other flaps such as anterolateral thigh fasciocutaneous flap and rectus abdominis muscle flaps have also been used. For a relatively smaller defect, gracilis muscle flap and serratus anterior muscle flap can also be used. When for some reason free flap cannot be performed, cross leg flap is performed. The advantage of providing immediate soft tissue cover is that it fills up the dead space in the wound cavity and provides good vascular cover to the bone ends thus preventing osteomyelitis of the bone.

After soft tissue healing, which is usually 3 to 4 weeks, external fixator is removed and distraction osteogenesis is started for bony reconstruction. Distraction osteogenesis can be done by Ilizarov ring fixator or other methods like the limb reconstruction system (LRS) and distraction over medullary nail.

An osteotomy is performed at a site away from the zone of injury,^{41,42} and the Hoffman external fixator or Ilizarov ring fixator is used to gradually transport the bone segment under carefully controlled mechanical conditions. As the transport segment is advanced, and the bone gap reduces, distraction osteogenesis generates new bone in the distraction gap, and restores bone mass and skeletal continuity.⁴² The docking site needs to be bone grafted in ~30 to 50% of cases.⁴³

Ilizarov ring fixator is used for distraction at the author's institute. The advantages of Ilizarov fixator are the ability to bear weight immediately and to correct any bony deformity that exists. It involves bifocal or trifocal osteosynthesis, compressing bone at one level to achieve union while simultaneously applying distraction to the same bone at another level to regenerate bone mass.⁴⁴ Extra focal, multilevel, multiplanar, and multidimensional fixation is possible. Distraction does not affect the vascularity of free flap. Studies have shown that there is no risk of free flap loss due to distraction.^{45,46} The vascular pedicle and the anastomotic site should be located in tissue that moves together with transferred flap.²⁶

The elastic fixation allows micromotion which is conducive for fracture healing.⁴⁷ There are also certain disadvantages of the Ilizarov technique, like need for special training, steep learning curve, and increased chance of pin tract infection.⁴⁸ The longer the period of distraction, the greater the chance of complications like pin tract infection.

The other distraction device used is the limb reconstruction system which is a uniplanar distraction device and is not as effective in correcting deformities.⁴⁹ It is also less stable than a ring fixator.⁵⁰ Infection rates have also reported to be less with ring than with LRS system, probably due to the smaller size of pins used in Ilizarov ring fixators.⁵¹ Lengthening over intramedullary nail has also been described with its advantage being shorter duration of external fixation; the disadvantages include more blood loss, increased cost, and more chance of infection.⁵²

Author's Practice

1. Early radical wound debridement and skeletal stabilization with external fixator. Early debridement is very important as open tibial fractures are prone to infection and malunion and need emergency debridement to remove devitalized tissue.^{53,54}
2. Soft tissue coverage within 72 hours, unless otherwise contraindicated, as early cover reduces flap complication rates.¹⁶ Early wound cover is essential to protect exposed tendons and nerves from dessication.⁵⁵ In the author's opinion, the adequacy of debridement can be assured by this time. Patient can also be stabilized and resuscitated well during this time.
3. Ilizarov ring fixator application and distraction after soft tissue healing (3–4 weeks). It has been our observation that if distractor is applied at the same time as free flap surgery, the anastomosis becomes technically difficult with requirement for long, special instruments as the rings would limit the surgical field access. We prefer to replace the regular external fixator with Ilizarov ring fixator after the wound has healed completely, which takes ~3 to 4 weeks.

For large and deep defects, latissimus dorsi is often chosen as the free muscle of choice for reconstruction.⁹ ►**Fig. 1** shows use of latissimus dorsi (LD) followed by distraction. In extensive defects, latissimus dorsi is harvested along with serratus anterior (SA) as chimeric flap.⁵⁶ ►**Fig. 2** shows the use of LD + SA flap reconstruction followed by distraction.

Other muscle flaps like gracilis and rectus abdominis may also be used for smaller defects. Fasciocutaneous flaps are also not used by the author in such defects as they are not able to fill the wound cavity. Only in cases where a free flap cannot be performed due to various reasons, a cross leg flap is performed. ►**Fig. 3** shows stages in management with cross leg flap.

At 3 to 4 weeks' time, the external fixator is removed and Ilizarov ring fixator is applied by the orthopaedic team. Distraction is done at a rate of 1 mm per day in four divided stages of 0.25 mm each time 6 hourly. The duration of distraction depends on the size of bony defect. Consolidation phase is usually twice as much as the distraction period. The ring fixator could be removed when radiological evidence of consolidation of regenerate is evident.

We have had 35 patients with composite defects of leg in whom free flap cover with LD was done followed by Ilizarov distraction after 3 weeks. Out of these, three patients had partial flap loss needing further procedure in the form of cross leg flap. Other patients had good flap take and bony healing.

Ilizarov fixator may also be used in the acute setting along with free LD flap for the reconstruction of soft tissue defect.^{48,57,58} This avoids the need for secondary surgery at 3 weeks to remove external fixator and apply the Ilizarov fixator. The only disadvantage is that doing a free flap with Ilizarov rings in situ is technically demanding, and is not practiced by the author.



Fig. 3 (A) Post-traumatic defect with external fixator in place in a single vessel limb. (B) Cross-leg flap done and stabilized with external fixator. (C) Ilizarov ring fixator applied after division and inset of cross leg flap (3 weeks after primary surgery). (D) Wounds healed well with no limb length discrepancy. (E) Good consolidation of regenerate seen on X-ray.

Vascularized Osteocutaneous Flap

When the bone loss in a composite limb defect is more than 6 cm, single stage soft tissue and bony reconstruction can also be done using free vascularized osteocutaneous flap^{24,25}

►Fig. 4.

The use of free fibula osteocutaneous flap can be done for long segment bone loss, when the soft tissue defect is not very extensive. The dead space around the bone may not be adequately filled by osteocutaneous fibula flap. In such cases, it is preferable to provide good soft tissue cover followed later by free fibula flap. In smaller defects, choice between free fibula and distraction osteogenesis is very individual as both have their advantages and disadvantages. Author's preference as mentioned is to use soft tissue cover followed by distraction.

Distraction is better in cases with shorter bone segment loss and in defects with extensive initial contamination/infection.⁵⁹ Major advantage of Ilizarov distraction is the possibility of immediate ambulation. Free fibula can be preferred for longer bone defects and in relatively cleaner wounds.⁵⁹ No difference in functionality has been observed with the use of either of the two techniques however, free fibula is combined with Ilizarov technique, it is doubly advantageous.^{60,61}

The advantages of single stage osteocutaneous reconstruction are reduced hospital stay and reduced number of surgical procedures.⁶² Free fibula is the most commonly

used bone flap for lower extremity reconstruction.⁵⁸ It has good bone stock, a long vascular pedicle,⁵⁸ and minimal donor site morbidity.⁶³ It provides a length of ~25 x 10 cm of bone²⁵ and a skin paddle of 32X14 cm can be obtained. It can also be harvested with muscles such as flexor hallucis longus and soleus for filling deep soft tissue defects.⁶⁴ The graft also hypertrophies with time.⁶⁵ It takes about one and half years for fibula to hypertrophy.⁶⁶ Detectable bony hypertrophy has been reported from as early as 3 months⁶⁷ to 2 years.⁶⁸ Patients need to be encouraged partial weight bearing with protection to promote hypertrophy and bone remodelling.⁶⁷ Primary bone union rate of 88.5% and average duration of 8.5 months have been reported.²⁴ The disadvantage of this technique, when compared with distraction, is the reduced strength of fibula graft in comparison with native tibia initially and the prolonged time it takes to hypertrophy. Refracture rate of 12.5 to 25.7%^{69,70} has been reported with free fibula. Donor site morbidity in the form of skin graft loss and peroneal nerve injury can also occur.

Free fibula transfer can be combined with Ilizarov ring fixator²⁶ which provides the advantage of immediate ambulation and correction of any developing deformity. ►Fig. 4 shows a compound fracture managed with free fibula and Ilizarov distraction.



Fig. 4 (A) Compound fracture of both bones of legs with contamination. (B) Post-debridement wound with external fixator in place. (C) Free osteocutaneous fibula harvested—13 cm. (D) Flap inset done. (E) Ilizarov fixator applied after 3 weeks. (F) Good hypertrophy of fibula at 10 months post-surgery. (G) Wound healed.

When free fibula is performed secondarily after an initial soft tissue cover, it is difficult to monitor the flap. Most of the times skin paddle is not taken along with the bone. Monitoring can then be done by hand held Doppler.

We had five patients in whom free fibula flap was done and two of those patients had Ilizarov fixator applied for fibula stabilization after 1 month time. No complications were seen in these patients. They all had good bone healing and fixators were removed between 8 months and 1 year.

Deep circumflex iliac artery flap along with up to 14 cm of ilium has also been described for lower limb reconstruction.^{6,71} A maximum safe skin paddle of 10x15 cm has been reported.⁷² The elevation of this flap is challenging and also the skin paddle is unreliable and bulky⁷³ with increased reported necrosis rate.^{66,72} Also, higher donor-site complication rates such as incisional hernia^{62,74} have been reported. Ribs with serratus anterior muscle⁶² and latissimus dorsi with lateral border of scapula have also been used⁷⁵ by some authors. Other osteocutaneous flaps like radius or metatarsals are not suitable for the reconstruction of tibial wounds.

Soft Tissue Reconstruction with Cancellous, Nonvascularized Bone Graft at the Same Stage or in a Second Stage

When the defect is less than 5 cm, nonvascularized bone graft can be used provided the surrounding tissues are healthy and there is enough vascular tissue around the graft.^{58,76} It is well documented that in long defects and in poorly vascularized surrounding tissues, nonvascularized grafts fail.^{77,78} Nonvascularized cancellous bone grafts are used to fill cavity defects and supplement osteosynthesis sites.⁴⁸

Summary

The amount of soft tissue and bone loss, the microsurgical expertise of the surgeon, and availability of orthopaedic surgeon trained in distraction osteogenesis techniques are all factors influencing the kind of reconstructive option in composite lower limb defects. There are different options available for soft tissue and bony reconstruction and the strategy appropriate for each patient has to be decided individually.

Single stage reconstruction in the form of primary bone shortening alone with wound closure is applicable for bone defects under 1.5 to 2 cm. Primary bone shortening of defects more than 2 cm requires secondary distraction. For large soft tissue and bone composite defects, primary soft tissue cover followed later by distraction osteogenesis proves to be the best form of reconstruction. This improved limb salvage, reduced deformities and resulted in better functional outcome of the limb. Free vascularized osteocutaneous or osteomusculocutaneous fibula flap is another option for single stage reconstruction of large composite defects. Ilizarov fixator can be combined with free fibula for early ambulation. The available options need to be weighed in each individual in terms of patient suitability and surgeon expertise for a particular technique.

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Authors have nothing to disclose.

Conflict of Interest

None declared.

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