Focus On
Management of traumatic bone loss

Introduction
Historically, limbs that sustained traumatic bone loss with associated soft-tissue injury were deemed unsalvageable and treated primarily by amputation. With current soft-tissue reconstruction techniques, it is now possible to obtain cover of large defects. However, what remains a challenge is the subsequent reconstruction of the bone defect while maintaining limb alignment and length.

Limb salvage procedures in this patient population are challenging, both for surgeon and patient, with no guarantee of a satisfactory outcome. In this review, we attempt to provide guidelines on how to approach the management of these injuries in the acute setting.

Classification of defects
Traumatic bone loss is a spectrum, from a small butterfly fragment through to complete loss of large sections of bone. There is no widely recognised classification of traumatic bone loss, either as the result of the injury or subsequent debridement. Perhaps the most commonly employed classification system for open fractures is that described by Gustilo and Anderson and then modified by Gustilo, Mendoza and Williams. Open fractures are classified according to the size and extent of the soft-tissue injury and the degree of contamination; bone loss is not part of this classification.

Robinson et al attempted to classify bone loss in tibial fractures (Table I) and this could potentially be applied to all long bone diaphyseal fractures.

Epidemiology
Significant traumatic bone loss is uncommon. As the tibia has a subcutaneous border its diaphysis is the most frequent area of bone involved. These injuries typically occur in young adults and the associated soft-tissue loss is usually Gustilo & Anderson grade III. When the fracture involves the metaphyseal and articular surface, the injury tends to be more severe because of the higher degree of energy transfer at the time of injury.

Management
Initial management. As with all fractures, the initial management should follow standard trauma resuscitation protocols. Once the primary survey is complete and the patient adequately resuscitated, the secondary survey is performed and an assessment is made of the injured limb. With severe limb trauma, a number of scoring systems have been described including the Mangled Extremity Severity Score (MESS), the Limb Salvage Index (LSI) and the Predictive Salvage Index (PSI). These scoring systems are to assist in the decision-making process as to whether the traumatised limb should undergo either primary amputation or salvage. Unfortunately, a recent study was unable to validate the clinical usefulness of any of the extremity injury scores and, as a result, scoring systems in this setting should be applied with caution. Large amounts of muscle loss, massive contamination and unreconstructable vascular injuries are probably indications for immediate amputation. In the past, the presence of an insensate foot was also a strong indication for amputation although not all authors would necessarily agree.

Once a decision has been made to attempt to salvage the limb, the soft tissues and bone need thorough debridement and the fracture must be stabilised. The initial debridement may result in a further loss of soft tissue and/or bone when grossly contaminated and devitalised tissue is removed. Skeletal stabilisation is required to restore alignment, eliminate gross movement at the fracture site, limit further soft-tissue damage and reduce bacterial contamination. Because of the unpredictable nature of these injuries, the method of skeletal stabilisation cannot be prescribed and an individualised approach is required. In the majority of cases with significant bone and soft-tissue loss, a temporary external fixator will be used to provide initial stabilisation. With limited bone loss, for example when a simple of wedge of bone has been lost, then immediate and definitive internal fixation may be used if the soft tissues allow.

Whatever method is selected to stabilise the bone, consideration should be given as to whether the overall length of the bone should be maintained or whether the defect should be reduced by an acute shortening procedure. This answer will depend on the length of the bone defect and the size and position of the soft-tissue loss. The
amount of acute shortening that can be tolerated in the adult tibia is approximately 5 cm.\textsuperscript{4} Acute shortening of more than this can result in distal complications such as oedema and venous occlusion.\textsuperscript{4} As an alternative, it is possible to combine an element of acute shortening with more gradual shortening to close larger defects.\textsuperscript{4} The advantage of acute shortening is that it may enable closure of a wound defect without the need for complex soft-tissue reconstruction. However, the obvious disadvantage is that a subsequent lengthening may subsequently be required.

If there is significant soft tissue loss after the initial stabilisation, early consultation with a plastic surgeon is advised. Definitive soft-tissue cover with skeletal stabilisation should ideally be achieved within 72 hours and should not be left for more than one week.\textsuperscript{10} **Definitive management.** The ultimate goal in the management of all fractures with bone loss is solid bone union, acceptable alignment, equal limb length and restoration of function.

If initial stabilisation has been with use of a temporary external fixator, and if the general condition of the patient and the local soft tissues allow, the surgeon should consider conversion to an alternative, definitive mode of fracture stabilisation within 72 hours.\textsuperscript{10} These include:

**Plate fixation.** With the advent of minimally invasive techniques and the use of locking plates, a fracture can be stabilised without significant further soft-tissue stripping. Wedge bone loss or short segments of complete bone loss can be bridged, with subsequent bone grafting of defects as required.

**Intramedullary fixation.** Most long-bone diaphyseal fractures of the femur and tibia can be treated with an intramedullary nail. This technique is also particularly useful for segmental fractures. An intramedullary nail should provide good skeletal stability, and enables early joint movement and improved functional recovery.

In cases with minor bone loss of less than 2.5 cm, an intramedullary nail to maintain the original bone length may be used. After this, delayed bone grafting or exchange nailing may sometimes be needed in order to achieve bony union. The femur has a good soft-tissue envelope and, therefore, may tolerate larger defects than the tibia.

With more significant bone loss measuring over 2.5 cm, an intramedullary nail alone is unlikely to be sufficient in the long term, and so a number of strategies may need to be considered, as follows:

a) Acute shortening with intramedullary fixation, and subsequent lengthening using an external fixator.\textsuperscript{11,12}

b) Acute shortening with intramedullary fixation and subsequent lengthening with a distractable nail.\textsuperscript{13}

c) Bone transport over an intramedullary nail.\textsuperscript{14}

**External fixation.** The use of circular external fixators in the management of bone loss is well established.\textsuperscript{15,16} The technique allows for the simultaneous treatment of bone loss, infection, non-union and deformity.

The results of initial management of traumatic bone loss can result in two scenarios:

1) Maintenance of overall length of the bone, with a defect that is typically > 5 cm in length.

Bone transport will be needed to manage this defect.\textsuperscript{17} This is a process in which the bone is divided proximally in order to produce a short segment, typically 5 to 10 cm in length. This segment is gradually moved distally with the external fixator, to eventually come in contact with the distal bone. The trailing defect fills with regenerate bone. At the time of distal bone contact (‘docking’), the site may be explored and bone grafted if needed.\textsuperscript{18}

2) An acutely shortened bone and no bony defect.

Shortening in this situation is typically < 5 cm. The restoration in length may be with an external fixator alone in conjunction with an intramedullary nail. The local soft-tissue environment where the bone has been lost will usually be traumatised and there may be local soft-tissue reconstruction required. This environment is not conducive to bone regeneration so an alternative site should be used with a better soft-tissue envelope. Consequently, the lengthening point is generally at a different point in the bone from the original fracture.

**Alternative methods to manage bone loss**

Although the use of an external fixator and internal fixation is the commonest method to manage traumatic bone loss, other surgical techniques can be used. These may be as follows:

**Vascularised free fibular graft.** The use of a vascularised free fibular graft to bridge a bone defect is a technically demanding procedure that requires microvascular surgical techniques.\textsuperscript{19,20} This method should be considered when there is a bone defect > 12 cm in size.\textsuperscript{21} Donor site morbidity can be problematic, although it may be possible to use the ipsilateral fibula when there is adjacent tibial bone loss.\textsuperscript{22,23}

**Allografts.** Insertion of an allograft into a defect is an attractive proposition as it avoids problems of donor-site morbidity and prolonged external fixation during either limb lengthening or bone transport.\textsuperscript{24,25} It is, however, associated with a lengthy recovery period to allow the allograft to incorporate into the host skeleton and complications including fracture\textsuperscript{26} and non-union.\textsuperscript{27,28}

**Conclusion**

Fortunately, extensive traumatic bone loss is an uncommon occurrence and, as a result, patients with major bone loss are perhaps best managed at larger trauma units. The transfer of a patient after adequate resuscitation should occur at an early stage. Significant bone loss will almost certainly be associated with extensive soft-tissue trauma, so a multidisciplinary approach between orthopaedic and plastic surgeons is essential. Complex soft-tissue reconstruction procedures may be required although with the judicious use of acute skeletal shortening, less complex techniques, or even primary wound closure, may be possible.

The orthopaedic approach to traumatic bone loss needs to be a flexible one. Treatment must take account of the amount of bone loss, any associated soft-tissue injuries, and the general health and wishes of the patient. Amputation must always be considered as an option, however difficult a decision that may be. In general, the management of the bone loss will require prolonged treatment times, especially with complex techniques such as bone transport. The patient must understand from an early stage that treatment that is likely to be long and difficult, the goal being solid bone union, acceptable mechanical alignment, equal limb length and acceptable restoration of function.
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References