Chapter 1

Timing and method of soft tissue reconstruction in patients with IIIb tibial fractures

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Introduction

Lower limb extremity injuries constitute a leading cause of hospital admissions among adolescents and young adults (18-54 years of age), accounting for almost 250,000 hospitalisations each year in the US [1].

For many centuries limb amputation had been the only option for patients disabled by a grossly traumatised or chronically infected lower extremity, with prosthetics providing satisfactory ambulation and support. In this present era when reconstructive options are many and varied, recognising a non-salvageable limb is perhaps the greatest challenge to the orthopaedic and plastic surgeon alike. Advances in fracture management, asepsis and microsurgical techniques have provided the basis for the development of limb salvage procedures and functional reconstruction.

H. Winnett Orr's method of plaster cast immobilisation of open extremity fractures, with wounds covered with dressings under a cast, largely ignored the principles of debridement of devitalised tissues as advocated by Pierre-Joseph Desault (1744-1795). Cases of osteomyelitis were all too frequent, prompting Joseph Trueta to undertake tissue debridement along with secondary wound closure, including the application of skin grafts to granulation tissue. This approach persisted between 1939-1942, but thereafter the importance of restoring the soft tissues over an open fracture within the first week of injury began to be appreciated, as evidenced by the incidence of post-fracture osteomyelitis following World War I (~80%), compared with that following World War II (~25%).

Within the last three decades the inception and development of free tissue transfer techniques for lower limb injuries [2] has revolutionised the management of open fractures and the prevention of osteomyelitis. Whatever the timing and method of reconstruction advocated in the many suggested protocols [3, 4, 5-13], the common aim remains the restoration or maintenance of limb function with expedient bony union and stable soft tissue coverage. More recently, attention has focused upon the additional goal of minimising flap donor-site morbidity [9, 13, 14] and a re-appraisal of the efficacy of free fasciocutaneous flaps as an alternative to muscle flaps for limb reconstruction [5, 6, 8-10, 14].

Methodology

Medline, PubMed and Cochrane databases were used to gather publications on open tibial fractures

Table 1. **Gustilo's revised classification of open fractures** [15].

Type I	**Open fracture** Clean wound <1cm in length
Type II	**Open fracture** Laceration >1cm long without extensive soft tissue damage, flaps or avulsions
Type III	**Open fracture** Extensive soft tissue laceration, damage or loss Open segmental fracture or traumatic amputation High velocity gunshot injuries Open fractures caused by farm injuries Open fractures requiring vascular repair Open fractures older than 8 hours
Type III subtype (1984)	
A	Adequate periosteal cover of a fractured bone despite extensive soft tissue laceration or damage High energy trauma irrespective of size of wound
B	Extensive soft tissue loss with periosteal stripping and bone exposure Usually associated with massive contamination
C	Associated with arterial injury requiring repair

using the medical subject headings 'tibial fractures', 'open', 'reconstruction', 'lower extremity', 'timing', 'treatment outcome'. Further publications were sourced from cited manuscripts.

Classification of open fractures

As with all classifications, the aim in the classification of open tibial fractures is to guide treatment and predict prognosis. Various systems have been proposed in an attempt to offer useful prognostic indicators and guide the optimal management plan [2, 11, 15, 16]. The most widely used classification is that of Gustilo, first outlined in 1976 [2] and modified in 1984 [15] (Table 1). The revised system divides Type III injuries into subgroups reflecting the state of the periosteum and adequacy of limb perfusion, but it has been criticised for inter-observer discordance [17, 18] and makes no allowance for nerve injury, crucial to treatment planning. Further attempts at classifying complex limb injuries have resulted in the Mangled Extremity Syndrome Index, Mangled Extremity Severity Score, Predictive Salvage Index and Limb Salvage Index. These indices are complicated and do not always accurately predict outcome [19].

Epidemiology

The annual incidence of open long bone fractures in the UK has been estimated to be around 11.5 per 100,000 population [20], with tibial diaphyseal fractures accounting for approximately 45% of such injuries. In the Edinburgh series of 515 open fractures in 474 patients over a six-year period, Gustilo IIIB fractures were observed in 10% of proximal tibial fractures, 30% of tibial diaphyseal fractures, 27% of distal tibial/pilon fractures and 5% of ankle fractures. Three quarters of tibial diaphyseal fractures occurred in males with a mean age of around 40 years, and 58%

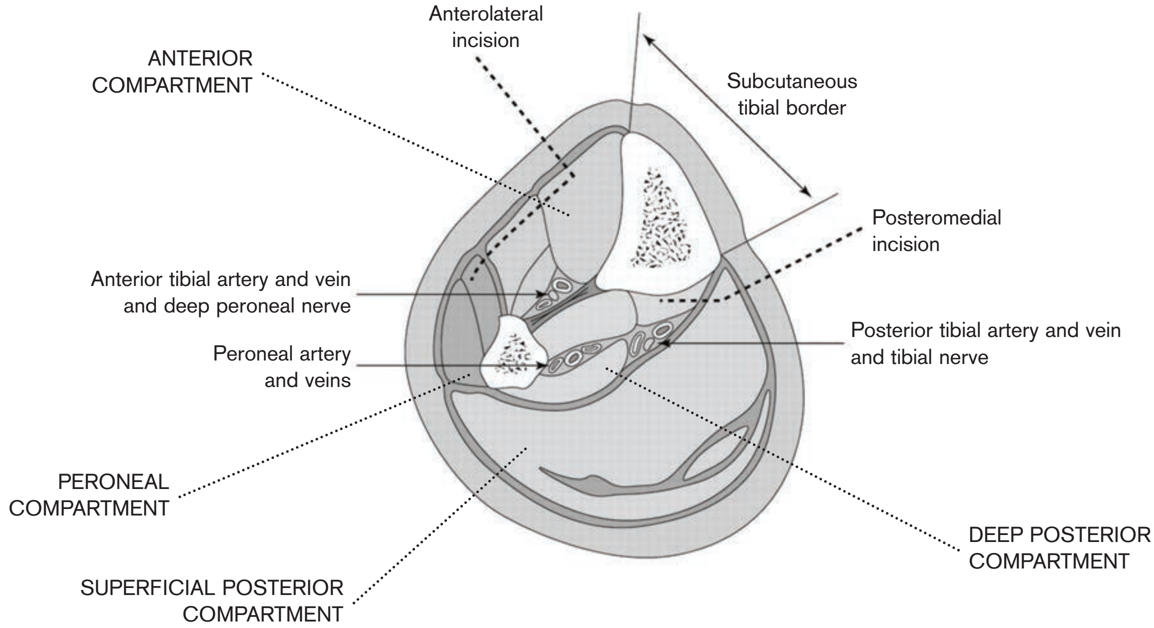

Figure 1. Double incision technique. *Reproduced with permission from the BMJ Publishing Group, © 2002. Pearse MF, et al* [28].

of all open fractures were high velocity injuries sustained in road traffic accidents. Similar observations were made in subsequent studies by Gopal *et al* [8] and Bosse *et al* [21]. This latter series of 545 patients identified predictors of poor outcome at two years, including readmission for a major complication, low education level, non-white race, poverty, lack of private health care, poor social support, low self-sufficiency, smoking and involvement in disability compensation litigation.

Compartment syndrome in open tibial fractures

The common misconception that open tibial fractures are not accompanied by compartment syndrome, on account of the associated soft tissue damage (automatically decompressing the compartment), does not hold true. A retrospective review of open tibial fractures in 180 patients by Blick *et al* [22] revealed an incidence of compartment syndrome of 9.1%. Compartment pressure measurements were made in the operating room on the day of admission after reduction and stabilisation of the fracture. Intra-compartmental pressure measurements over 30mmHg were deemed to be pathological and an indication for four-compartment fasciotomies using the double-incision technique described by Mubarak and Owen [23]. Compartment syndrome was found to be directly related to the degree of soft tissue and bony injury, and occurred most often in Gustilo grade III injuries in pedestrians. DeLee and Stiehl [24] observed that 6% of open tibial fractures were accompanied by a compartment syndrome - all Gustilo grade II injuries. In this study, the diagnosis of compartment syndrome was based on clinical findings alone.

Variations exist in the level of intra-compartmental pressure that constitutes a diagnostic value [25]. McQueen *et al* [26] recommend that decompression should be performed if the differential pressure level (i.e. diastolic pressure minus compartment pressure) drops to under 30 mmHg. When it is less than this, a fasciotomy should be performed unless there is clear evidence that the total tissue pressure is rapidly dropping and the differential pressure is increasing [27].

Pearse *et al* [28] also recommend the double-incision technique [23] for lower limb decompression (Figure 1), a technique that is endorsed by the Joint Working Committee of the British Association of Plastic Surgeons and the British Orthopaedic Association [27]. The superficial and deep posterior compartments are decompressed via an incision placed 1 2cm posterior to the medial border of the tibia. A second longitudinal incision 2cm lateral to the anterior tibial border decompresses the anterior and peroneal compartments. The medial incision should be anterior to the posterior tibial artery to avoid injury to the perforating vessels that supply the skin used for local fasciocutaneous flaps. When decompressing the deep posterior compartment, care must be taken to avoid damage to the posterior tibial neurovascular bundle which lies just deep to the investing fascia. With the lateral incision, exposure of the fibular periosteum or peroneal tendons is to be avoided as this increases the risk of delayed healing, infection, and ultimately amputation. Muscle viability is then assessed and all non viable tissue excised.

Timing of soft tissue reconstruction

The optimal timing for the provision of soft tissue cover to open fractures remains controversial. Current evidence indicates that bone infection is more frequently linked with hospital-acquired *Staphylococcus aureus* and aerobic gram-negative bacilli compared with any initial contaminating organisms [16]. Gustilo's landmark review of 1025 open long bone fractures, published in 1976 [3], recommended primary closure of all Type III fractures within five to seven days post-injury for the prevention of non-union and osteomyelitis. Similar recommendations were made in a later report by Russell *et al* [29] in which wound infection, non-union and amputation were all more frequent amongst patients in whom immediate soft tissue closure was achieved, presumably without adequate debridement, compared with those in whom wound closure was delayed but not beyond one week post-injury. Patient numbers were too small to permit statistical comparison. Beyond one week, however, there is clear evidence to demonstrate a worse outcome with regard to wound healing and bone union [3], although arguably the zone of injury is more easily defined following a more protracted period of repeated surgical debridement [10].

A significant contribution to the debate on timing of soft tissue cover emerged from the microsurgical reconstructions undertaken in 532 patients by Godina in Ljubljana in the late '70s and early '80s [6]. The findings of this series are summarised in Table 2. Definitive soft tissue reconstruction within 72 hours of injury translated into fewer failed flaps, a reduction in the incidence of wound infection, a reduced time to bone healing, fewer operations and a shorter hospitalisation time compared with reconstructions undertaken between 72 hours and three months post-injury or beyond three months. Furthermore, there is a measurable increase in wound bacterial count with time after injury and a transition from a contaminated to a colonised wound after day five with a concomitant increase in wound healing complications [4] (Table 3).

Gopal *et al* reported similar findings in their series of 80 Gustilo IIIB or IIIC tibial fractures between 1990 and 1998 [8]. Immediate (within 24 hours of injury) bone and soft tissue debridement and fracture stabilisation was undertaken and, where possible, flap reconstruction was performed in a single stage. Early (up to 72 hours post-injury) or late (beyond 72 hours) flap cover was achieved in the remainder. The series contained 75 free muscle flaps (58 latissimus dorsi, 10 rectus abdominis, 7 gracilis) with a flap failure rate of 3.5%. The observed incidence of deep infection was less following immediate soft tissue replacement (3%), compared with either the early (10%) or late (30%) reconstruction groups, but results lacked statistical significance. The use of external fixator devices was associated with pin tract infections (a proportion of which became chronic), an increased time to bone union, malunion and the practical problems resulting from reduced access for microsurgical anastomosis or even simple skin grafting.

More recently, the Lower Extremity Assessment Project (LEAP) Study Group reported on 601 patients in a prospective multi-centre study of wound-related complications occurring in 190 patients following high energy trauma to the lower extremity, of which 90% were classified as IIIB tibial injuries [30]. Wound-related complications requiring operative intervention were least prevalent when definitive wound closure was achieved between four and seven days post-injury (18%) and greatest when soft tissue reconstruction was undertaken beyond seven days (32%). When