Open supracondylar femur fractures with bone loss in the polytraumatized patient – Timing is everything!

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A B S T R A C T

Introduction: Open supracondylar femur fractures are rare, complex injuries which occur in polytrauma patients and are complicated by bone loss, contamination, compromised soft tissues, and poor host condition. The purpose of this study is to demonstrate a successful treatment protocol for these challenging injuries.

Methods: A consecutive series of 15 open supracondylar femur fractures in 14 polytrauma patients (ages 16–75, mean 41) were treated at one Level I trauma centre by a single surgeon. Fracture patterns included seven AO/OTA Type C2 and eight Type C3 fractures. All fractures were open and classified by Gustillo/Anderson as type IIIA (10 fractures) and type IIIB (five fractures). Stage I was performed within 24 h and included thorough open fracture care and early definitive fixation with a laterally based locking device and antibiotic bead placement. Stage II was performed several months later (average 3.6 months) when the soft tissue envelope had revascularized and the polytrauma patient had recovered from their other injuries. Stage II consisted of either an anterior incision or subvastus approach to the distal femur, bone grafting, BMP application, and addition of medial column support to create rigid fixation.

Results: All fractures (15/15) healed uneventfully. Union was determined by absence of pain and radiographic union in 3/4 cortices. Mean time to union was 4 months. There were no deep infections and alignment was maintained (average tibiofemoral angle of 5° of valgus) although several limbs were complicated by knee stiffness.

Conclusions: Healing of open supracondylar femur fractures with critical sized bone defects requires diligent surgical timing in order to optimise the host and wound bed. Thorough initial debridement and early definitive fixation halt ongoing soft tissue injury, restores length and alignment, and allow for stabilisation of the wound. After patients have recovered from their other injuries and the soft tissue sleeve has revascularized, bone grafting with BMP supplementation and medial column plating allows for rigid fixation of the femur and offers the biology these fracture patterns require for successful union without infection.

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Introduction

Open high energy supracondylar femur fracture with bone loss in the polytrauma patient presents unique therapeutic challenges when the pathway of limb salvage surgery is prescribed. Although amputation maybe the preferred reconstructive strategy for the multiply injured patient in extremis, limb salvage using a staged approach to care should be considered. Management factors to consider include the scope of open fracture care, type of skeletal stabilisation, soft tissue coverage, and bone grafting strategy.1

Arguably, however, timing of the reconstructive effort to achieve limb salvage is the most important factor to consider. The physiology of the severely traumatised host and local musculoskeletal environment deserve special consideration.2 Although, early skeletal stabilisation and open fracture care stops the cycle of injury, removes nidus for infection, and halts ongoing haemorrhage, it may be prudent to delay further reconstructive surgery until the host and local soft tissue conditions are optimised.2

The purpose of this study was to determine whether a staged protocol using thorough open fracture care, early fixed angle
bridge plating, and antibiotic bead usage followed by delayed autogenous bone grafting was an effective strategy for managing the polytrauma patient with an open supracondylar femur fracture and critical sized bone defect. We contend that a laterally locked bridge plate will maintain optimal fracture alignment until conditions are suitable for a bone grafting procedure. Secondly, thorough open fracture care in conjunction with antibiotic bead usage will minimise the chance of septic complication. Third, delayed bone grafting in concert with medial column plating in the optimised host and musculoskeletal sleeve will encourage optimal rates of bone union.

**Methods**

Between 2006 and 2012, a consecutive series of 15 supracondylar femur fractures with critical sized bone defects in 14 polytrauma patients were treated with a staged protocol at a single level one trauma centre. Retrospective analysis of both clinical and radiographic parameters was utilised to determine treatment outcomes. Primary outcomes measures included rate/time to union, alignment, knee functionality, and complication rate.

**Limb salvage protocol for open supracondylar femur fractures in the polytraumatized patient**

The multiply injured patient with an open supracondylar femur fracture was brought to the operating theatre within the first 24 h for thorough open fracture care and immediate skeletal fixation (Fig. 1). Radical soft tissue and bone debridement was performed. The articular block was anatomically fixed with lag screw fixation. The reconstructed articular segment was secured to shaft with a bridging laterally based locking plate (Fig. 2). Antibiotic beads (with either vancomycin, tobramycin, or both) were placed at the site of critical sized defect. A VAC system was used for soft tissue defects defying tension free closure.

Patients were brought back to operating room for second look debridement within 2-3 days in conjunction with antibiotic bead exchange. Subsequently, serial VAC changes were performed in the operating room until the soft tissues were closed. A reconstructive plastic surgeon was utilised for the definitive delayed closure or soft tissue coverage procedure. The decision for closure was based on maturation of the soft tissue sleeve and improving host parameters. Additionally, special attention was paid to optimising our polytrauma patient’s nutrition with protein enhanced supplements and high protein meals.

Timing of further reconstructive surgery was determined in the outpatient setting. Bone grafting combined with medial column plating was performed once the previous polytrauma patient had achieved both physical and psychological wellness. As determined by the general surgery trauma service, the patient was required to have resolution of associated injuries (head, chest, and abdomen) prior to continuation of orthopaedic reconstruction. Nutrition was optimised prior to orthopaedic reconstruction. Further, the local soft tissues associated with the previously open supracondylar femur fracture were required to be completely healed and remodelled which suggested re-vascularisation of the soft tissue envelope surrounding the bony injury. Lastly, psychologic disorder, namely transient depression and/or posttraumatic stress associated with the polytrauma event, was identified and treatment was initiated prior to further orthopaedic limb salvage procedure.

Definitive reconstruction of the supracondylar femur fracture consisted of retaining the locked lateral bridge plate, antibiotic bead removal, cancellous autograft with or without supplementation with allograft chips, bone morphogenic protein application, and medial column plating. Surgical approach was dictated by degree and location of bone loss. An extensile anterior approach as described by Henry was used most commonly (Fig. 3). However, a medial subvastus approach was used for more distal fractures with less extensive bone deficit. (Fig. 4).

Cancellous graft was harvested from the iliac crest when feasible. Alternative harvest site for autologous bone was used with history of previous pelvic or acetabular fracture or when body habitus (BMI > 35) precluded safe harvest from the iliac crest. The graft was packed into the biologic vascularised envelope left behind after antibiotic bead removal (Masquelet technique). Allograft chips were used as bone graft extender when necessary.
Bone morphogenic protein (BMP) in the form of a BMP-2 sponge (Infuse; Medtronic, Memphis, TN) or BMP-7 powder (OP-1; Stryker Biotech; Hopkinton, MA) was placed over the autogenous graft at the site of femoral defect prior to closure.

Rigid stabilisation of the distal femur was achieved via plate osteosynthesis of the medial column which complemented the existing lateral support. Plating was performed either direct medially or anteromedially and dictated by the existing indwelling hardware and the size of distal articular block. Small fragment combination plates were used most commonly.

Patients were non-weight-bearing for six weeks following bone graft procedure. Knee physiotherapy was instituted after surgical wound healing was evident at 2 weeks. Patients were followed to union with serial radiographic examination.

Union was defined as bridging bone on 3 of 4 cortices and resolution of pain in the supracondylar region (Fig. 5). In questionable cases, a computed tomography scan was used to assess uneventful bone healing across the critical sized femoral defect (Fig. 6).

Alignment was determined by the tibiofemoral angle, which is accepted to be on average 6 degrees of valgus. Tibiofemoral angles measured immediately postoperatively and at final follow up were all within our acceptable range.

Results

A consecutive series of fourteen polytrauma patients with 15 limb threatening open supracondylar femur fractures with bone
loss were identified from the trauma registry. Near equal proportions of men and woman were studied (8 men and 7 women) with an average age of 41 (range 16–75). Each patient had multisystem injury with associated injuries (ISS ≥ 16). High energy trauma was causative in all cases (motor vehicle accident n = 8, motorcycle crash n = 3, high energy fall n = 3, blast n = 1).

All high energy open supracondylar femur fractures had intra-articular involvement. Fracture patterns as defined by AO/OTA classification system included 7 Type C2 and 8 Type C3 injuries. All fractures were open and included 10 grade 3a and 5 grade 3b injuries according to the Gustillo Anderson classification. After thorough open fracture care, all supracondylar fractures were left with a critical size bone defect averaging 8 cm (range 2.2–11.7 cm).

The average time to the second stage of bone reconstruction which included antibiotic bead removal, cancellous bone grafting, BMP application and medial column plating was 3.6 months from the first surgery (range 1–6 months.) Successful bone union was realised in 100% of our cases (15/15). Time to union was on average 4 months (range 2–8 months). Tibiofemoral angles averaged 4.8 (−1 to 11) degrees immediately postoperatively and 5.0 (−6 to 13) at final follow up with an average change of 0.46 degrees (−2 to +5). No cases of infection were identified. Knee stiffness, however, was an undesirable effect of these injuries and our treatment protocol with an average motion arc of 2–88 degrees. Range of extension was 0–10° and flexion from 40–120°.
Discussion

As improvements have been made in emergency medical services and critical care medicine, polytrauma patients are surviving their life-threatening injuries and require functional orthopaedic reconstruction to promote wellness.9–11 Long-term functional outcomes of the multi-system trauma patient are often predicated on extremity trauma management.12,13 Complications such as nonunion, malunion, or infection after lower extremity reconstruction can have a profound negative impact on this unfortunate patient population.14 In this study, we have demonstrated that optimal union rates can be realised with staged mindful care of the polytraumatized patient with a limb threatening open supracondylar femur fracture with bone loss. Our approach was successful in avoiding both local and systemic complication by respecting the tenuous nature of the host and local soft tissue environment by delaying definitive reconstruction until the patient and soft tissue sleeve were optimised.

The initial care prescribed included thorough open fracture care and usage of antibiotic beads, which was successful in “sterilising” the wound bed as evidenced by a 0% incidence of deep infection. Further, usage of a locked lateral precontoured internal fixator at the index operation was integral for achieving alignment and stability. The plate bridged a critical size metaphyseal defect. The precontoured plate was used intraoperatively as a template to achieve adequate coronal alignment of the articular block to the shaft. Locked technology was especially useful for stabilising the often diminutive articular segment.15,16 Successful use of the internal fixation strategy was evidenced by no significant change in coronal alignment recorded when comparing immediate postoperative to final follow-up radiographs.

Delayed bone grafting optimises the likelihood of cancellous bone graft incorporation at site of bone defect after open supracondylar femur fracture. Each case in our series required only one bone grafting procedure to achieve union with defects up to 11 cm in size. The merits of delayed bone grafting have been recognised by Fisher and Gustillo et al.17 They identify that re-epithelialisation and vascularisation of the wound bed increases the rate of uneventful osseous integration after bone grafting. Several others have also concluded that maturation of the damaged soft tissues prior to bone grafting procedure provides superior incorporation of the graft with a diminished occurrence of infection.18–20

Usage of antibiotic beads as described in the Masquelet technique6 prepares the site of bone defect with a vascularised pouch ideal for cancellous autograft. Gardner et al. describe successful union in 9/10 open AO/OTA Type C3 pilon fractures with segmental bone loss utilising antibiotic beads for wound sterilisation.18 Donegan et al. also demonstrated successful use of antibiotic spacers in a heterogenous study including patients with both acute open fractures with bone loss as well as chronic infected and noninfected nonunions in the femur and tibia.19 They demonstrated successful, aseptic union in 10/11 patients identifying the versatility of this method to sterilise a wound bed and provide a useful biomembrane for implantation of bone graft at a later date. Further, Ostermann et al. describes the usefulness of local antibiotic therapy as evidenced by a decrease in chronic infection rates from 12% to 3% with the use of antibiotic beads in a large heterogenous population of Gustilo and Anderson grade I-IIb open upper and lower extremity fractures.21

Creating a rigid biomechanical environment at the second stage of care is integral for uneventful union and bone graft incorporation as evidenced by our reported 100% union rate. Addition of a medial plate to the distal femur creates bicolumbar fixation, which prevents deformity and promotes graft integration. Wang and Weng demonstrated the importance of stabilising the medial column to prevent varus, but they recreated it with cortical allograft struts.22 Chapman et al. used bicolumnar plate fixation in 15 patients treated for supracondylar nonunion with a union rate of a 100%.23

Bone morphogenetic proteins were used in our study to synergistically provide osteoinductive activity to the bone graft matrix.24–28 The cost and potential carcinogenic potential of BMP was balanced against the limb threatening nature of the fractures treated. Despite their profound bone forming capabilities, bone morphogenetic proteins must be used judiciously given emerging risks. Bone morphogenetic proteins have been implicated as a cancer causing agent with new reports from the FDA indicating an increased rate of cancer in patients treated with BMP2 as opposed to controls.29,30 It is crucial to make patients aware of the emerging risk when discussing use BMP as a potential treatment adjunct.

Despite the encouraging results demonstrated with our limb salvage protocol, certain limitations of this treatment paradigm deserve attention. Due to the staged approach prescribed, an extended treatment course is inevitable. The time course from injury to union averaged 8.5 months. With nearly a year of life spent attempting to salvage their limb, this process proved taxing for most patients. Further, despite a united well-aligned limb, knee dysfunction precluded normality in most patients. Final knee range of motion ranged from 0-10 degrees of extension and 40-120 degrees of flexion.

Conclusion

We have demonstrated the union of 15/15 open supracondylar femur fractures with critical sized bone defects in polytrauma patients. With thorough initial debridement, antibiotic bead placement for wound sterilisation, and restoration of length and alignment with a lateral locking plate at the time of initial surgery, we removed any nidus for infection and halted ongoing injury to the already tenuous soft tissues. Patients were then allowed to heal their other injuries in addition to their traumatic and surgical orthopaedic wound. After patients achieved physiologic and mental wellness and the soft tissues had revascularized sufficiently, bone grafting was performed in addition to medial column plating to achieve rigid fixation and prevent the femur from collapsing into varus. The combination of these orthopaedic principles in addition to diligent operative timing provided sufficient biology for all our patients to achieve union with no septic complications.

Conflict of interest statement

None of the authors of this manuscript have any conflicts of interest to report, including employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

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