Treatment of Segmental Tibial Fractures With Supercutaneous Plating

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abstract

Segmental tibial fractures usually follow a high-energy trauma and are often associated with many complications. The purpose of this report is to describe the authors’ results in the treatment of segmental tibial fractures with supercutaneous locking plates used as external fixators. Between January 2009 and March 2012, a total of 20 patients underwent external plating (supercutaneous plating) of the segmental tibial fractures using a less-invasive stabilization system locking plate (Synthes, Paoli, Pennsylvania). Six fractures were closed and 14 were open (6 grade IIIa, 2 grade IIIb, 4 grade II, and 2 grade I, according to the Gustilo classification). When imaging studies confirmed bone union, the plates and screws were removed in the outpatient clinic. Average time of follow-up was 23 months (range, 12-47 months). All fractures achieved union. Median time to union was 19 weeks (range, 12-40 weeks) for the proximal fractures and 22 weeks (range, 12-42 weeks) for the distal fractures. Functional results were excellent in 17 patients and good in 3. Delayed union of the fracture occurred in 2 patients. All patients’ radiographs showed normal alignment. No rotational deformities and leg shortening were seen. No incidences of deep infection or implant failures occurred. Minor screw tract infection occurred in 2 patients. A new 1-stage protocol using supercutaneous plating as a definitive fixator for segmental tibial fractures is less invasive, has a lower cost, and has a shorter hospitalization time. Surgeons can achieve good reduction, soft tissue reconstruction, stable fixation, and high union rates using supercutaneous plating. The current patients obtained excellent knee and ankle joint motion and good functional outcomes and had a comfortable clinical course.

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Segmental tibial fractures feature a unique fracture type characterized by a completely isolated intercalary osseous fragment separated by at least 2 distinct fracture lines. These fractures are usually the result of high-energy trauma and are often associated with significant morbidity caused by severe soft tissue injury, nonunion, delayed union, malunion, and osteomyelitis. Treatment modalities include nonoperative management, fixation with plates and screws, intramedullary nailing, and external fixator devices, and each modality has significant morbidity. Currently, the optimal management of these injuries remains controversial.

A locking plate, such as the less-invasive stabilization system (LISS) plate (Synthes, Paoli, Pennsylvania), is advocated as an internal-external fixator given its angular stable screw fixation. These properties make locking plates good candidates for external plate fixation. The purpose of this study was to evaluate the use of the LISS locking plate as an external fixator for the management of segmental tibial fractures. Analogous to so-called submuscular plating, the authors have coined this technique supercutaneous plating.

**Materials and Methods**

Between January 2009 and March 2012, twenty adult patients (12 men and 8 women) with segmental fractures of the tibia were treated at the authors’ institution using supercutaneous plating. Mean patient age was 36.9 years (range, 22-67 years). The fracture site was at the proximal middle third of the tibial shaft in 9 patients, the proximal distal third of the shaft in 5 patients, and the middle distal third of the tibial shaft in 6 patients. The fractures were classified according to the AO classification (proximal fractures: 6 type A, 8 type B, 6 type C; distal fractures: 5 type A, 7 type B, 8 type C). Fractures were caused by car accidents in 13 patients, industrial injuries in 4 patients, and falling from heights in 3 patients. Six fractures were closed and 14 were open (6 grade IIIa, 2 grade IIIb, 4 grade II, 2 and grade I, according to the Gustilo classification). Multiple fractures were present in 4 patients, and 3 patients had multiple organ injury.

**Treatment Protocol**

The open segmental fractures were treated with immediate irrigation and debridement. If the condition of the patient was unstable, the fracture was stabilized with a standard external fixator. Good reduction was achieved using the direct method through the open wound or through short incisions extending from the wound. In the 6 patients with closed fractures, reduction was achieved by an indirect method or by making small incisions with limited soft tissue stripping around the fracture site. If necessary, limited internal fixation of fragments was performed using screws or K-wire. After reduction and limited fixation of the fragments, a LISS distal femur plate was applied as an external fixator. Position of the LISS external fixator was located in the anteromedial side of tibia to minimize screw site problems associated with soft tissue motion. If the fixator was in the way of later soft tissue coverage, a standard external fixator would be applied.

Mechanical stability of the external fixator was increased by placing the plate as close to the bone as possible but still allowing room for some swelling. Therefore, the plate was positioned 1 to 2 cm above the skin, according to the authors’ experience. The authors only use locking screws that were predrilled with the appropriate size locking drill. Although unicortical screw fixation has been suggested for standard use of these plates, it seems prudent to choose bicortical fixation when using the plates as an external fixator until biomechanical data for this application provide more insight. To ensure secure fixation, 3 to 5 screws were placed into both ends of the fractures, and 1 or 2 screws were inserted to stabilize the segmental fragment according to the size of the fragment. Soft tissue reconstruction started immediately after stabilization of the bone. Although no specific protocol for soft tissue coverage was used, all patients were treated using primary wound repair without tension, skin graft, or pedicled flaps.

Prophylactic antibiotics (first- or second-generation cephalosporin) were applied for 24 hours in closed fractures and for 48 hours in grade I, II, and IIIa open fractures. If there was evidence of infection, therapeutic antibiotics were administered according to drug sensitive test. In grade IIIb open fractures, the authors used therapeutic antibiotics for 7 days. Postoperative dressings included a nonadherent dressing and gauze around the screw tracts. Three to 5 days postoperatively, the dressings were removed and screw tracts were treated weekly with a dry dressing, placed to minimize skin-pin motion, without pin-site care. Active knee and ankle range of motion and isotonic quadriceps exercises were begun on the first postoperative day. Loading was increased for each individual from partial to full weight bearing, depending on the stage of healing as diagnosed clinically and radiographically.

Patients were evaluated clinically and radiographically at 4-week intervals. Time to union, nonunion, malunion, leg shortening, knee and ankle ranges of motion, and infection were evaluated. Union was defined when a bridging callus was identified on radiographs and the fracture site was painless during weight bearing. Delayed union was defined as bone healing that occurred without additional surgery but with a healing time that exceeded 6 months. Nonunion was defined as deficient bone healing that required additional surgical measures, such as cancellous bone grafting or revision osteosynthesis. Malunion was defined as bone healing with an axial deviation in any direction exceeding 5° or 1 cm of leg-length discrepancy. Deep infection was defined as infection involving tissue below the muscular fascia. Functional results were based on 5 criteria: presence of a limp, stiffness...
of the knee or the ankle, pain, soft tissue sympathetic dysfunction, and the inability to perform previous activities of daily living. An excellent result was defined as the absence of all aforementioned outcomes; a good result was defined as the presence of 1 outcome criteria; a fair result was defined as the presence of 2 outcome criteria; and a poor result was defined as the presence of 3 or more criteria.

RESULTS

Mean follow-up was 23 months (range, 12-47 months). Mean union time was 19 weeks (range, 12-40 weeks) for the proximal fractures and 22 weeks (range, 12-42 weeks) for the distal fractures. Pedicled flaps were used in 2 patients. Median duration of hospitalization was 16 days (range, 5-40 days). Median duration of hospitalization was 12 days (range, 5-17 days) for patients with isolated tibial fractures and 25 days (range, 13-40 days) for patients with polytrauma. Delayed union of the fracture occurred in 2 patients. Eventually, complete union was achieved in all patients, with no re-fractures after removal of the supercata-neous locking plates.

All patients’ radiographs showed normal alignment. No rotational deformities or leg shortening were seen. No cases of deep infection and no implant failures were observed. Minor screw tract infection occurred in 2 patients; 1 patient was treated with subsequent daily cleaning with povidone iodine and the other by screw removal. When imaging studies confirmed bone union, the plates and screws were removed in the outpatient clinic. The plate was in situ for an average of 27 weeks (range, 16-46 weeks). At the most recent follow-up, mean knee range of motion was 0° to 130° and mean ankle range of motion was 0° to 40°. All patients had excellent or good functional results (17 excellent and 3 good) and were walking freely at the final follow-up. The pictures of the representative cases are shown in Figures 1-4.

DISCUSSION

Segmental tibial fractures often are associated with high-energy transfer, severe soft tissue injury, and periosteal stripping, resulting in significant impairment of the blood supply to the central fragment. The principal concerns arising from segmental tibial fractures relate to the biology and stability of the fracture. The presence of compartment syndrome, reported in 10% and 48% of fractures,3,16 can add to this. Some of the fractures are open, posing the additional threat of infection.

Many authors have stressed the need for the chosen treatment to incur the least damage to the remaining biological reserve. The biological advantages of non-operative treatment are limited because of a long period of cast immobilization and inadequate stability.7

Segmental tibial fractures challenge the ability of standard implants to provide adequate stability at all levels. Although it can be argued that plate fixation may achieve this, the additional surgical injury to a compromised soft tissue envelope, even with modern submuscular techniques, has to be balanced against the benefit of improved stability. Furthermore, proximal tibial shaft fractures are frequently associated with a noncontiguous, more distal ipsilateral tibial fracture. These bifocal injuries, especially those that produce a long central diaphyseal tibial segment, may prove to be difficult to manage with a single plate, even the longer lateral locking implants.

Many authors agree that internal fixation using intramedullary nailing interlocking bolts has an improved outcome.17,18 However, use of intramedullary nails for open fractures or those due to...
high-energy trauma can cause decreased cortical circulation, endosteal necrosis, and elevation of compartment pressures and is associated with an increased risk of infection.\textsuperscript{4,19,20} Reduction of tibial fractures with unstable intercalary segments is technique demanding and usually requires blocking screws or additional plates while reaming is performed.\textsuperscript{21-23}

Blocking screws are effective to helping obtain and maintain the alignment of proximal third fractures of the segmental tibial shaft treated with intramedullary nails.\textsuperscript{23} However, it is difficult to apply a blocking screw in severely displaced diaphyseal segmental fractures due to the rotational malalignment of the central segment, and a markedly displaced fragment cannot be reduced using a blocking screw alone. The additional or provisional plates method can result in unnecessary stripping of the soft tissues and periosteum, further denuding the bone ends of their blood supply. Moreover, this method may be undesirable in the open tibial fractures and poor skin condition of the proximal metaphyseal area. In these circumstances, skin problems or infections may occur. In addition, further impairment of the blood supply can occur during the reaming procedure if the central fragment is not stabilized to avoid iatrogenic devascularization of the fracture site. Furthermore, it is difficult to apply the intramedullary nails and locking screws if the fracture segments are either too proximal or distal.

The final option for stabilization of the fracture is external fixation, which has the potential to leave a small footprint on the biology of the fracture. Previous reports have documented its success for segmental tibial fractures but have also noted problems with malunion, nonunion, and deep infection.\textsuperscript{2,3} A possible explanation for some of the complications is related to the use of uniplanar types of fixators. These types of fixators are biomechanically inferior compared to the multplanar circular fixators popularized by Ilizarov,\textsuperscript{11} which provide better resistance to bending and torsion. The difficulty in application is the most common complaint about the Ilizarov fixator for fracture care. In addition, the technique is associated with the risk for pin infections or loosening, neurovascular injury, muscular damage, articular injury, persistent pain, scarring, and refractures.\textsuperscript{24} In addition, the external fixator frames are often bulky and cumbersome for the patient. When used on the legs, patients typically encounter problems with sleeping, wearing clothes, and impediment of the contralateral limb when walking.

The recently popularized locking compression plate is commonly used to treat osteoporotic fractures, comminuted fractures, and short segmental metaphyseal fractures.\textsuperscript{25,26} The biomechanics of the locking plate differ from those of conventional compression plates in that the stable connection of the locking screws to the load carrier (plate) does not rely on friction between the load carrier and the bone. This is similar to what is seen in the external fixator. Therefore, the locking plate has been advocated as an internal-external fixator.

Recently, several reports described the use of locking plates as external fixators for the treatment of infectious nonunion and open fractures.\textsuperscript{13,27,30} This technique proved to be versatile, low profile, and well tolerated by the patients. In the current study, because the locking plate provided enough stability and did not cross the joint, supercutaneous plating was used as a definitive fixation, allowing for early rehabilitation to be instituted, and thus afforded a great chance for improved ankle and knee function. Based on the current authors’ protocol, good anatomic reduction was more easily obtained when the procedure was performed early, and all fractures achieved union, although delayed union occurred in 2 patients. In addition, hardware removal was performed in an outpatient setting without anesthesia. The total duration of hospitalization was relatively short. The average duration of hospitalization was 12 days for patients who had isolated tibial fractures.

Ma et al\textsuperscript{30} described an alternative 2-stage protocol for treating segmental tibial fractures. In this protocol, a locking plate used as a temporary external fixator was replaced with a definitive internal fixation using the minimally invasive plate osteosynthesis technique in the second stage. Although minimally invasive plate osteosynthesis fixation of tibia fractures using a metaphyseal locking plate is safe and efficient, complications such as late wound

Figure 4: Photographs showing good function of adjacent joint with locking plate in situ 6 months postoperatively. The dorsiflexion position of the ankle (A). The extension position of the knee (B). The plantarflexion position of the ankle (C). The flexion position of the knee (D).
infection and impingement are relatively common.\textsuperscript{31} Compared with the 2-stage protocol, the advantages of maximum tissue preservation, lower costs, and shorter hospitalization were obvious in the current study.

The limitation of supercutaneous plating is that the small space beneath the plate makes it difficult to apply vascularized soft tissue cover in the anteromedial of tibia. In this situation, the strategy of using a standard external fixator with soft tissue reconstruction that is replaced with supercutaneous plating in the second stage is more reasonable. Another pitfall is the suboptimal alignment of the bone before placing the screws. In contrast to the standard external fixator with clamps and tubes, as an external fixator the plate can be harder to manipulate and adjust. However, when careful attention is paid to alignment before placing the screws, the authors have not found placement of this frame to be more difficult or time consuming than the standard external fixator.

**Conclusion**

The treatment of segmental tibial fractures is associated with high complication risks due to the high-energy nature of this injury and the surrounding soft tissue traumas. The authors have described a new 1-stage protocol using supercutaneous plating as a definitive fixator for segmental tibial fractures that is less invasive, costs less, and has a shorter hospitalization time. Surgeons can achieve good reduction, soft tissue reconstruction, stable fixation, and high union rates using supercutaneous plating. The authors' patients obtained excellent knee and ankle joint motion and good functional outcomes and had a comfortable clinical course.

**References**


