Abstract
Dual plating of complex, bicondylar tibial plateau fractures through an anterolateral and posteromedial approach is often performed to treat fractures complicated by a significantly displaced posteromedial fragment or a depression of the medial articular surface. The purpose of the present study was to (1) determine the deep infection rate of such fractures that are operatively fixed after allowing for soft tissue recovery and (2) compare this rate to other series in the literature. The study group was comprised of 29 patients with 29 AO/OTA 41-C bicondylar tibial plateau fractures. The average length of follow-up was 16.4 months. The deep infection rate was 13.8% (4/29). A lower rate of deep infection was observed compared to historical reports. This is likely a result of a treatment algorithm that requires recovery of the soft tissue envelope prior to definitive fixation.

High-energy fractures of the tibial plateau include bicondylar injuries with significant articular depression; multiple, displaced condylar fracture lines; metadiaphyseal fracture extension and comminution; and open wounds or extensive, closed degloving injuries. Management of such injuries is controversial. Treatment options include limited internal fixation combined with tensioned-wire, hybrid, or uniplanar external fixation; fixed-angle implants utilizing percutaneous exposure and reduction; lateral periarticular plates; and dual plating. Formal open reduction with dual plate fixation optimizes articular surface reduction when compared to indirect and percutaneous methods, especially in cases with significantly depressed fragments. Dual plating is preferred to fixed-angle implants in the setting of a significantly displaced fracture of the medial articular surface. Unfortunately, this technique, when performed through a single, midline extensile incision with wide stripping of the proximal tibia, has been associated with deep infection, wound dehiscence, and soft tissue complications in 23% to 100% of patients.

The literature has not definitively established a standard for dual plating of bicondylar tibial plateau fractures. The treatment algorithm used at our institution is based upon the senior investigator’s experience in treating such fractures, and is similar to that described by Barei and colleagues. This algorithm requires recovery of the soft tissue envelope prior to definitive fixation. Resolution of fracture blisters and edema as well as the return of skin wrinkling are key indicators of recovery. Temporary knee-spanning external fixation is often used to aid soft tissue recovery and maintain length and stability. Open reduction and internal fixation via two incisions (anterolateral and posteromedial) is then performed. Indirect reduction techniques and subperiosteal dissection, limited to the fracture margins and region of plate application, are utilized.

Type 41-C bicondylar tibial plateau fractures are high-energy, bicondylar fractures and include both Schatzker type V and VI fractures. The purpose of the study was to (1) determine the deep infection rate of bicondylar tibial plateau fractures treated via plating through two incisions and (2) compare this rate to other series in the literature.

Materials and Methods
At a level I trauma referral center, the results of all AO/OTA type 41-C tibial plateau fractures treated via the two-incision dual plating technique were evaluated, from 1997 to 2003. A retrospective chart review identified 29 consecutive patients with 29 bicondylar (AO/OTA type 41-C) tibial plateau fractures treated at our institution via dual plating.
through two incisions, from 1997 to 2003. Dual plating was performed when the injury radiographs demonstrated a posteromedial fragment with significant displacement or articular depression of the medial plateau, thus, necessitating a separate medial incision to obtain an adequate articular reduction.

Injury and postoperative radiographs as well as CT scans were used to identify each of these bicondylar fractures. Data regarding patient demographics, associated injuries, and postoperative wound complications were obtained from the charts. Data pertinent to postoperative functional status were also recorded. Deep infections were defined as those that extended below the fascia; superficial infections remained above the fascia.

Decisions regarding method of initial immobilization and timing of definitive fixation followed a specific treatment algorithm that was guided by the attending surgeon’s experience and judgment. Clinical signs of soft tissue recovery were most important. These signs included decreased swelling, healing of fracture blisters, and wrinkling of the skin around the proximal tibia. In closed fractures not requiring fasciotomy for compartment syndrome, temporary knee-spanning external fixation was favored in cases of excessive limb shortening, deformity and/or joint subluxation, significant polytrauma, and severe soft tissue injury. Definitive fixation via the dual incision technique was performed after the soft tissue envelope had improved. The time from injury to definitive fixation varied widely (range: 2 to 24 days) as a result of an equally variable degree of soft tissue compromise noted at initial presentation. Closed fractures associated with compartment syndrome were treated with immediate four-compartment fasciotomy, using two incisions and temporary knee-spanning external fixation, followed by delayed primary closure or split-thickness skin grafting. Fixation of closed fractures that were complicated by compartment syndrome was performed through the same two incisions after soft tissues had recovered. When split-thickness skin grafting was performed, fracture fixation was performed prior to definitive soft tissue coverage. Open fractures were managed initially with irrigation and debridement, knee-spanning external fixation, and antibiotic bead placement (tobramycin 3.6 grams mixed with one package of Palacos® cement). This was followed by repeat irrigation, debridement, and delayed dual plating. No open fractures...
had associated compartment syndrome.

The technique for fixation of closed fractures was similar to that described by Barei and associates. Briefly, fixation of the medial column was performed first, using an incision made 1 cm posterior to the posteromedial border of the tibial metaphysis, with dissection through the interval between the pes anserinus tendons and the medial head of the gastrocnemius (Fig. 1). When the medial plateau fracture contained a sagittal split involving the articular surface, the fracture site was entered and the coronary ligaments were elevated to expose the medial meniscus and the depressed joint surface. This required splitting of the medial collateral ligament in line with its fibers. The anterolateral incision was started 1 cm to 2 cm lateral to the patella and extended distally over Gerdy’s tubercle and 1 cm lateral to the crest of the tibia (Fig. 2). A transverse submeniscal arthrotomy was performed to expose the articular surface (Fig. 3). Subperiosteal dissection was limited to the fracture margins as well as the region of anticipated plate application. Depressed fragments were elevated and then supported with allograft. Buttress plates were applied once anatomic reduction had been achieved (Fig. 4). Plain radiographs were taken in the operating room to verify adequate articular reduction and hardware placement (Figs. 5 and 6).

Open fractures were approached via the method described by Benirschke and coworkers. Incisions were based upon the fracture pattern and location of the traumatic wounds. The goal was to limit the creation of large flaps and to minimize soft tissue stripping.

**Results**

**Injury Characteristics**

The study population was comprised of 22 male and 7 female patients. The average age at presentation was 45.1 years (range: 16 years to 70 years). There were nine motorcycle injuries, eight motor vehicle accidents, seven falls from height, two pedestrian versus automobile accidents, one boating accident, one industrial accident, and one jet ski accident. All fractures were AO/OTA type 41-C. The average length of follow-up was 16.4 months (range, 1 month to 59 months). Six patients were followed between 1 month and 6 months; seven patients between 6 months and 12 months; five patients between 12 months and 18 months; three patients between 18 months and 24 months; and eight patients were followed for more than 24 months. Seventeen patients sustained a total of 29 associated traumatic musculoskeletal injuries. These included fractures of the ankle (5), navicular (3), tibial pilon (2), femoral shaft (2), scapula (2), humeral shaft (1), proximal humerus (1), tibial shaft (1), distal radius (1), thumb metacarpal (1), both-bone forearm (1), clavicle (1), pubic ramus (1), sacrum (1), and lumbar vertebra (1). There were also two Lisfranc fracture-dislocations, one Monteggia fracture, one rotator cuff tear, and one knee dislocation.

Three of 29 (10.3%) fractures were open and classified according to Gustilo as grade II (one patient) and grade IIIB (two patients). Fourteen fractures (48.3%) were initially treated with temporary knee-spanning external fixation prior to definitive fixation. Five of the 26 patients (19.2%) with closed fractures required fasciotomy for compartment syndrome. Delayed primary closure or split-thickness skin grafting of fasciotomy wounds was performed at an average of 5.2 days (range, 2 days to 7 days). Time from injury to definitive fixation averaged 10.1 days (range, 2 days to 24 days).

**Infectious Complications**

The overall infection rate in those fractures treated with dual incisions was 17% (5/29). The deep infection rate was 13.8% (4/29). Two of three (67%) open fractures developed deep infection. One of five (20%) closed fractures requiring fasciotomy was complicated by deep infection. Two of 21
(9.5%) closed fractures not requiring fasciotomy developed infection (one superficial and one deep). The rate of deep infection in this closed group was therefore 4.8% (1/21).

Both grade III B open fractures were initially treated with knee spanning external fixation and repeat irrigation and debridement. Definitive fixation was performed via dual plating and local flap coverage 4 and 5 days after injury. Deep infection with *Pseudomonas aeruginosa* occurred 2.5 and 3.5 months later, requiring multiple debridements, free flap coverage, and long-term intravenous antibiotics. Both infections were resolved at last follow-up (30 and 42 months, respectively).

One of the three closed fractures requiring fasciotomy was treated via dual plating 17 days after injury. Deep infection with *Enterobacter* species and an anterolateral wound dehiscence developed and were managed with repeat irrigation, debridement, and local gastrocnemius muscle flap coverage. The infection was controlled with this treatment, plus 6 weeks of intravenous antibiotics, and chronic suppression with oral antibiotics. This patient was recently seen at 1 year follow-up and has been scheduled for hardware removal.

One closed fracture was treated via dual plating 10 days after injury; subsequently, wound dehiscence and deep infection developed (methicillin-resistant *Staphylococcus aureus* and *Enterobacter* species) 16 days after fixation. Multiple debridements were required prior to gastrocnemius flap coverage 4 days later, followed by 6 weeks of intravenous antibiotics. This patient is clinically free of infection at 18 months follow-up.

One closed fracture was complicated by superficial hematoma formation 15 days after definitive fixation from excessive anticoagulation following the diagnosis of deep vein thrombosis. Intraoperative cultures were positive for methicillin-resistant *Staphylococcus aureus*. The patient was treated with hematoma evacuation and intravenous antibiotics and was last seen for follow-up at 9 months. There were no signs or symptoms of infection.

**Postoperative Functional Status**

Eight of 29 (28%) patients developed nonseptic complications that significantly affected function and necessitated further surgery. Four patients developed severe arthritis requiring total knee arthroplasty. Varus malunion managed by corrective osteotomy occurred in three patients. One patient underwent manipulation under anesthesia for severe postoperative stiffness.

**Discussion**

Operative management of complex tibial plateau fractures remains controversial, with considerable debate regarding optimal fixation methods. Treatment options include limited internal fixation combined with tensioned-wire, hybrid, or uniplanar external fixation; lateral periarticular plates; fixed-angle implants utilizing percutaneous exposure and reduction; and dual plating.\(^1\)\(^-\)\(^14\) In addition, some investigators have advocated the use of arthroscopic techniques to aid reduction while minimizing surgical trauma.\(^24\) Dual plating via a two-incision technique has received recent support, as it allows for direct visualization of the articular reduction.\(^1\) Although lateral fixed-angle implants have largely replaced the need for medial metadiaphyseal plating, dual plating is still a useful approach in the presence of a significantly displaced posteromedial fragment or articular depression of the medial plateau.\(^16\)

Historically, a number of series have reported high wound complication rates after dual plating of complex tibial plateau fractures. Reported infection rates have ranged from 23% to 100%.\(^6\)\(^-\)\(^19\) These studies have demonstrated that the use of a single incision and/or performance of substantial soft tissue stripping in the area of the fracture site often leads to poor results. Most surgeons have abandoned such techniques.

Benirschke and colleagues\(^23\) reported good results after operative fixation of open complex tibial plateau fractures. The investigators presented a series of 14 Gustilo grade II and IIIA open complex tibial plateau fractures managed via a protocol that included immediate irrigation, debridement, and rigid internal fixation, followed by delayed wound closure at 5 days. Variable single incisions were used and included anterolateral, midline, and medial. Incisions were based upon the fracture pattern and goal of limiting the creation of large flaps. At an average follow-up of 31 months (range, 6 months to 60 months), there were no deep infections.

Barei and associates\(^16\) reported complications after operative treatment of complex tibial plateau fractures using dual plating through two incisions after allowing for adequate recovery of the soft tissue envelope. They reported seven (8.4%) deep infections in 83 AO/OTA 41-C3 fractures. Although the complication rate was significant, the investigators noted a substantial improvement with this technique as compared to use of a single, midline anterior incision. Three infections occurred in open fractures, two of which were acutely dysvascular limbs.

Four out of 29 (13.8%) patients in this retrospective review developed deep infections after operative fixation of complex tibial plateau fractures through two incisions. These results are favorable to earlier reports\(^17\)\(^-\)\(^19\) of the dual plating technique and comparable to the recent report by Barei and coworkers.\(^6\)

Two of three (67%) open fractures and one of five (20%) closed fractures requiring fasciotomy developed deep infection. There was one deep infection (4.8%) and one superficial infected hematoma (4.8%) in 21 closed fractures not complicated by compartment syndrome. The number of open fractures and closed fractures complicated by compartment syndrome was small, which precludes any specific conclusions based upon these data. However, it has been demonstrated in the literature that most infections after open fractures are caused by pathogens acquired in the hospital and that the fracture site and surrounding soft tissues are cleanest after initial irrigation and debridement.\(^25\)\(^-\)\(^27\) Gopal
and colleagues demonstrated a deep infection rate of 6% in grade IIIB and IIC fractures treated with fixation and flap coverage within 72 hours of injury, as compared to 30% in those treated greater than 72 hours from injury. Immediate open reduction and internal fixation with early skin closure or flap coverage of open fractures requiring dual plating may be beneficial.

Eight of 29 (28%) patients developed nonseptic complications that significantly affected function and necessitated further surgery. Barei and associates reported a major nonseptic complication rate of 10.8%. These results, together with our findings, underscore the severity of high-energy bicondylar tibial plateau fractures.

Limitations of this study include its retrospective design and small sample size. The quality of data is dependent upon the accuracy of the medical record.

## Conclusion

Operative fixation of complex fractures of the tibial plateau remains quite difficult and is associated with postoperative functional limitations in a large percentage of patients. Dual plating through an anterolateral and posteromedial approach is recommended in fractures complicated by a significantly displaced posteromedial fragment or depression of the medial articular surface. Our results demonstrate a lower risk for deep infection in such fractures when compared to earlier reports. This is likely a result of a treatment algorithm that requires recovery of the soft tissue envelope prior to definitive fixation.

## References