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Treatment of Bicondylar Tibia Plateau Fractures Using Locked Plating Versus External Fixation
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Abstract

Bicondylar tibial plateau fractures can be difficult to treat due to the extent of articular cartilage, metaphyseal bone, and soft tissue injury. The purpose of this study was to compare the outcomes of open reduction and locked plating vs fine-wire external fixation of 58 consecutive bicondylar tibial plateau fractures at a level I trauma center. All bicondylar tibial plateau fractures were classified as Schatzker V/VI or AO/OTA type 41C. Twenty-eight patients in one group were treated using a locked plating system, and 30 patients in another group were treated with a hybrid or circular external fixation frame. The 2 groups were similar demographically. When compared with external fixation, locked plating was associated with a decreased time to union (5.9 vs 7.4 months), decreased incidence of articular malunion (7% vs 40%; P=.003), decreased knee stiffness (4% vs 13%), and decreased overall complications (27% vs 48%). The Schatzker VI subgroup accounted for 25 of the 27 complications (93%) in the locked plating group and 40 of the 48 complications (83%) in the external fixation group. We reserve the use of external fixation devices in the treatment of tibial plateau fractures to span the fracture site until the patient is amenable to definitive fixation with locked plating.

Injuries involving an intra-articular bicondylar fracture of the proximal tibia are notoriously difficult to treat. These injuries are often associated with significant soft tissue and bony injury, which results in a high complication rate and poor clinical outcome. Common complications include infection, wound breakdown, joint stiffness, joint instability, malunion, nonunion, and post-traumatic arthrosis.

Historically, closed treatment of displaced tibial plateau fractures including traction and immobilization resulted in unacceptably high rates of malunion and joint stiffness. With advancements in internal fixation principles, operative treatment modalities were explored but were often associated with high complication rates. Difficulties arose in finding a balance between adequate surgical exposure and protection of the compromised soft tissue environment. Anatomic reduction and stable fixation often required extensive exposure of both the medial and lateral aspects of the proximal tibia that led to problems with wound healing and infection in the compromised soft tissue environment. Because of these soft tissue problems, minimal internal fixation and external fixation techniques have been reported with some success. Problems with these minimally invasive techniques include inadequate reduction, unstable fixation, and pin tract complications.

Recent advancements in angle-stable locking plate technology has allowed for a new approach to these difficult fractures. Locking plates allow the surgeon to place a biomechanically stable internal fixator on the lateral side of the proximal tibia through a limited surgical exposure. This technique will potentially allow for anatomic reduction and stable internal fixation while minimizing soft tissue problems often associated with the subcutaneous medial border of the proximal tibia. Whether this soft tissue-preserving technique will improve the clinical outcome of patients is yet to be determined.
The purpose of this study was to determine if the clinical outcomes of patients with bicondylar tibial plateau fractures treated with open reduction and internal locking plate fixation (ORIF) are better than those achieved with external fixation alone.

Materials and Methods

From January 2000 to August 2004, all bicondylar tibia plateau fractures (Schatzker type V/VI or AO/OTA type 41C) occurring at a level I trauma center were retrospectively reviewed. Each of the injuries was treated by 1 of 3 staff orthopedic traumatologists. Eight of these fractures were treated using Synthes standard locking plates (Paoli, Pennsylvania) and 20 were treated using the Less Invasive Stabilization System (LISS), compared with 30 fractures treated with external fixation, either hybrid or circular frames, which were used at our institution along with conventional plating. With the advent of locked plating systems, external fixation was primarily used at our institution to span the fracture pattern until the soft tissue swelling had subsided, at which point locked plating systems were used. The majority of the tibial plateau fractures treated with external fixation devices were treated prior to the advent of locked plating systems.

Clinical and radiographic analyses were completed prior to operative fixation, and this workup included standard anteroposterior (AP) and lateral knee and tibia radiographs, as well as computed tomography (CT) scans to better evaluate the fracture fragment/pattern and articular surface. Thirteen of the locked plating patients with more severe soft tissue injuries were initially treated with a bridging external fixator prior to definitive ORIF once the soft tissue condition improved. The average time in the external fixator prior to plating was 13 days (range, 2-60 days), and 11 of the 13 frames used were knee spanning. The primary indications for bridging fixation were contaminated open fractures, compartment syndrome, high-energy trauma with a compromised soft tissue condition, and unstable patients. There were 2 cases of compartment syndrome in the locked plating group and 3 in the external fixation group. These were treated with fasciotomy, and the soft tissue wounds were treated with standard antibiotic prophylaxis and surgical debridement.

Once the soft tissue condition had improved, the external fixator was removed and a standard lateral incision was used to access the proximal tibia. Once the reduction was obtained, periarticular clamps and temporary K-wires were used to maintain the reduction prior to definitive placement of the lateral locking plate and screws. In 21 of the cases, medial-to-lateral 4.5- or 5.0-mm cancellous lag screws were used to buttress the medial plateau fragment and supplement the temporary fixation of the lateral plateau until definitive fixation could be obtained. Bioabsorbable pins were used in 1 case to supplement the buttress effect, and a 3.5-mm medial buttress plate (Synthes) was necessary in 3 cases secondary to severe comminution. Autograft was used in 1 case and bone graft substitute in 6 cases. On the lateral side, the LISS or standard 4.5-mm proximal tibia locking plate was placed in a submuscular fashion (Figure 1). The plate was held in position with a provisional K-wire, and the standard method of fixation was followed as outlined in the company technique guide. All fractures received a minimum of 4 screws proximal and distal to the fracture.
In the external fixation arm of the study, 9 of the patients required a spanning knee frame, with the remainder receiving only a below-knee frame. Sixteen of the frames used were Hoffman II Hybrid (Stryker Howmedica, Allendale, New Jersey; Figure 2) and 14 were standard ring fixators. The average time to external fixator removal was 3 months (range, 2-7 months). The hybrid frames consisted of a proximal ring with 3 K-wires and 2 distal 5.0-mm half-pins with a multi-pin clamp. Three connecting rods were used to complete construction of the frame. Special attention was given to maintaining the proximal wires a minimum of 14 mm from the joint line, thus avoiding intracapsular placement.\textsuperscript{27,28} With regard to the circular frames, a similar procedure was followed, but 2 rings were used, each with 3 K-wires and 3 connecting rods.
In both constructs, olive wires were used as needed to achieve compression similar to the lag screw technique. Two of the patients treated with external fixation as definitive treatment also received additional 4.5-mm cannulated cancellous lag screws, and 1 had Steinman pins used as supplemental fixation. In addition to manual manipulation, olive wires under compression were used, including lag screws and Steinman pins, in the external fixator construct in an attempt to obtain reduction of the articular surface. Three of the patients also required bone graft substitute to maintain subchondral bone support.

Physical therapy was started in the immediate postoperative period, focusing on maintenance of proximal muscle strength, knee range of motion (ROM), gait, and transfers. The postoperative protocol consisted of strict nonweight bearing in both cohorts for a minimum of 6 to 8 weeks and until evidence of significant fracture healing was noted, with the majority being nonweight bearing for a minimum of 3 months. Passive knee ROM was started on postoperative day 2 with a limit of 90° maximum flexion, except in patients treated with knee-spanning fixation. The patients were gradually advanced to gentle active assisted ROM when the fracture became more stable and symptoms became tolerable.

Patients were followed closely with clinical examinations and follow-up radiographs obtained at 2 weeks, 6 weeks, 3 months, and then monthly until fracture union. Follow-up then increased to 6-month and 1-year intervals. At follow-up visits, particular attention was paid to knee ROM, continued generalized reports of pain, signs or symptoms of infection, painful hardware, instability, and any deformity. Radiographic evaluation centered around union of the fracture, signs of arthritis/arthrosis, malunion either of alignment or articular depression, signs of infection, heterotopic bone formation, refracture, or hardware failure. Malunion was defined as stepoff of the articular surface of 2 mm on AP/lateral knee radiographs or malalignment of >5° in any plane on full-length tibia radiographs. A significant loss of knee ROM was defined as flexion <90°. Careful records were maintained with regard to each of these variables, as well as any required additional procedures. Statistical analysis was performed using the two-sample paired t test assuming unequal variances.

Results

The 2 groups were similar demographically (Table 1). The locked plating group comprised 14 men and 14 women with an average age of 47 years (range, 22-76 years), and the external fixation group comprised 9 men and 21 women with an average patient age of 49 years (range, 25-81 years). Average follow-up was 10 months (range, 6-24 months) for the locked plating group and 16 months (range, 6-53 months) for the external fixation group, with a minimum of 6 months in both groups. There were 4 open fractures in the locked plating group and 5 in the external fixation group, with 21
Schatzker VI fractures in both cohorts. Twenty-one of the 28 locked plating and 17 of the 30 external fixation patients suffered polytrauma, and the most common mechanism of injury was a motor vehicle or motorcycle accident in both groups (Table 2). There was an overall 19% lost to follow-up rate, with 4 locked plating (14%) and 7 external fixation (23%) patients lost. There was 1 death in the locked plating cohort but this occurred following fracture healing documented at 6-month follow-up.

The average time to union with locked plating was 6 months (range, 3-14 months) vs 7 months (range, 3-15 months) in the external fixation group. There were 3 (10%) nonunions in the locked plating group and 4 (13%) in the external fixation group, with malunion occurring in 4 (14%) of the locked plating and 13 (43%) of the external fixation patients (Figure 2). The majority of the malunions were secondary to articular depression, including 7% (2 of 28) of the locked plating and 40% (12 of 30) of the external fixation patients, which was statically significant ($P=.003$). With respect to delayed union, 7 (25%) locked plating and 11 (37%) external fixation patients took >6 months to achieve union.

The average knee flexion and extension in locked plating patients was 109° (range, 75°-150°) and -2.2° (range, 0° to -15°), respectively, vs 103.8° (range, 80°-135°) and -2.9° (range, 0° to -30°), respectively, in external fixation patients. When analyzing these patients further, 1 (4%) locked plating patient and 4 (13%) external fixation patients had <90° of flexion at latest follow-up. It should be noted that many of these variables demonstrated a trend favoring the locked plating group, but only the articular surface malunion was statistically significant.

Various other complications occurred, but none demonstrated individual statistical significance or even a trend toward significance (Tables 3 and 4). Overall there were 27 complications in the locked plating group and 48 in the external fixation group. The most common complication was infection, with 10 (35%) locked plating and 20 (67%) external fixation patients experiencing it. Other complications included compartment syndrome, nerve injury, and deep vein thrombosis, but none were statistically significant.
fixation group. The locked plating patients required 8 additional procedures in 7 patients vs 24 procedures in 10 external fixation patients (Table 5). The most common procedure necessary in the locked plating group was closed manipulation of the knee in 2 patients with post-traumatic arthritis and/or heterotopic bone formation. In the external fixation group, 3 patients also required manipulation, but significantly more patients required other procedures, including irrigation and debridement, manipulation and/or alteration of the external fixator, bone grafting for delayed/nonunion, arthroscopic releases, and excision of bone.

When the data analysis focused on differences between Schatzker V vs Schatzker VI fracture types, it was evident that a higher percentage of the complications occur in the latter subtype involving the tibial metaphysis (Tables 3 and 4). The Schatzker VI subgroup accounted for 25 of the 27 complications (93%) in the locked plating group and 40 of the 48 (83%) in the external fixation group. Even after adjusting for the higher percentage of Schatzker VI fractures in each group (75% and 70%, respectively), there is a higher complication rate with this type of fracture. In particular, complications of malalignment, nonunion, and delayed union occurred at a significantly higher rate in both the locked plating and external fixation groups with Schatzker VI fractures. Looking at the adjusted complication rates with respect to open vs closed and polytraumatized vs isolated trauma patients, the differences were not as significant.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Locked Plating Complications</th>
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<tbody>
<tr>
<td></td>
<td>Schatzker V</td>
</tr>
<tr>
<td>Arthritis/post-traumatic arthritis</td>
<td>5</td>
</tr>
<tr>
<td>Stiffness (&lt;90° flexion)</td>
<td>1</td>
</tr>
<tr>
<td>Malunion (angulation)</td>
<td>2</td>
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<tr>
<td>Malunion (depressed articulation)</td>
<td>2</td>
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<tr>
<td>Nonunion</td>
<td>3</td>
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<tr>
<td>Infection</td>
<td></td>
</tr>
<tr>
<td>Deep</td>
<td>1</td>
</tr>
<tr>
<td>Cellulitis</td>
<td>1</td>
</tr>
<tr>
<td>Heterotopic bone formation</td>
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<tr>
<td>Painful hardware</td>
<td>2</td>
</tr>
<tr>
<td>Instability of knee</td>
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</tr>
<tr>
<td>Delayed union (&gt;6 months)</td>
<td>7</td>
</tr>
<tr>
<td>Refracture</td>
<td>0</td>
</tr>
<tr>
<td>Gastrocnemius equinus</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
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</table>
Operative treatment of displaced bicondylar tibial plateau fractures is the current standard of care. Various surgical techniques are proposed in the literature for the treatment of tibial plateau fractures. Directly comparing the clinical results from these studies is complicated by the heterogeneous injury, treatment, and outcome measure characteristics.

Bicondylar injuries, which are commonly classified as Schatzker V/VI or AO/OTA 41C, are notoriously difficult fractures associated with severe bone and soft tissue injury that lead to high complication rates and poor clinical outcomes. Recent literature has focused on ORIF with dual plating or external fixation, either hybrid or circular frames, with or
without limited internal fixation.\textsuperscript{10-20} These 2 treatment modalities are not without problems, however,\textsuperscript{5,8,10,30,43-45} which has led to the development of new techniques for fixation with locked plating.\textsuperscript{3,6,21-26}

Locking plate techniques began with studies involving the distal femur, including minimally invasive methods.\textsuperscript{46-49} Expanding on this success, several studies have demonstrated that the mechanical stability and overall stiffness of a laterally placed locked plate in the proximal tibia is equivalent to the historical control of dual plating.\textsuperscript{3,6,22} In addition, these studies have shown that there is no difference in medial condyle fragment displacement between the 2 groups. To our knowledge, no study in the literature directly compares the outcomes of patients with bicondylar tibial plateau fractures treated in the same institution with locked plating vs external fixation; this was the purpose of our study.

Our study demonstrates improved outcomes in the locked plating group based on several variables evaluated. The 12% higher union rate at 6 months is superior to that of the external fixation group. The average time to union was superior in the locked plating group (5.9 vs 7.4 months), although the overall nonunion rates at latest follow-up were similar (10% vs 13%, respectively). The improved healing rate may potentially be related to the fixation characteristics of the locking plates, increased use of bone grafting, and/or a more adequate reduction. It should be noted that the overall union rate of 90% is supported by numerous studies in the literature that report union rates of 94% to 100% with locked plating.\textsuperscript{21-22,24,26}

Significant loss of knee ROM was less in the locked plating group than in the external fixation group (4% vs 13%). This may be attributable to the soft tissue impingement inherent to external fixator pins. In addition, the decreased time to union seen in the locked plating group may have allowed for earlier ROM. Another potential contributor may have been the increased rate of articular malunion seen with external fixation, which is a known factor in the development of abnormal articular surface contact forces and knee function.\textsuperscript{45,50,51} The soft tissue damage associated with the injury may also play a role in the final outcome of these patients and is often an overlooked variable.\textsuperscript{52} Both Cole et al\textsuperscript{21} and Egol et al\textsuperscript{22} reported similar ROM results when using locked plating for these fractures (range, 1°-122° and 1°-109°, respectively).

Obtaining and maintaining reduction of the articular surface is both surgeon and implant dependent. Malunion of the articular surface as judged on radiographic examination was significantly less in the locked plating group compared to the external fixator group (7% vs 40%, respectively). This decreased incidence of articular malalignment is supported by Cole et al\textsuperscript{21} who cite a 2.6% rate. The long-term consequences of this observed malunion were not measured in our study, although several studies suggest malunion is associated with increased post-traumatic arthrosis.\textsuperscript{45,50,51}

The rate of complications, especially infection, is often a variable that orthopedic surgeons have cited in favor of external fixation over ORIF. The results of our study were contrary to this theory, with almost half the number of complications in the locked plating group as compared to the external fixation group. Looking at infection, there was only 1 superficial cellulitis and 1 deep infection in the locked plating group (overall rate 7%) vs 2 superficial and 2 deep infections in the external fixation group (overall rate 13%). It is clear that locked plating offers a safe treatment option for these difficult fractures when used in the correct indications. These findings are supported in studies by Egol et al\textsuperscript{22} with no reported infections, Stannard et al\textsuperscript{28} with a 5.9% rate of infection, and Cole et al\textsuperscript{21} with an infection rate of 4% and major complication rate of 9%.

The limitations of our study include short-term follow-up of a small sample of patients who were treated at a single institution. This weakness may also be viewed as a strength given the ability to oversee the data collection methods and the uniformity of this process that is possible at a single facility. In addition, the follow-up period was long enough to observe the primary outcome measurements of union, malunion, and short-term complications, which should be apparent in the time frame over which the study was conducted. Long-term outcomes, such as the incidence of post-traumatic arthritis, will require a more comprehensive study with long-term follow-up, which is difficult in the trauma population.
In addition, CT scan evaluation provides a more definitive assessment of nonunion/malunion, but our protocol, based on clinical history and standard radiographs, is practical for the typical clinical situation, with CT scans being reserved for specific cases. Along the same lines, long-leg standing radiographs may provide better evaluation for overall alignment than the standard full-length tibia radiographs used in our study. Because of the retrospective nature of the study, certain variables such as postoperative care were not strictly standardized as may have been possible with a prospective design. Upon reviewing the protocols used, however, there were only minimal differences between the individual patient treatment regimens, which likely can be attributed to the study occurring in a single institution with standard treatment algorithms in place.

A strength of this study is that it directly compares the outcomes of a similar group of patients who underwent 2 different surgical treatments of their bicondylar tibial plateau fractures. By retrospectively reviewing these 2 groups of patients, we were able to objectively measure outcome characteristics. The logistical and ethical limitations of prospective orthopedic trauma studies make studies such as this valuable in our understanding of optimal treatment strategies.

Our institution has gradually moved from treating bicondylar tibial plateau fractures with external fixation to lateral locked plating with or without limited medial fixation with percutaneous cannulated screws. The importance of soft tissue management cannot be overemphasized. In many cases, we will place a spanning external fixator to provide gross alignment and stability while the soft tissue injury declares itself and passes the initial inflammatory stage. Each patient's injury has its own characteristics, some dependent on the patient's overall condition and some dependent on the injury itself. These characteristics must be fully evaluated when treatment plans are developed.

Although locked plating is increasing in popularity and can be associated with improved outcome measures, every bicondylar fracture will not be amenable to such treatment. External fixation, either temporary or definitive, will certainly maintain a role in the treatment of many of these patients. The importance of injury, patient, surgeon, and institutional characteristics will always play a role in defining the optimal treatment strategy. Future studies should investigate these variables in an attempt to identify best practices for given patient and injury types and help patients with these severe injuries obtain optimal outcomes.

**Conclusion**

Locked plating offers a good treatment option for difficult bicondylar tibial plateau fractures. When compared with external fixation, locking plates provide improved healing rates, restoration of the articular surface, and decreased complications, including fewer incidences of knee stiffness and reoperation. External fixation offers a good bridge to plating or definitive treatment modality in cases with severe soft tissue injury, severe comminution, and unstable patients, and should therefore remain in our treatment armamentarium.

**References**


**Authors**

Drs Krupp, Malkani, Roberts, Seligson, and Crawford and Mr Smith are from the University of Louisville, Kentucky.

Drs Krupp, Malkani, Roberts, Seligson, and Crawford and Mr Smith have no relevant financial relationships to disclose.

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