Journal of Orthopaedic Trauma Publish Ahead of Print
DOI: 10.1097/BOT.0000000000001167

Costs and Complications of Single Stage Fixation Versus Two-Stage Treatment of Select Bicondylar Tibial Plateau Fractures

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The authors report no conflicts of interest related to this work.

Presented in part at the annual meeting of the Orthopedic Trauma Association, October 2017, Vancouver, British Columbia, Canada

This is the author's manuscript of the article published in final edited form as:

Virkus, W. W., Caballero, J., Kempton, L. B., Cavallero, M., Rosales, R., & Gaski, G. (2018). Costs and Complications of Single Stage Fixation Versus Two-Stage Treatment of Select Bicondylar Tibial Plateau Fractures. Journal of Orthopaedic Trauma, Publish Ahead of Print. https://doi.org/10.1097/BOT.0000000000001167

Objectives: To determine the differences in costs and complications in patients with bicondylar tibial plateau (BTP) fractures treated with one stage definitive fixation compared to two stage fixation following initial spanning external fixation.
Design: Retrospective cohort study
Setting: Level one trauma center
Patients/Participants: Patients with OTA 41-C (Schatzker 6) treated with open reduction internal fixation (ORIF).
Intervention: Definitive treatment with ORIF either acutely (one stage) or delayed following initial spanning external fixation (two stage).
Main Outcome Measures: Wound healing complications, implant costs, hospital charges, PROMIS outcome measures.
Results: 105 patients were identified over a three-year period, of which 52 met inclusion criteria. There were 28 patients in the One-Stage group and 24 patients in the Two-Stage group. Mean follow-up was 21.8 months, and 87% of patients had at least 12 months follow-up. The mean number of days to definitive fixation was 1.2 in the One-Stage group and 7.8 in the Two-Stage group. There were no differences between groups with respect to wound healing or any other surgery-related complications. Functional outcomes (PROMIS) were similar between groups. Mean implant cost in the Two-Stage group was $10,821 greater than the One-Stage group, mostly due to the costs of external fixation. Median hospital inpatient charges in the Two-Stage group exceeded the One-Stage group by over $68,000 for all BTP fractures and by $61,000 for isolated BTP fractures.
Conclusions: Early single stage treatment of BTP fractures is cost effective, and is not associated with a higher complication rate than two stage treatment in appropriately selected patients.
Level of Evidence: Level III- Retrospective cohort study

Keywords: bicondylar tibial plateau fractures; staged fixation; cost analysis; complications

Introduction

Bicondylar tibial plateau (BTP) fractures typically result from high-energy injuries associated with significant soft tissue insult. The timing of definitive surgical fixation is dictated by the surgeon's subjective assessment of the soft tissues in the zone of injury. Immediate definitive fixation through compromised soft tissue historically led to high rates of wound complications and deep infection.[1-12] Therefore, two-stage treatment allowing for resolution of acute soft tissue injury is a common strategy to reduce complication risk. This involves initial application of an external fixator followed by delayed definitive fixation within one to three weeks. [13-16] Alternative strategies to avoid early open surgery include percutaneous fixation and definitive external fixation. [15, 17-23] The benefits of two-stage treatment come with higher monetary costs related to multiple procedures, additional implants, and prolonged or repeat hospitalizations. Additionally, delayed definitive treatment may increase the difficulty of fracture reduction. These drawbacks of staged treatment make early definitive fixation preferable in appropriately selected patients at low risk for soft tissue complications.

Recent reports have suggested early definitive fixation is safe for lower extremity fractures when careful patient selection and sound surgical techniques are utilized.[24, 25] The purpose of this study is to compare the outcomes and costs between BTP fractures treated in one versus two stages. We hypothesized that (1) outcomes of surgically treated BTP fractures would be equivalent for one- versus two-stage treatment with appropriate patient selection for each pathway and (2) that one stage treatment would convey significantly lower costs.

Methods

We performed a retrospective review of all complete articular BTP fractures (OTA 41-C and Schatzker 6) treated at our Level 1 trauma center by one of six fellowship trained orthopaedic traumatologists from 2013-2015. Inclusion criteria were age ≥17 years and follow-up to one of two endpoints: healed fracture (minimum 6 months) or diagnosis of nonunion. Patients were identified by searching Current Procedural Terminology (CPT) billing codes submitted by the treating surgeon for open treatment of bicondylar tibial plateau fracture (27536). Patients with partial articular fractures (OTA 41-B), compartment syndrome, Gustilo type 3 open fractures, and those not definitively treated with open reduction and internal fixation (ORIF) were excluded. Additionally, patients hospitalized with prolonged delay (more than three days) to surgery for reasons unrelated to trauma were excluded as the resultant "artificial" increase in the cost of care would confound study results.

In this series of patients, time to fixation was based on surgeon assessment of the soft tissue envelope. While there is no universally accepted objective criteria to define acceptable soft tissues, fracture blisters were considered a contraindication, but absence of skin tension and "wrinkle test" was not utilized due to subjectivity. In general, the decision for one-stage versus two-stage treatment was based on the status of the soft tissues at the time of the index surgery. The possibility of postoperative deterioration of the soft tissue envelope was typically not a consideration when choosing the treatment pathway. Surgeons became more comfortable with this approach later in the study, but as a result, there is a bias toward a more conservative approach earlier in the study. Additionally, between the six surgeons, there was varying "risk tolerance", particularly early in the study period, which contributes to the selection bias in this study.

Patients were divided into two groups. One-stage treatment was defined as ORIF at the index procedure with no immediate plans for additional surgical treatment to revise fracture reduction or fixation. Two-stage treatment was defined as placement of a temporizing knee-spanning external fixator followed by definitive ORIF at a separate operative session. These definitions allowed for grouping of all patients in our cohort without exception.

For each patient, direct implant-related costs and hospital charges were obtained via in-house customized surgical inventory software and hospital charge data. All cost data is reported in US dollars. Implant charges are reported as list price, and hospital charges are undiscounted. Hospital charges were chosen as a surrogate for hospitalization-related costs as actual cost data are often inaccurate and proprietary. Charges were reported in means for normally distributed charges (implant costs) and as medians for non-normally distributed charges (hospital charges). Total implant costs and hospital charges were compared between groups. A separate subgroup analysis was performed for Two-stage patients treated in a single hospital admission versus those treated over two separate hospitalizations. Due to the concern that some patients' hospital charges would be increased as a result of multiple injuries unrelated to the BTP fracture (i.e. a potential confounder to cost), an additional analysis was performed including only patients with an isolated BTP fracture (i.e. no injuries of any type other than the BTP fracture).

Demographic data, injury characteristics, clinical outcomes, OTA fracture classification, incidence of nonunion, fixation strategies, and fracture alignment after ORIF were compared between groups. Functional outcomes were assessed through the Physical Function (PF) and Pain Interference (PI) domains of the Patient-Reported Outcomes Measurement Information System (PROMIS) score. Fracture union was assessed by radiograph review and medical record documentation.

Student's t-test, Mann-Whitney U test, and Fisher's exact test were utilized for statistical analyses. A p-value of <0.05 was considered statistically significant.

Results

Applying the inclusion criteria to our CPT code search yielded 105 patients over a three-year period, of which 53 were excluded: 24 patients had less than 6 months follow-up; 14 patients had compartment syndrome; 6 patients were treated with intramedullary nails; 4 patients were treated with ring fixators; 2 patients had ipsilateral trans tibial amputations for mangled extremities; and 3 patients had prolonged delay to surgery due to medical issues unrelated to trauma. This resulted in 28 patients in the One-Stage group and 24 patients in the Two-Stage group.

Demographics, comorbidities, and fracture characteristics were similar between groups (Table 1). Mean follow-up was 21.8 months (range 6-41 months), and 87% of patients had at least 12 months follow-up. The mean number of days to definitive fixation in the One-Stage group was 1.2 (range 0-3) and was 7.8 (range 3-15) in the Two-Stage group. A nonsignificant trend towards an increased reoperation rate was observed in the Two-stage group compared to the One-stage group (29% vs. 7%, p=0.06) (Table 2). There were no differences between groups with respect to incidence of deep infection, superficial infection, nonunion, or change in alignment. Functional outcomes at final follow-up via PROMIS PF and PI were also similar between groups (Table 2).

One-stage procedures were performed on 50% of the cases in the early study period (2013) and increased to 75% of the cases at the end of the study period (2015). Mean implant cost in the Two-Stage group was $10,821 greater than the One-Stage group, mostly due to the costs of external fixation (Figure 1). Median hospital inpatient charges in the Two-Stage group exceeded the One-Stage group by over $68,000 for all BTP fractures and by $61,000 for isolated BTP fractures (Table 3, Figure 2). Hospital charges for two-stage cases done in the same admission were $175,457 compared to cases discharged and readmitted when soft tissues had recovered, for which the median charges were $148,274. This is likely due to a higher percentage of concomitant injuries in the patients who had both stages of their fixation in one admission (9/13 vs 2/11).

Discussion

Historically, early definitive ORIF for lower extremity periarticular fractures was met with a significant incidence of wound related complications.[1, 5, 12, 26-29 30] This led to technique modifications and alternative strategies for soft tissue management.[18, 21, 22, 28, 31, 32] After good initial results were reported with a two-stage approach in tibial pilon fractures [33], this technique spread to tibial plateau fractures.[13, 14] Initial placement of a spanning external fixator was found to restore gross fracture alignment, maintain length, accelerate resolution of soft tissue swelling, and facilitate delayed fixation.

Barei et al. reported on the complications of ORIF via dual incisions in 83 high energy tibial plateau fractures (OTA 41-C3).[1] Open fractures were present in 13% of the patients, and 50% were treated initially with a spanning external fixator. They stated that use of a temporizing spanning fixator increased during the study period. Time to definitive surgery averaged 9.2 days (range 0-40), with a 19% major complication rate, including an 8% deep infection rate. These outcomes are similar to our findings, but interestingly, they had an increasing rate of staged procedures during their study period, and we had a decreasing rate during ours. Our decreasing use of staged treatment without an increase in complications may suggest an opportunity for earlier definitive treatment. In 2005, Egol et al. reported the results of a staged protocol for high energy tibial plateau fractures (Schatzker 4-6) in 57 patients. [13] Definitive treatment included ORIF via single or dual incisions or ring fixation. Reoperation occurred in 16% of patients, and the wound complication rate was 5%.

During the time period when staged treatment of periarticular tibia fractures was gaining popularity, modifications in approach and technique were concurrently described to lower risks of wound complications. Dual (medial and lateral) incisions, locking fixation, and minimally invasive techniques have all reportedly contributed to fewer soft tissue and infectious complications.[17, 21, 31, 34-38] While two-stage treatment became a popular widespread practice, it is unclear to what extent this practice was responsible for improved results in the treatment of tibial plateau fractures compared to refined techniques of soft tissue dissection and implant evolution.

Staged treatment, while usually considered a more conservative and safer strategy, has many potential disadvantages. First, external fixators applied during the first stage are very costly implants. Additionally, the prolonged initial admission or readmission for definitive fixation, adds significant costs to the treatment of these injuries. Finally, fracture fragment mobility is often diminished when these fractures are fixed 10-14 days after injury, making anatomic reduction more difficult. Prolonged surgery and potential surgical site contamination from the external fixator and pin tracts increase the risks of postoperative infection.

The cost differences between one and two stage fixation in our cohort result from differences in both implant costs as well as hospital charges related to additional operations and length of stay. The vast majority of the implant costs differences are attributable to the cost of external fixation. External fixators are among the most expensive implants used in orthopedics, with complete constructs costing more than most total joint implants. This is due to the multiple components (clamps, bars, etc.) each of which can cost $500 to $1000. These components accounted for 73% of the implant costs in the two stage group. Although implant costs and hospital charges were generated differently, implant charges did account for 15% of the difference in charges between the one stage and two stage patients. The additional costs related to two stage treatment are due to the difference in charges for two operations versus one, and the additional hospital days related to two stage treatment. Even excluding implant related charges, two operative sessions (versus one) will have increased facility related operating room charges that add to overall costs. Additionally, the higher time to definitive surgery in the two stage group, over half of which were performed during the index admission, added hospital days and the resultant charges to the two stage group. While multiple injuries can account for some of these increased costs, these differences were still seen in isolated tibial plateau injuries, with the two stage hospital costs being nearly double even in the isolated plateau injuries.

In our practice, we noticed an evolution away from the thought that nearly all "high energy" tibial plateau fractures must be treated with a two-staged approach. Prior to treatment of this cohort, even when the soft tissues looked amenable to immediate surgery, patients were often treated with a two-stage approach due to concerns that swelling would progress during and after ORIF, making wound closure difficult and risking wound complications. We began a more aggressive approach using single stage treatment in appropriately selected patients in 2013. We determined the safety of definitive fixation at the time of the initial surgical encounter using recognized albeit subjective criteria to evaluate the soft tissues. If a fracture was associated with blisters or taut skin, we treated it in a staged fashion utilizing a spanning external fixator. If skin was felt to be amenable, we proceeded with definitive ORIF regardless of concern for progressive post-operative swelling. We used modern surgical technique including separate medial and lateral incisions rather than midline incisions (when open access was needed both medially and laterally), careful soft tissue handling, and minimal periosteal stripping. While there was not a statistically significant difference in complication rates between the two groups in this study, there was a trend toward fewer complications in the early fixation group (7% vs 29% unplanned reoperation, 7% vs 17% deep infection). The potential selection bias in our study does not allow definitive explanation of this trend, but possible explanations include higher severity of injury or the difficulty of fixation and manipulation of less compliant soft tissues in the staged group lead to a higher complication rate.

Recent studies have reported acceptable results in both tibial pilon and plateau fractures in appropriately selected patients using contemporary surgical techniques.[24, 25] Unno et al recently reported on a cohort of 102 non-consecutive OTA/AO 41C fractures, most treated in one stage less than 72 hours from injury.[24] They treated 91% with one operation, and 82% of these were treated with ORIF mostly (71%) through a single lateral approach. They had an aggressive interpretation of soft tissue readiness, only using two-stage treatment in the face of circumferential blisters, necrosis, and medical issues preventing early surgery. They did not feel that a "wrinkle sign" was an important factor in determining soft tissue readiness. Reoperation within 12 months occurred in 16% of patients. They had adequate reductions in 95% of cases, and patient reported outcomes were similar to previous reports of BTP fractures. A major difference in our cohort may arise from the criteria used to assign patients to one versus two-stage treatment. Although we were fairly aggressive in proceeding with early definitive ORIF (54%), the criteria we used to determine one-stage treatment were much more conservative than those used by Unno et al (91% treated in one stage).

This investigation has a number of limitations. The number of patients in each group is somewhat low due to focus on a very specific fracture pattern (Schatzker 6, OTA 41-C). This limits the power of our study to draw conclusions regarding the lack of statistically significant differences in clinical and radiographic outcomes, but our conclusions regarding the cost implications of one- versus two-stage treatment remain valid. Additionally, a minimum of six months follow-up was set for inclusion in an attempt to truly understand all the ramifications of one versus two stage surgery on BTP fractures. We chose six months as our minimum follow-up as we felt that was sufficient follow-up to identify the complications most associated with the decision for one versus two stage treatment, namely, wound healing complications. However, this follow-up could be too short to identify radiographic or functional outcome differences between the two treatment methods in this cohort.

Another limitation of this study is the subjective nature of soft tissue assessment when determining whether one or two-stage treatment should be undertaken. There is no validated, objective, reproducible soft tissue scoring system that can quantify the extent of soft tissue injury. Therefore, extrapolation of our results to other centers may be difficult.

Selection bias is a limitation of most retrospective studies, and it is here as well. However, 96% of the fractures in the study were OTA 41-C3 fractures. Therefore, using the best fracture classification scheme available, there were no significant differences in fracture severity between the groups. We acknowledge, however, that there can be different severity of injury within the C3 group. Additionally, if one assumed that more severe injuries were more likely to be treated conservatively with a two-staged approach, one could expect the wound complication rate for the two-stage group to be lower, which it was not.

Using hospital charges as a surrogate for the cost of hospitalization is another limitation. True hospital costs, which would be the ideal metric, are nearly impossible to obtain, are not uniformly reported, and are somewhat proprietary. Hospital collections would be subject to differences in payor mix and contractual adjustments. While hospital charges can certainly vary widely, they are accurate, independent of payor, and readily available.

We used PROMIS Physical Function and Pain Interference as our patient reported outcomes as we record these prospectively for all patients at regular office follow-up. Although increasingly common, these validated PROMIS scores have not been widely used in other orthopaedic manuscripts, making result comparison between studies difficult. Because of the retrospective nature of our study, we did not collect WOMAC or Olerud outcomes, which have commonly been reported in other tibial plateau fracture studies.

Conclusions

This study demonstrated that single stage definitive treatment of BTP fractures without staged external fixation dramatically decreases costs without an increase in complications in appropriately selected patients. The retrospective nature of this investigation lends itself to selection bias with respect to level of injury severity in each group. Future prospective studies may better define appropriate selection criteria for early definitive fixation of BTP fractures.

Acknowledgements: The Authors would like to thank research coordinators Krista Brown, MS, CRCC, and Lauren Hill, BS, CRCC, for their assitance including IRB submission, contacting patients, and obtaining functional outcome scores.

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Table 1. Patient Demographics and Injury Characteristics

	One-Stage Fixation (N=28)	Two-Staged Fixation (N=24)	p-value
Age (mean)	48	51	0.48*
Sex (M:F)	14:14	17:7	0.16†
BMI (mean)	30	31	0.43*
Smoker (%)	36	42	0.78†
Diabetes (%)	18	17	1.00†
Osteoporosis (%)	3	4	0.91†
OTA 41-C3 : OTA 41-C1/2	24:4	24:0	0.12†
Open Fracture (%)	14	4	0.36†
Dual plating : Unilateral plate	21:7	20:4	0.52†

*two-tailed student's t-test, †two-tailed Fisher's exact test

Table 2. Clinical and Radiographic Outcomes

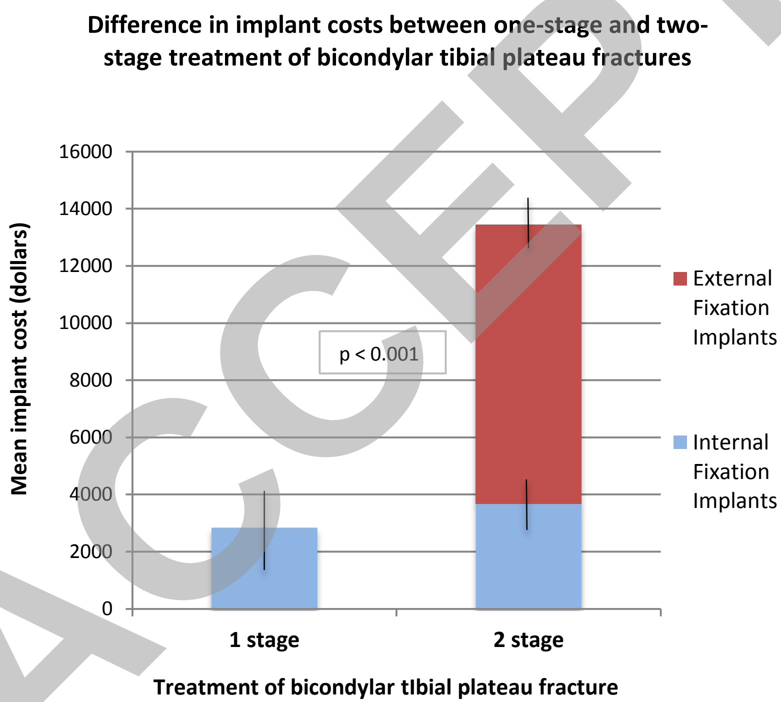
	One-Stage Fixation (N=28)	Two-Stage Fixation (N=24)	p-value
Days to definitive fixation: mean (range)	1.25 (0-3)	7.8 (3-15)	<0.01*
Mean months of follow-up			
Unplanned Reoperation	2 (7%)	7 (29%)	0.07†
Nonunion	1 (4%)	3 (13%)	0.32†
Deep Infection	2 (7%)	4 (17%)	0.40†
Coronal or Sagittal Malalignment >5 deg	3 (11%)	4 (17%)	0.69†
Mean PROMIS Physical Function (higher is better)	40	40	0.82*
PROMIS Pain Interference (lower is better)	61	56	0.10*

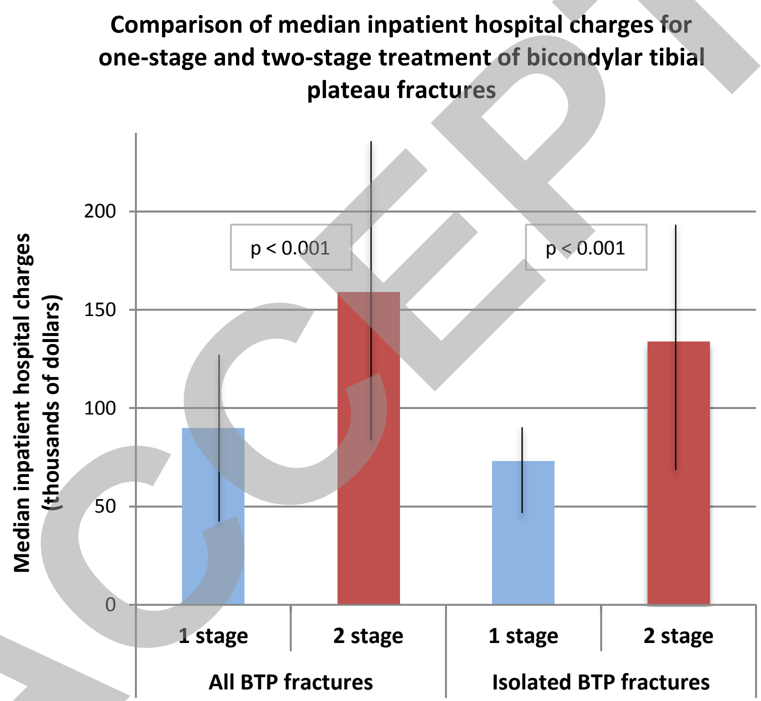
*two-tailed student's t-test, †two-tailed Fisher's exact test

Table 3. Cost Analysis

	One-Stage Fixation	Two-Stage Fixation	p-value*
Implant Cost (mean)	$2,843	$13,428	<0.01
Inpatient Hospital Charges (median)	$90,085	$158,659	<0.01
Inpatient Hospital Charges for two stage performed in two admissions (median)	N/A	$148,274	N/A
Inpatient Hospital Charges for two stage performed in one admission (median)	N/A	$175,457	N/A
Inpatient Hospital Charges for Isolated BTP (median)	$69,085	$132,319	<0.01

*two-tailed student's t-test for mean values, Mann-Whitney U test for median values


Difference in implant costs between one-stage and two-stage treatment of bicondylar tibial plateau fractures
Mean implant cost (dollars)
16000
14000
12000
10000
8000
6000
4000
2000
0
p < 0.001
External Fixation Implants
Internal Fixation Implants
1 stage
2 stage
Treatment of bicondylar tIbial plateau fracture


Comparison of median inpatient hospital charges for one-stage and two-stage treatment of bicondylar tibial plateau fractures
Median inpatient hospital charges (thousands of dollars)
200
150
100
50
0
p < 0.001
p < 0.001
1 stage
2 stage
1 stage
2 stage
All BTP fractures
Isolated BTP fractures