Are Locked Plates Needed for Fixation of Split Depression Tibial Plateau Fractures (Schatzker Type II)?

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Background/Purpose: Displaced tibial plateau fractures most often need surgical treatment. Usually a plate and screw construct is used in treatment of these fractures. Locking plate technology has seen an increase in usage for both complex and simple fracture patterns without evidence demonstrating their efficacy. The purpose of this study is to compare the clinical use of locked versus unlocked plating for repair of displaced Schatzker type II tibial plateau fractures.

Methods: 91 consecutive patients treated surgically for Schatzker type II tibial plateau fractures were prospectively seen over a 5-year period. 42 patients (46.2%) were treated using a locked plate and screw construct and 49 (53.8%) were treated with an unlocked plate and screw construct. Pre- and postoperative care, plate morphology and length, and patient demographic factors were similar in both groups. Clinical outcomes of the two groups were assessed using Short Musculoskeletal Function Assessment (SMFA) scores, pain levels, and range of knee motion. Radiographic outcome was assessed with plain films at all follow-up points. Implant costs for the 2 types of constructs were calculated from hospital purchasing records.

Results: Patients were assessed at a mean 13.9 months (range, 6-72) of follow-up. Comparing patients treated with locked versus unlocked constructs, no significant differences were seen in physical exam parameters or radiographic outcomes. Total SMFA scores did not differ; however, the SMFA Functional Domain was significantly better in the unlocked group (Table 1). The locked construct cost an average $400 more than the unlocked construct.

Patients Treated With Locked and Nonlocked Plating

	Length of Stay (days)	Time to Fracture Union	Residual Depression	Degree of Mechanical Alignment	ROM Extension	ROM Flexion	Pain
Locked	4.4	3.8	1.2	87.0	1.0	121.6	3.7
Nonlocked	3.3	3.6	0.8	87.4	1.0	125.1	2.9
P value	0.50	0.66	0.22	0.34	0.98	0.39	0.20

ROM = range of motion.

Conclusion: Based on the clinical outcomes and cost per implant, we can find no evidence to support the routine use of locked plating for simple split depression fractures of the lateral tibial plateau. The use of standard nonlocked, precontoured implants provide adequate fixation for these fracture patterns.

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Δ Inflammatory Cytokine Response Following Tibial Plateau Fracture Does Not Correlate with Fracture Grading of "Low Versus High Energy"

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Purpose: This study is designed to evaluate the inflammatory cytokine response following intra-articular tibial plateau fracture. Prior studies have linked both inflammatory response and grade of injury to the development of arthritis, and we hypothesized that higher grade fractures would have a more robust inflammatory response.

Methods: After IRB approval, investigators prospectively aspirated synovial fluid from the injured and uninjured knees of 23 patients with tibial plateau fractures who were between the ages of 18 and 60 years. Patients with open fracture, history of autoimmune disease, preexisting arthritis, or presentation greater than 24 hours from injury were excluded. The 10 patients requiring spanning external fixator followed by definitive fixation were aspirated at both surgeries. The concentrations of 15 inflammatory cytokines (interferon [IFN]-γ, interleukin [IL]-2, -4, -6, -7, -8, -10, -12 (p70), -13, -17, -1β, -1Ra, tumor necrosis factor [TNF]-α, monocyte chemotactic protein [MCP]-1, and macrophage inflammatory protein [MIP]) were quantified using a human inflammatory cytokine multiplex panel.

Results: We enrolled 23 patients (9 females, 14 males), with an average age of 44.3 years (range, 20-60). There were 9 low-energy (OTA 41B or Schatzker 1-3, all OTA 41B) tibial plateau injuries and 14 high-energy (Schatzker 4-6) tibial plateau injuries. Of the high-energy fractures, 5 were OTA 41B3 and 9 were OTA 41C. There was a significant difference between injured and uninjured knees in all cytokines except IL-1β, IL-1Ra, IL-2, IL-7, and IL-12p70 (P = 0.15, 0.20, 0.08, 0.10, 0.11, respectively). There was no difference in inflammatory response between high- and low-energy injuries for any of the cytokines (see table below). IL-7, MCP-1, and TNF-α all remained elevated at an average of 8.5 days from initial surgery. While not significant, IL-1Ra experienced an increase in concentration between the two time points ($P = 0.24$). All other cytokine concentrations decreased between index and secondary surgery.

Conclusion: There is a significant inflammatory response in most of the cytokines tested in the injured knee compared to the control knee, demonstrating the effect to be local, not systemic. Most surprisingly, there was no difference in inflammatory response between high- and low-energy injuries. While there is an established link between inflammatory cytokines and the development of arthritis, in these patients with articular injury, the inflammatory response is not correlated to the grading systems commonly used to distinguish high energy versus low energy.

Δ OTA Grant

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Time 0 Cytokine Comparison of High-Energy to Low Energy Injuries (Not All Cytokines Listed Here)

	High Energy (n = 14)	Low Energy (n = 9)	Mean Diff (95% Confidence Interval)	*P* Value
IFN-γ	15.19 (14.69)	58.67 (18.32)	–43.48 (–92.31, 5.35)	0.08
IL-1Ra	270.11 (93.00)	113.20 (116.04)	156.91 (–153.62, 467.45)	0.30
IL-1β	6.47 (3.13)	2.57 (3.92)	3.90 (–6.6, 14.41)	0.45
IL-2	8.29 (5.93)	15.38 (7.41)	–7.09 (–27.04,12.86)	0.47
IL-6	41,539 (6381)	33,658 (8003)	7881 (–13,730, 29,493)	0.27
IL-7	42.4 (3.13)	33.94 (3.91)	8.46 (–2.03, 18.94)	0.31
IL-8	846.81 (176.03)	635.53 (220.87)	211.27 (–385.53, 808.08)	0.47
MCP-1	14,610 (4864)	5260 (6261)	9350 (–8285, 26,986)	0.28
MIP-1β	375.43 (98.9)	442.72 (123.9)	–67.29 (–401.17, 266.59)	0.68
TNF-α	41.68 (4.82)	44.56 (6.02)	–2.87 (–18.98, 13.25)	0.71

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•Fix It or Discard It? A Retrospective Review of Functional Outcomes After Surgically Treated Patellar Fractures Comparing Open Reduction and Internal Fixation With Partial Patellectomy

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Background/Purpose: The goals of surgical treatment of patellar fractures are to provide a congruous articular surface and restore the quadriceps extensor mechanism. To achieve these goals open reduction and internal fixation (ORIF) is the operative technique of choice when anatomic reduction is possible. In comminuted fractures where some fragments are unreconstructable, partial patellectomy (PP) offers an alternative means of restoring the extensor mechanism. The prognosis for these procedures is not clear; thus, the goal of this study was to compare functional outcomes of patients treated with ORIF to those treated with PP.

Methods: We identified 73 patients with isolated displaced patella fractures who underwent surgical treatment between 2002 and 2009 at our institution. Of the 73 qualifying patients, 52 patients (71%) with isolated unilateral patellar fractures with a minimum of 1-year follow-up agreed to participate and were enrolled in the study. Patients completed outcome questionnaires, visual analog pain scale (VAS), and participated in a physical exam including evaluation of gait, passive range of motion and the presence or absence of an extensor lag. Standard AP and lateral radiographs were also collected to assess fracture healing. Outcome instruments included the Knee Outcome Survey – Activities of Daily Living scale (KOS-ADLS), Short Form-36 (SF-36) Health Survey, and Short Musculoskeletal Function Assessment survey (SMFA).

Results: Of the 52 patients who agreed to participate, 26 underwent partial patellectomy and 26 underwent ORIF. There were no significant differences in age, sex, or preinjury functional status between the two groups. The mean follow-up time was 35 months in the PP group and 33 months in the ORIF group. There were no significant differences in any of the functional outcome instruments including KOS-ADSS (ORIF: 64.1 ± 11 vs PP: 62.1 ± 7.9; $P = 0.76$), SF-36 Physical Component score (ORIF: 40.8 ± 5.4, vs PP: 41.1 ± 5.2; $P = 0.94$), SF-36 Mental Component (ORIF: 47.7 ± 5.1 vs PP: 51.8 ± 4.9; $P = 0.19$), SMFA Function Index (ORIF: 28.6 ± 9.1 vs PP: 27.7 ± 6.7; $P = 0.78$) or SMFA Bother Index (ORIF: 26.0 ± 9.7 vs PP: 23.6 ± 8.8; $P = 0.72$). There was also no significant difference in pain as assessed by VAS (ORIF: 2.8 ± 1.35 vs PP: 2.9 ± 1.0; $P = 0.27$). There were more patients in the ORIF group who had an extensor lag greater than 5° at follow-up; however, this did not achieve statistical significance (ORIF: 2/26 [7%] vs PP: 5/26 [19%]; $P = 0.42$). There was no significant difference in total range of motion between the two groups (ORIF: 114 ± 27° vs PP: 119 ± 17°; $P = 0.42$). Complications included 14 secondary procedures for removal of hardware (ORIF: 8/26 [31%] vs 6/26 [23%]; $P = 0.76$), 4 nonunions (ORIF: 3/26 [12%] vs PP: 1/26 [3.8%]; $P = 0.6$), and 2 incidences of knee arthrofibrosis (ORIF: 1/26 [4%] vs PP: 1/26 [4%]; $P = 1.0$).

Conclusion: This study demonstrates that functional impairment persists after surgical treatment of patellar fractures. Both ORIF and PP demonstrated similar final range of mo-

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tion, functional scores, and complication rates. Despite its purported benefits, in this study ORIF did not result in superior outcomes compared to PP.

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• Time to Spanning External Fixation for High-Energy Tibial Plateau and Plafond Fractures has No Impact on Rates of Infection, Compartment Syndrome, or Secondary Procedures

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Purpose: The purpose of the study is to retrospectively investigate if the time delay to spanning external fixation of high-energy tibial plateau and plafond fractures had any impact on rate of complications, time to definitive fixation, secondary procedures, and length of stay (LOS). Our hypothesis is that these outcomes will be no different in patients who underwent early versus late fixation.

Methods: We retrospectively reviewed patients greater than 18 years of age who presented to our Level I trauma center with a high-energy tibial plateau (Schatzker IV-VI) or tibial plafond fracture requiring provisional external fixation followed by definitive repair from 2006-2012. Patients were excluded if they had less than 6 months of follow-up or did not receive both the temporizing and definitive surgeries at our institution. Patients who received surgery <12 hours after injury were classified as early external fixation (EEF) and those who underwent surgery >12 hrs after injury constituted the delayed external fixation group (DEF). Demographic data including age, sex, tobacco use, mechanism, and comorbidities were recorded. Infection, LOS, time to definitive fixation, and secondary surgeries (after definitive fixation) were recorded.

Results: Between 2006 and 2012, 215 (109 tibial plateaus and 96 tibial plafonds) fractures met inclusion criteria. 63 (39 plateaus and 24 plafonds) patients were excluded for <6 months follow-up. There were 76 patients (37 plateaus and 38 plafonds) in the EEF cohort with a mean age of 41.8 (range, 20-77) and 72% were male. There were 66 patients (33 plateaus and 34 plafonds) in the DEF cohort with a mean age of 43.2 (range, 19-66) and 70% were male. Average follow-up was similar between early (13.4 months; range, 6-68) and delayed (16.47 months; range, 6-70) groups ($P = 0.17$). Subgroup analysis of plafond fractures demonstrated there were 24 open injuries (33.3%) and an overall infection rate of 22.2%. Similarly, there were 7 open plateau fractures (10%) and an overall infection rate of 20%. There were significantly more open plafonds in the early group ($P = 0.045$), but there was no significant difference in the number of open plateau fractures in the early group ($P = 0.11$). Using linear regression controlling for open fracture, there was no significant difference in infection between early versus late fixation for plafond fractures ($P = 0.42$) or plateau fractures ($P = 0.32$). Overall rate of compartment syndrome was 8.6% in plateau fractures and 7.9% in plafond fractures; these rates were no different between EEF and DEF for plateaus ($P = 0.29$) or plafonds ($P = 1.0$). There was no difference between EER and DEF for LOS for plafond fractures ($P = 0.88$) or plateau fractures ($P = 0.12$). Plateau fractures in the EEF group underwent definitive fixation a mean of 8.46 days after initial fixation compared to 11.5 days for those in the DEF group ($P = 0.058$). There was no difference in time to definitive fixation for plafond fractures ($P = 0.80$). Overall, 61% of plateau and 46% of plafond patients required secondary surgery. There was no difference in number of patients requiring secondary surgeries or overall number of secondary surgeries between early and delayed fixation for either plateau ($P = 0.46$, $P = 0.19$) or plafond fractures ($P = 0.10$, $P = 0.11$).

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Conclusion: There is no detectable difference in rates of infection, secondary surgeries, or hospital stay between patients with high-energy tibial plateau or plafond fractures receiving provisional external fixation <12 hours versus >12 hours. There was a trend toward fewer days to definitive fixation in patients with a plateau fracture who were spanned early; this difference was not present for plafond fractures.

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Intramedullary Nailing With an Internal Compression Device for Transverse Tibial Shaft Fractures Decreases Time to Union When Compared to Traditional "Backslapping" and Dynamic Locking

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Purpose: This study was conducted to compare the time to union and union rate for transverse tibial fractures treated with compression applied through the intramedullary rod or traditional technique of compression by "backslapping" and dynamic locking.

Methods: This was a retrospective analysis of skeletally mature patients with a transverse diaphyseal tibial fracture (OTA 42-A3) managed at a single institution between 2005 and 2012. Group 1 consisted of 22 patients managed with an intramedullary nail having the ability to apply controlled fracture compression using an internal compression device. Group 2 consisted of 32 patients managed with traditional "backslapping" and use of a single interlocking screw placed in the dynamic mode. All patients were permitted immediate weight bearing as tolerated. Inpatient and outpatient charts as well as complete radiographs were reviewed to determine patient demographics, injury characteristics, and time to radiographic and clinical union. Union was defined as the presence of bridging bony callus on at least three cortices and pain-free full weight bearing. Patients were excluded from analysis if they had inadequate follow-up, incomplete radiographs, or the mode of compression could not be ascertained from operative reports.

Results: Both groups were similar with respect to age, gender, fracture location and soft-tissue injury, use of bone stimulators, patient comorbidities, and weight-bearing allowance. The time to radiographic and clinical union was 103 days for group 1 versus 148 days for group 2 ($P = 0.018$). When patients treated with bone stimulators and/or bone morphogenetic proteins were excluded, the time to union was 88 days for group 1 versus 143 days for group 2 ($P = 0.002$). The incidence of nonunion was 0% in group 1 versus 9% (3 patients) in group 2; this difference was not statistically significant due to insufficient power.

Conclusion: Transverse tibial shaft fractures treated with an intramedullary rod with an internal compression device have a significantly shorter time to union and may have an overall lower nonunion rate compared to traditional intraoperative "backslapping" and dynamic locking.

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Can All Tibial Shaft Fractures Bear Weight Following Intramedullary Nailing? A Randomized Clinical Trial

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Background/Purpose: There currently exists no consensus regarding the appropriate postoperative weight-bearing status following intramedullary (IM) nailing of tibial shaft fractures. This prospective randomized study was designed to examine the potential benefits or risks associated with immediate postoperative weight bearing versus non–weight bearing. The null hypothesis was that early weight-bearing status had no effect on outcome following tibial nailing.

Methods: Over a 2.5-year period 60 tibial shaft fractures (OTA Type 42) indicated for surgical treatment with an IM nail that met inclusion criteria were identified. Patients were asked to consent to randomization of their postoperative protocol. Patients were randomized to one of two groups: immediate weight bearing as tolerated (WBAT), or non–weight bearing for the first 6 postoperative weeks (NWB). Regular follow-up was obtained, including radiographs. The Short Musculoskeletal Function Assessment (SMFA) questionnaire was used to record functional outcomes at regular intervals. Patients were followed until union or until treatment failure/revision surgery. All complications were recorded.

Results: A total of 46 patients with 48 tibia fractures had complete follow-up. The WBAT and NWB groups did not differ with regard to demographics, ISS, open/closed fracture status, or fracture pattern. There was no difference in the observed time to union between groups. Rates of complications, including hardware failure and delayed/nonunion, did not differ between groups. No incidents of significant loss of reduction leading to malunion were recorded. SMFA scores for all domains were similar between groups, both at 6 weeks postoperatively and at union.

Conclusion: Immediate weight bearing following IM nailing of tibial shaft fractures is safe and is not associated with an increase in adverse events or complications. Patients should be allowed to bear weight as tolerated following IM nailing. This has potential implications in improving patient satisfaction, earlier return to work, and faster rehabilitation.

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Does a 6-Month Wait Before Reoperation Improve Tibial Nonunion Rates?
A Comparative Examination of Patients Not Enrolled in SPRINT

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Purpose: The SPRINT trial had lower than expected reoperation rates for nonunion based on previous literature (5% vs 11%), and it was hypothesized that the 6-month prohibition against reoperation was a major contributing factor. We compared rates and timing of reoperation in a subset of patients enrolled in SPRINT to those who were eligible but not enrolled to evaluate the effect of the 6-month waiting period and assessed the influence of a large randomized controlled trial on a parallel observational cohort.

Methods: The billing records of 6 of the SPRINT centers were searched for current procedural terminology (CPT) codes indicating intramedullary nailing of a closed tibia fracture and reoperation for fracture healing. Patients were grouped into SPRINT and unenrolled patients, and the rate and timing of reoperation were compared. A Fisher exact test was used to compare categorical variables and a Student t test was used to compare continuous variables. $P < 0.05$ was considered significant.

Results: 114 unenrolled patients were compared to 328 patients enrolled in SPRINT from the 6 sites. 105 (92%) underwent reamed nailing versus 167 (51%) of the SPRINT patients ($P < 0.001$). There were 7 reoperations (6.1%) in unenrolled patients versus 18 (5.5%) in SPRINT patients (odds ratio [OR] 1.13, 95% confidence interval [CI] 0.39 to 2.92; $P = 0.815$). There was no difference in the time to reoperation for nonunion (6.3 vs 6.8 months, 95% CI of the difference –3.75 to 2.65; $P = 0.701$). The proportion of patients who underwent reoperation before 6 months was substantially but not statistically significantly higher in the unenrolled patients (28% vs 43%, OR 1.9, 95% CI 0.20 to 16.53; $P = 0.640$).

Conclusion: Patients not enrolled in the SPRINT trial but who were treated at the same centers had similarly low rates of reoperation for nonunion following intramedullary nailing for closed tibial shaft fractures. A 6-month waiting period may explain the lower than expected rates. It is possible that clinical trials associated with improved outcomes may beneficially influence the care of nonenrolled patients; however, the extent of this influence requires further investigation. Parallel observational studies can be useful adjuncts to randomized controlled trials.

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What Is a "Critical Bone Defect" in Open Tibia Shaft Fractures Definitively Treated With an Intramedullary Nail?

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Background/Purpose: Tibia fractures are the most common long bone fractures representing 2% of all fractures with 12% to 23.5% open injuries, making them the most common open long bone injuries. When focusing on patients treated with intramedullary nailing (IMN), reported nonunion rates range from 3.4% to 18%. Currently, some treatments approaches include early, staged intervention for "critical bone defects". It is unclear when these staged treatments are indicated as the literature has yet to define the minimum threshold for bone loss requiring surgical intervention. This study aims to better define a "critical bone defect" based on clinical outcomes of union versus nonunion.

Methods: 180 patients age 18 to 65 years with open tibia diaphyseal fractures definitively treated with IMN from January 1, 2007to June 30, 2012 were retrospectively identified. 35 patients had 1 to 5 cm of bone loss on ≥50% of the cortices, at the time of definitive fixation, with a recorded outcome or at least 6 months of follow-up. Factors analyzed included: defect size, time to surgery, Gustilo-Anderson classification, number of procedures, use of additional fixation or biologic agents, deep infection requiring surgical intervention, presence of impaired vascular status, malignancy, diabetes, simultaneous injuries, autoimmune disease or immunosuppression, and total number of comorbidities. Average defect size measurements were calculated from cortical gap between bone fragments on standard AP and lateral radiographs. Analysis used a multivariate regression model to identify factors contributing to nonunion.

Results: Overall 50 of 180 patients with open tibial shaft fractures treated with IMN had defects of 1 to 5 cm on ≥50% of the cortices. 15 patients with qualifying defects were lost to follow-up. Patients achieving union averaged a defect size of 1.9 ± 0.5 cm/cortex, while those with nonunion averaged 3.0 ± 1.1 cm/cortex (P <0.01). No other covariates predicted healing outcomes. To further elucidate the definition of a critical bone defect, patients were group by bone defect size. Comparing patients with average cortical defects of 1 to 3 versus ≥3 cm revealed union rates of 61.5% and 0%, respectively (P = 0.018). Receiver operating characteristic curve analysis produced an area under the curve of 0.80, defining a 3-cm average defect as a good prognostic threshold for predicting union without intervention (P = 0.0001).

Conclusion: Determining initial injury factors that predict patient outcomes provide surgeons useful information for operative planning. Knowing the chances a patient will likely go on to nonunion at the time of initial fixation provides an opportunity to set both patient and surgeon treatment expectations. This study demonstrates that patients with a 1 to 3-cm average cortical defect have a high probability of achieving union. In patients with an average defect of ≥3 cm, nonunion was universal, thus increasing the value of early planned intervention. Diaphyseal bone grafting research addressing clinically significant differences should employ a conservative threshold for a "critical bone defect." An average

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cortical defect of ≥3 cm appears to be a reasonable threshold defect size. Limitations of this study include the retrospective nature and small cohort size. Further studies, including multicenter retrospective and prospective observational studies, are necessary to further characterize critical bone defects.

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Alignment After Intramedullary Nailing of Distal Tibia Fractures Without Fibula Fixation

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Background/Purpose: Recent studies have shown lower rates of malalignment after intramedullary nailing of distal tibia shaft fractures with fixation of the fibula. However, fixation of the fibula brings with it risks of its own. The purpose of this study is to evaluate the efficacy of intramedullary nailing of distal tibia fractures using modern techniques without fibula fixation in obtaining and maintaining alignment and to evaluate the level of fibula fracture and the OTA tibial fracture type on alignment.

Methods: 137 consecutive patients with distal tibia fractures form the basis of this study. Demographic data, comorbidities (smoking, diabetes mellitus), mechanism of injury, fracture characteristics (open vs closed, OTA/AO classification, presence and location of fibula fracture), canal fill ratio, and the techniques used for reduction and nailing were documented. Malalignment (occurring in the operating room) and malunion (at union) were defined as greater than 5° of angulation on the initial postoperative AP or lateral radiographs and the final radiographs after union, respectively. Complications included unplanned secondary procedures (dynamization, exchange, removal locking screws), infection, wound dehiscence and delayed/nonunion. The effect of the OTA fracture type and the presence of fibula fracture and its level on alignment were evaluated using analysis of variance.

Results: There were 137 consecutive patients (96 men and 41 women) aged 16-93 years (average 43) with 41 (30%) open and 96 (70%) closed fractures. Five patients with indirect ankle fractures were excluded. Ten were lost prior to complete union but are included in the analysis of postoperative alignment. Mechanism of injury did not predict presence or level of fibula fracture. Fibula fractures were proximal (39), at the level of (46), distal to (30), segmental (7), and absent (10) with respect to the tibia fracture. Varus/valgus and procurvatum/recurvatum angulation upon presentation was greatest when the fibula was fractured at the level of the tibia fracture ($P = 0.001$ and 0.028). Reaming was performed in 84% and distal locking was with two medial to lateral locking screws in 95% with 5% having an additional AP locking screw for coronal plane fracture or osteopenia. Three patients had blocking screws. 36 patients (26%) had intra-articular extension of which 20 were fixed with screws and or plate outside the nail. The ratio of the nail to narrowest canal diameter at the level of the tibia fracture averaged 1.93 (range, 0.5-3) and did not correlate with malalignment or malunion. The most common intraoperative reduction aids were nailing in relative extension, transfixion external fixation, and clamps at the fracture site. The most important factor was felt to be the ability to visualize the reduction in both planes through the point of distal locking. The overall malalignment rate was 2%. Two additional patients had hardware removal prior to union for wound complication or infection and united at 6° and 8° resulting in a final malunion rate of 3%. The OTA fracture type or level/presence of fibula fracture did not influence alignment ($P = 0.8$ and 0.9), malunion ($P = 0.9$ and 0.99), or the change in alignment during union, which averaged 0.9° and was within measurement error. There were 2 wound problems/infection, 5 delayed/nonunions, and 4 distal screw removals for irritation.

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Conclusion: We found an overall low rate of both malalignment (2%) and malunion (3%) after intramedullary nailing of distal tibial shaft fracture without fibula fixation. We conclude that when techniques that allow for visualization through distal locking are used, fibula fixation is not necessary to obtain or maintain alignment. Additionally, standard two medial to lateral screws distally affords adequate stability to hold the reduction during union with a 0.9° difference in the initial postoperative and final united films.

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Outcomes of the Patients With Cultured Pathogens at the Time of Nonunion Surgery

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Purpose: This study was conducted to evaluate the incidence and outcomes of patients who cultured positive (PCP) during the surgical treatment of long bone nonunion.

Methods: 288 consecutive patients referred to a tertiary care medical center with a long bone nonunion were consented and enrolled in a prospective database. 216 (75%) who had undergone previous surgery were cultured intraoperatively for aerobic, anaerobic, and fungal pathogens. Standard preoperative lab data were collected on all patients and infectious laboratory markers were ordered on patients suspected for infection. When applicable, patients were recultured at follow-up débridement or revision surgery. All patients with positive operating room cultures were treated in consultation with an infectious disease specialist who prescribed culture sensitivity directed intravenous antibiotics. Patients were followed for at least 1 year after our institution's first intervention. The primary outcomes assessed are wound complications, antibiotic use, healing, function, and readmission for further surgery.

Results: Initial operative cultures returned positive on 23.6% of patients with an additional 3.1% culturing positive during the course of secondary treatments. All long bones were represented in the sample, but the majority of positive cultures were from tibial nonunions (41.5%). Preoperative white blood cell counts, erythrocyte sedimentation rate, and C-reactive protein were significantly elevated among PCPs (P <0.02). A significantly greater percentage of PCPs (46.7%) developed wound complications during follow-up visits (P <0.01). Antibiotic use averaged 3.2 months, versus 3 days in all other patients (P <0.01). Significantly more PCPs returned to the operating room for irrigation and débridement, averaging 1.3 visits per patient (P <0.01). At 9.8 months, PCPs required an additional 3.5 months more than others to progress to union (P <0.02). Poor outcomes appeared in the 3.1% of patients who initially cultured negative, but converted to positive during the course of treatment. Their mean healing time was 14.3 months. Overall, the PCP group was significantly more likely to undergo removal of hardware (P <0.01) and revision surgery (P <0.05). The poorest outcomes were seen in two of the PCPs (3.3%) who failed several revision surgeries and opted for amputation over further reconstruction attempts. At 1-year follow-up, PCPs reported significantly worse function on 5 of 6 Short Musculoskeletal Function Assessment indices (P <0.01).

Conclusions: In a large sample of nonunion patients, the infected nonunion stood apart on essentially all measures of outcome. Positive operating room culture at any point during the management of long bone nonunion was a prognostic indicator of impaired healing and poorer long-term functional outcomes in this study.

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Acute Compartment Syndrome: Where Pressure Fails, pH Succeeds

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Background/Purpose: Failure to recognise and treat acute compartment syndrome (ACS) early leads to significant morbidity. Current practice is dependent on the use of clinical signs and intracompartmental pressure (ICP) monitoring to identify the syndrome but there is still debate regarding the accuracy and interpretation of these findings. A more direct and reliable system is required.

Methods: Patients admitted with limb injuries at risk of developing an ACS underwent intramuscular (IM) pH and ICP monitoring with regular clinical assessment for the presence of the syndrome during their hospital stay. Fasciotomies were performed on those with clinical and/or pressure-based evidence of an ACS as per the unit's protocol. All patients were subsequently assessed for evidence of a missed compartment syndrome during routine follow-up and at specific research clinics at 6 and 12 months.

Results: Of the 62 patients participating in the trial, 51 subjects completed the follow-up protocol and were therefore included in the final analysis. They were divided into 2 groups: those who had evidence of a compartment syndrome, either initially (fasciotomies [n = 13]), or at follow-up (no fasciotomies [n = 7]), and those who had no evidence of an ACS (n = 31). The sensitivity and specificity for the worst values for each variable were calculated allowing receiver operator characteristic (ROC) curves to be created. These identified an area under the curve of 0.921 for pH, 0.732 for absolute pressure, and 0.591 for delta pressure. To achieve a sensitivity of 95%, an absolute pressure of greater than 30 mm Hg was only 30% specific, and a delta pressure of less than 33 mm Hg was 27% specific, while IM pH was 80% specific at this level (pH <6.38).

Conclusion: This study highlights the issues concerning the current diagnostic methods for ACS and provides the breakthrough that has been long anticipated. Despite the dependence on clinical and pressure-based evidence for diagnosing ACS in this study, intramuscular pH radically outperformed both the highest ICP and the lowest delta pressure. Using IM pH to diagnose ACS, clinicians can confidently identify patients early and accurately, significantly reducing the morbidity associated with this syndrome.

See pages 91 - 132 for financial disclosure information.

Interobserver Reliability in the Measurement of Lower Leg Compartment Pressures

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Purpose: Accurate measurement of compartment pressures may be crucial to the correct diagnosis of a compartment syndrome. Commercially available monitors have not been validated as reliable in clinical practice. We hypothesized that there would be significant interobserver variability in measuring compartment pressures in a simulated compartment syndrome cadaveric lower leg model.

Methods: Four above-knee cadaveric specimens were used to create a compartment syndrome model with consistent lower leg compartment pressures at a mean of 47 mm Hg. This pressure was monitored with indwelling slit catheters and the authors' serial measurements (standard deviation [SD], 2.8 mm Hg). 38 emergency department, general surgery, and orthopaedic surgery residents, fellows, and attending physicians examined the limb for firmness and a diagnostic impression assuming a diastolic blood pressure of 70 mm Hg. They assembled the compartment pressure monitor with a side-port needle and measured the pressure in the four compartments of the leg. They were observed for correct assembly of the monitor, reading the instructions, proper zeroing and flushing of the monitor for each measurement, and anatomically correct measurements. The measurements were recorded and compared to the standard pressure measurements.

Results: 47% of participants were clinically concerned for compartment syndrome based on the firmness of the leg. 61% of participants did not read the instructions. Of the 152 separate compartment measurements, 48 (31.6%) were made with proper technique, 45 (29.6%) were made with catastrophic errors in technique, and 59 (38.8%) with lesser variations in technique. Participants' level of training, experience using a compartment pressure monitor, and reading the monitor's instructions did not have a significant effect on the likelihood of making a catastrophic error nor did they have a significant effect on accuracy to within 5 mm Hg of the standard compartment pressure. Using proper technique significantly improved the accuracy of the measurements ($P<0.005$): 60% of proper technique measurements were within 5 mm Hg of the standard pressure while 42% of those with lesser variations in technique and 22% of those with a catastrophic error were within this range. Proper technique measurements were a mean of 5.9 mm Hg (SD 7.1) from the standard pressure while those with variant technique were a mean of 10.8 mm Hg (SD 12.8) and those with catastrophic errors in technique were a mean of 20.1 mm Hg (SD 14.0) from the standard pressures, respectively. This difference between the catastrophic error group and the other two groups was significant ($P<0.001$). 41% of measurements were below 40 mm Hg, which corresponded to a delta P of 30 mm Hg in this model. These would have resulted in the missed diagnosis of compartment syndrome.

Conclusion: There was significant variability in technique and results obtained with a compartment pressure monitor. Catastrophic errors and variations in technique were com-

PAPER ABSTRACTS

- The FDA has not cleared this drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an "off label" use). For full information, refer to page 496.

mon. Proper technique improved accuracy, but even with proper technique 40% of the measurements were at least 5 mm Hg from the correct pressure. We recommend review and education of proper technique for all clinicians measuring and diagnosing compartment syndrome. The numeric value obtained when measuring compartment pressure must be seen as an approximation.

See pages 91 - 132 for financial disclosure information.