Long-Acting Local Anesthetic in Ankle Fractures Requiring ORIF Reduces Postoperative Narcotic Use: A Randomized Trial

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Purpose: Our objective was to determine the efficacy of liposomal bupivacaine with bupivacaine compared to placebo for postoperative pain control in patients undergoing operative fixation of ankle fractures.

Methods: After IRB approval, 50 patients with acute ankle fractures (OTA 44A-C) requiring operative fixation that met inclusion criteria were identified at a Level I trauma center. Patients were randomly assigned to one of two groups, standard of care (general anesthesia alone) or local intraoperative liposomal bupivacaine with bupivacaine (interventional) and remained blinded to study arm. Postanesthesia care unit (PACU) pain medications administered and pain according to visual analog scale (VAS) were recorded. Patients were discharged on oxycodone/acetaminophen (Percocet) 5/325 mg for pain control. Pain levels and pain medications taken were recorded at postoperative time points of 4, 24, 48, and 72 hours by a trained researcher. Patients followed up in the operative surgeon's office until union and then continued to be followed until maximal medical improvement. At each follow-up visit, patients were given a short questionnaire regarding satisfaction with pain control. Pain scores were again recorded using VAS at these visits.

Results: 23 males and 27 females (mean age = 45 ± 16 years) were enrolled and obtained adequate follow-up. 26 patients were randomized to the control group and 24 to the interventional group, with no statistically significant differences between groups with regards to severity of injury and patient demographics including gender, age, and body mass index (BMI). Pain scores were lower in the interventional group versus control at each time point assessed, achieving significance for pain levels at 4 hours (3.4 vs 5.8, P = 0.01). Percocet ingestion at 4 hours and 48 hours postoperatively were significantly lower in the interventional group (0.35 vs 1.1, P = 0.004, and 1.5 vs 2.6, P = 0.007, respectively) with no significant differences in Percocet taken postoperatively at all other time points assessed (P = 0.243, P = 0.606). There was no significant difference regarding PACU morphine use between the control group and the interventional group (0.74 doses vs 0.45 doses, P = 0.301). There was no difference in pain score and total pain medication used between postoperative day three and postoperative day fourteen (P = 0.684, P = 0.378, respectively). The overall satisfaction with pain control was not statistically different between the two groups (P = 0.467).

Conclusion: Local intraoperative infiltration of liposomal bupivacaine with bupivacaine for ankle fractures requiring open reduction and internal fixation (ORIF) affords improved pain relief in the immediate postoperative period resulting in a reduction in Percocet ingestion, with resultant effects seen up to two days postoperatively. Interestingly, this reduction did not result in a reduced length of PACU stay, reflecting the comprehensive criterion composing PACU discharge. Continued investigation of this drug for use with extremity fractures is warranted.

Association Between Opioid Intake and Disability After Operative Treatment of Ankle Fractures

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Background/Purpose: The opioid-centric pain management strategies in the United States have contributed to an epidemic of prescription opioid abuse that is the most common cause of death of young adults. A prospective cohort study documented comparable pain intensity and satisfaction with pain relief after open reduction and internal fixation (ORIF) of an ankle fracture among patients using acetaminophen in the Netherlands and oxycodone in the United States. Another prospective cohort study found that increased inpatient opioid intake after operative fracture treatment was associated with more pain and decreased satisfaction with pain relief independent of the type, number, and severity of fractures. The effective coping strategy of self-efficacy was associated with less pain and greater satisfaction with pain relief after fracture surgery. In yet another prospective cohort study, opioid intake 1 to 2 months after fracture surgery correlated with psychological distress (PTSD [posttraumatic stress disorder], symptoms of depression). Studies consistently identify psychosocial factors as more strongly associated with symptom intensity and magnitude of disability after injury. Continuing this line of research, this prospective cohort study addressed the null hypothesis that disability (Foot and Ankle Disability Measure) at suture removal does not correlate with opioid intake, measured by oral morphine equivalents following ankle fracture surgery, accounting for demographics, trauma and surgery factors, treatment satisfaction, and psychological measures. Secondarily we assessed disability at 5 to 8 months after surgery and treatment satisfaction.

Methods: Following institutional review board approval, we prospectively enrolled 102 adult patients at suture removal after ankle fracture surgery, no more than 4 weeks after injury. We recorded patient demographics, opioid use before injury, oral morphine equivalents taken between discharge and suture removal, injury mechanism, Pain Anxiety Symptoms Scale, Pain Catastrophizing Scale, symptoms of depression (Patient Health Questionnaire-2), 11-point ordinal rating scales for active and resting pain intensity and for satisfaction with pain management and overall treatment, and foot and ankle-specific disability (Foot and Ankle Disability Measure). To address our secondary study questions 59 patients (60%) completed questionnaires 5 to 8 months after surgery.

Results: Accounting for interaction between variables using multivariable analysis there was no association of taking opioid medication and disability at the time of suture removal. Being married (β regression coefficient [β] 13, 95% confidence interval [CI] 4.2 to 21, P = 0.003; partial R2 0.087), sports injuries (β 15, 95% CI 4.7 to 26, P = 0.005; partial R2 0.080), and less pain catastrophizing (β -1.2, 95% CI -1.7 to -0.72, P <0.001; partial R2 0.20) were associated with less disability at the time of suture removal. Among the 60% of patients evaluated 5 to 8 months after surgery, greater disability was independently associated with more pain anxiety (β -1.1, 95% CI -1.7 to -0.48, P = 0.001; partial R2 0.19). Greater treatment satisfaction at suture removal was independently associated with less pain catastrophizing (β-0.088, 95% CI -0.12 to -0.053, P <0.001; partial R2 0.21). Five to eight months after surgery,

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no variables were associated with treatment satisfaction. Additionally, greater pain at rest at suture removal was associated with more oral morphine equivalents at suture removal (β 0.042, 95% CI 0.0021 to 0.063, P <0.001; partial R2 0.14) and greater pain with activity at suture removal was associated with more oral morphine equivalents at suture removal (β 0.048, 95% CI 0.024 to 0.072, P <0.001; partial R2 0.14).

Conclusion: Opioid use and injury characteristics were not independently associated with disability or treatment satisfaction in patients recovering from ankle fracture surgery. Managing psychological distress and optimizing coping strategies are consistently identified as the best opportunities for decreasing symptom intensity and magnitude of disability during recovery from musculoskeletal trauma. It's time to move away from the opioid-centric model for pain management and proactively address stress, distress, and ineffective coping strategies.

Incisura Morphology as a Risk Factor for Syndesmotic Malreduction

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Background/Purpose: Although it has been recognized that syndesmoses have variable morphology among the population, previous studies have not shown an association between incisura morphology and malreduction following injury. Recently, specific measurements have been developed to assess the syndesmotic reduction based on bilateral CT scans. The effect of syndesmotic morphology on reduction accuracy has not been established. We hypothesized that sagittal plane and rotational reduction would vary based on depth of the syndesmotic incisura.

Methods: At a single institution, a prospective cohort of 35 patients with injuries to the syndesmosis underwent postoperative CT scans of the bilateral ankles after open reduction and internal fixation (ORIF) of the malleoli and syndesmosis. The accuracy of the syndesmotic reduction was assessed by comparing the operative ankle to the contralateral, uninjured ankle. The depth of the incisura was quantified at a level 1 cm proximal to the tibial plafond. The patients were subdivided into shallow (<2.5 mm, 8 patients), average (2.5-4.5 mm, 18 patients), and deep (>4.5 mm, 9 patients) incisura.

Results: There was a significant correlation between more shallow syndesmoses and increased anterior translation of the fibula in the incisura ($r = -0.63$, $P < 0.001$). Six of the "shallow" patients (75%) were anteriorly malreduced 1.5 mm or greater compared to the contralateral ankle. The "shallow" anterior malreduction rate in those with a shallow incisura was significantly greater than in the "non-shallow" patients ($P < 0.001$). Five of the "deep" patients (55%) had posterior malreductions >1.5 mm. The posterior malreduction rate in the "deep" group was significantly greater than the "non-deep" patients ($P = 0.02$). There was a significant correlation between increasing syndesmotic depth and increased malrotation ($r = 0.34$, $P = 0.048$).

Conclusion: Syndesmotic morphology was found to be associated with specific malreduction patterns. Shallow syndesmoses were correlated with anterior fibular malreduction, and were less likely to be malrotated. Conversely, deep syndesmoses predispose to posterior sagittal plane and rotational malalignment. Preoperative CT scans that assess the syndesmosis morphology may allow surgeons to alter reduction strategies to avoid syndesmotic malreduction.

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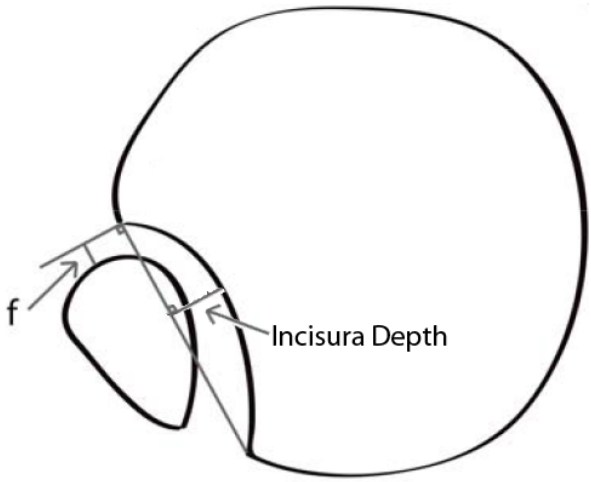

Figure 1- Demonstrates the measurements taken at 1cm proximal to the tibial plafond. The incisura depth was measured in addition to the anterior-posterior translation of the fibula (measurement f)

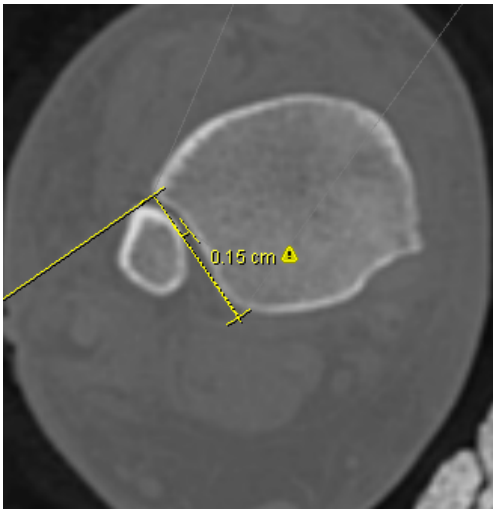

Figure 2- injured limb showing anterior translation of fibula in shallow native incisura on post-operative CT scan. Syndesmosis depth is shallow (0.15cm), and the fibula is at the level of the anterior point of the incisura (f= 0cm)

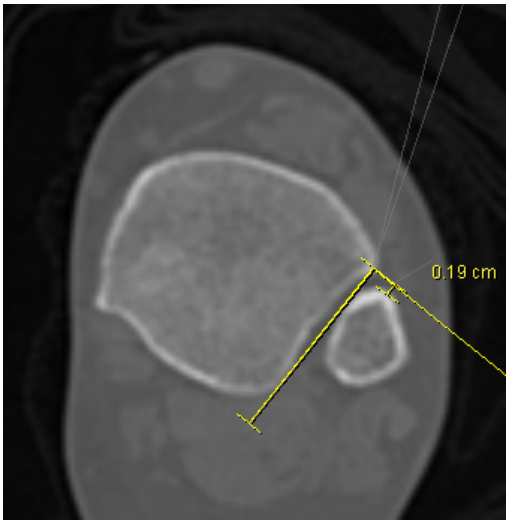

Figure 3-uninjured limb as control, measurement f=0.19cm.

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Does Physical Therapy Predict Outcomes after Ankle Fractures and Ankle Fracture-Dislocations?

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Purpose: Despite the widespread use of physical therapy for treatment of lower extremity injury and specifically for ankle fractures, its role in functional rehabilitation and patient outcomes is poorly understood. Although addressed by several authors, no definitive study has determined the treatment effect of postoperative physical therapy for this group. The purpose of this study is to determine the pragmatic effectiveness and outcomes associated with physical therapist-supervised rehabilitation (PT) compared to surgeon-directed rehabilitation (NoPT). We hypothesized that the long-term clinical outcomes for patients who receive supervised physical therapy-directed rehabilitation will have similar outcome to those receiving surgeon-directed rehabilitation.

Methods: After IRB approval, 80 patients with bimalleolar or trimalleolar ankle fractures with or without dislocation were enrolled in a prospective observational study. The study population included patients with displaced ankle fractures or fracture dislocations who were treated operatively. Injury characteristics, patient demographics, and pre/post fixation and follow-up radiographs were captured. Patient-reported outcome scores were assessed using FAAM (Foot and Ankle Ability Measure) and SFMA (Short Musculoskeletal Function Assessment) questionaires at 6,12, and 24 months. Patients were prescribed physical therapy at the discretion of their treating surgeon based upon their clinical judgement and patients' individual postoperative course between 6 weeks - 6 months. Patient reported outcome scores and complication rates for patients receiving therapist-directed rehabilitation (PT) were compared to those receiving physician-directed rehabilitation (NoPT).

Results: Of the 80 patients, 38 patients (47.5%) were prescribed supervised rehabilitation (PT) while the remaining received exercise instruction from the physician or ACP at a clinic visit (NoPT). 34 patients (89.5%) attended at least one PT session. Number of sessions attended by each patient ranged from 1 to 36 (average = 16). Whether or not a patient received a PT prescription did not differ by injury characteristics or demographics but did differ by insurance status. 37 (56%) of patients with insurance versus 1 (7%) patient without were prescribed PT ($P < 0.001$). Patient-centered outcome scores collected at 6 months show mean FAAM score of 69.7 for PT compared to 70.9 for NoPT groups ($P = 0.868$). Combination SMFA scores for PT cohort were 20.1 compared to 24.4 in NoPT group ($P = 0.454$), and there were no significant differences on any of the subscale scores. Physician and practice-specific differences were observed between provider subset groups. Postoperative complications were rare and equivalent between the groups. Costs associated with the PT group were $125.81 average per patient/session. The total cost of supervised rehabilitation was $62,401 for our patient cohort.

Conclusion: The comparison of the outcomes between patients with operatively treated displaced ankle fractures or ankle fracture-dislocations with therapist-directed versus

physician-directed rehabilitation showed no difference in validated SMFA and FAAM outcome scores. These findings would suggest that patients receiving supervised physical therapy produced a similar outcome to those under routine physician-directed rehabilitation at 6 months postoperatively. The cost related to the therapy averaged $2012.96 per patient receiving PT.

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Peroneal Irritation After Lateral Malleolar Fractures

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Purpose: Peroneal irritation is a common finding after open reduction and internal fixation (ORIF) of lateral malleolar fractures. It has been correlated with posterior plate position, but no specific investigation has been performed to determine factors associated with this finding. There were two goals of this trial: first, to evaluate the patient, surgical, and construct factors associated with peroneal symptoms; second, to document the incidence of peroneal symptoms over time after fixation.

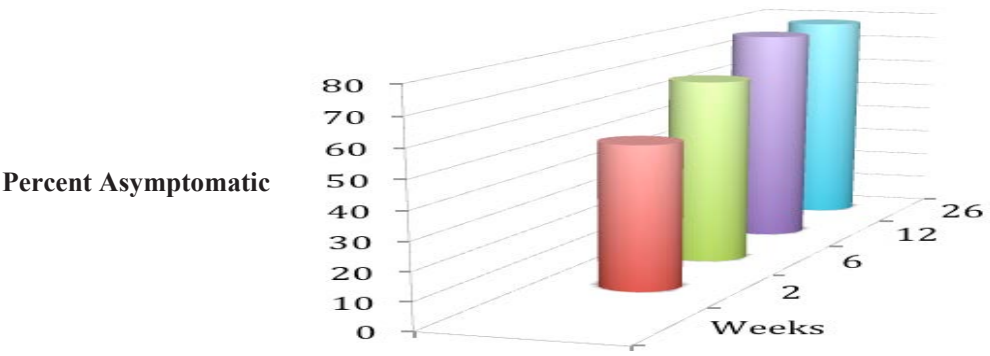
Methods: 227 patients with Weber B ankle fractures were prospectively evaluated at 2, 6, 12, and 26 weeks after fibular fixation in a multicenter trial. Patient demographics, plate location and position, and syndesmotic fixation were documented. At each follow-up examination, the status of the peroneal tendons was documented as: asymptomatic, sensitive to touch, occasionally bothersome, or significantly bothersome. Comparisons were made between asymptomatic versus all other groups and between asymptomatic or sensitive to touch versus any category or bothersome. Statistical significance was set at $P < 0.05$.

Results: 227 patients were enrolled and form the basis of this trial. There were 128 women and 99 men aged 18-77 years (average 43) treated with 114 lateral and 113 posterior plates. At 6 months of follow-up none of age, gender, race, ISS, BMI (body mass index), incision length, posterior versus lateral plating, plate length, number of screws distal to the fracture, or the presence of syndesmotic fixation correlated with peroneal symptoms when comparing asymptomatic against all others, or when comparing any level of bothersome versus not. However, active smokers were less likely to be asymptomatic ($P = 0.0004$) and more likely to have bothersome sequelae ($P = 0.006$). Patients with low-energy injuries were more likely to be asymptomatic ($P = 0.0001$). There was a greater distance from the tip of the fibula to the plate in asymptomatic patients compared to all others ($P = 0.05$). The percentage of asymptomatic patients improved from 52% at 2 weeks, to 67% at 6 weeks, and stabilized at 78% by 12 weeks (figure).

Conclusion: The rate of peroneal symptoms after ankle fracture stabilizes by 12 weeks. Smokers and patients who sustained high-energy injuries had greater rates of peroneal symptoms.

The only surgeon-controlled factor predicting peroneal symptoms was a shorter distance from the tip of the fibula to the plate. Surgeons should attempt to keep plates as proximal as feasible. Additionally, smoking cessation should be examined as a possible intervention.

Peroneal Irritation After Lateral Malleolar Fractures



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Reduction Clamp Force Associated with Syndesmotic Overcompression: A Pilot Study

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Background/Purpose: Syndesmotic malreduction is one of the strongest predictors for a poor outcome in patients with ankle trauma. Recent studies have found that syndesmotic overcompression is possible and very common. Syndesmotic reduction typically involves using a reduction clamp to position the fibula within the distal tibial incisura. The relationship between the magnitude of force generated by the reduction clamp during syndesmotic reduction and the incidence of syndesmotic overcompression has not been previously studied. The purpose of this study was to quantify the clamp force used during syndesmotic reduction and to evaluate the effect of clamp force on overcompression in a clinical cohort. Our hypothesis was that increased reduction clamp force will lead to syndesmotic overcompression.

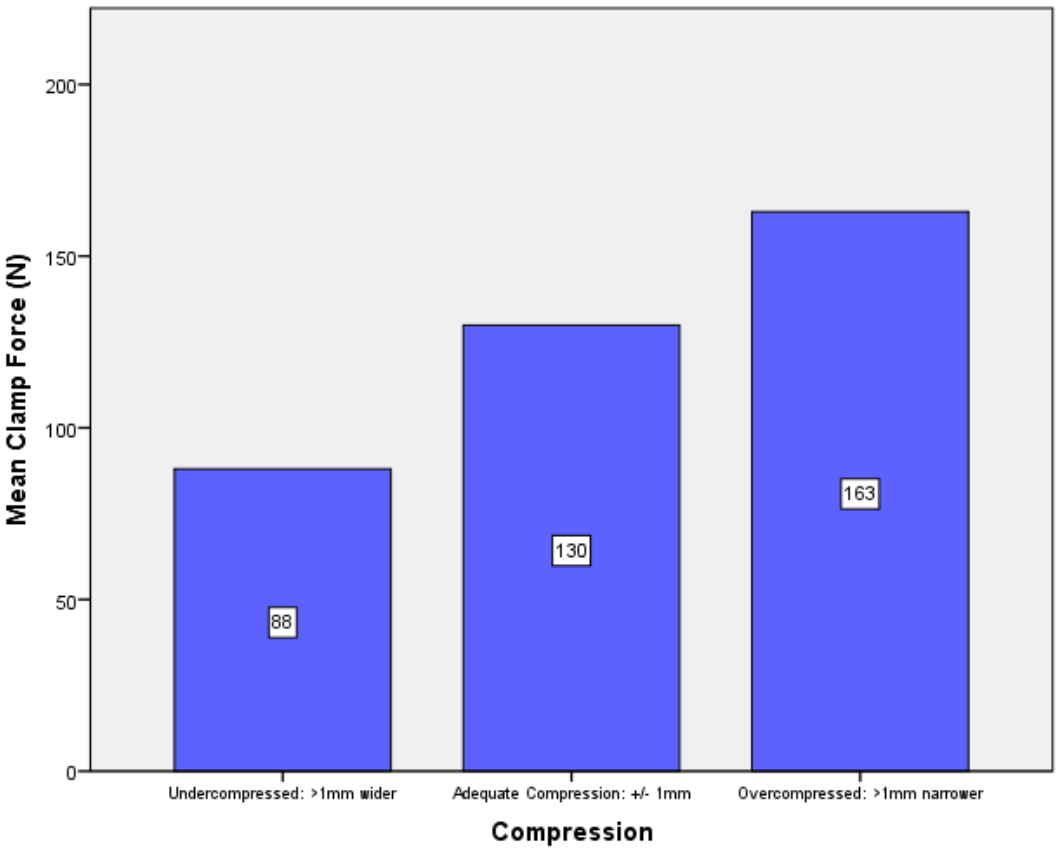
Methods: A prospective cohort of 21 patients with syndesmotic injuries treated with clamp reduction and screw fixation were enrolled. A standard pointed reduction clamp modified to include a load cell on one tine was utilized for syndesmotic reduction. One of three fellowship-trained orthopaedic trauma surgeons reduced the syndesmosis using standard techniques using the modified load cell clamp. Clamp force was recorded after final clamping and prior to screw fixation. Reduction was assessed fluoroscopically, and compared to the contralateral uninjured ankle. Surgeons were blinded to the clamp force. Bilateral ankle CT scans were obtained postoperatively to assess reduction accuracy. Multiple standardized measurements, based on a previously published protocol, were used to assess reduction. These measurements evaluated sagittal and coronal plane translation, and rotation of the fibula relative to the incisura. "Overcompression" was defined as 1 mm or greater of difference in fibular medialization when comparing the operative side to the noninjured side. The clamp force was also correlated to patient factors including BMI (body mass index), age, and number of days from injury to surgery. Two-tailed t tests and Pearson correlations were used to compare the results of the reduction with the intraoperative clamp force, as well as correlate clamp force with the patient factors, using $P < 0.05$ as significant.

Results: Increased clamp force significantly correlated with syndesmotic overcompression ($r = 0.444$, $P = 0.044$). Syndesmotic overcompression was seen in 11 of 21 patients (52%). Two patients (10%) had undercompression of the syndesmosis of >1.0 mm compared to the noninjured side. Eight patients (38%) had adequate syndesmotic compression, where the coronal plane fibular translation was within 1.0 mm of the noninjured side. The mean reduction clamp forces were 88 N (standard deviation [SD] 11) for the undercompressed group, 130 N (SD 56) for the adequately compressed group, and 163 N (SD 79) for the overcompressed group. The overall range of recorded clamp force was 36 to 261 N. Of the patient factors examined, both increased BMI ($r = 0.140$) and days from injury to surgical fixation ($r = 0.101$) positively correlated with increased clamp reduction force.

Conclusion: This pilot study demonstrated a significant correlation between increased clamp forces and syndesmotic overcompression, and determined objective forces that lead

to overcompression. Biomechanical studies have shown that the distal tibiofibular joint undergoes physiologic widening with ankle dorsiflexion, therefore it is likely that overcompression and rigid fixation of the syndesmosis results in decreased ankle motion. Our results indicate that surgeons should be cognizant of the clamp force used for syndesmotic reduction. Further investigation will correlate clamp force and overcompression to ankle range of motion and functional outcomes.

Figure 1. Reduction Clamp Force vs. Amount of Syndesmotic Compression



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A Clinical Comparison of Treatment of Deltoid Ligament Injuries in Ankle Fracture: Repairing the Deep Deltoid or Superficial or Not

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Background/Purpose: Decades ago, it was common for surgeons to repair the injured deltoid ligaments at the time of fibular osteosynthesis. In the last 30 years, many reports showed no significant difference in outcomes when patients received conservative or surgical treatment if the medial clear space reduced in Weber type B and C fractures. However, there has been varied opinion on when to do open repair of the deltoid ligament. This study compared the clinical outcomes in patients with repairing the injured superficial deltoid ligaments and deep deltoid ligaments, and patients without direct surgical intervention after anatomic restoration of the fibular fracture and the medial clear space.

Methods: Since April 2013, a prospective study of ankle fractures associated with deltoid ligament rupture and lateral or lateral-posterior dislocation of the talus was conducted on 3 groups of subjects: 22 patients were treated by superficial deltoid ligament repair, 25 patients received deep components augmentation at the time of fibular osteosynthesis, and 21 patients accepted no direct surgical intervention. For the deep components group, a suture anchor was placed in the talus at the talar insertion of the deep deltoid ligaments and the four suture limbs were passed through the bony canal of medial malleolus to augment them. For the superficial one, the suture anchor was placed in the tip of medial malleolus, and sutured the injured ligaments directly. All the patients were evaluated with stress views preoperatively and intraoperatively. The outcomes were evaluated with Philips and Schwartz clinical scoring system of ankle and AOFAS (American Orthopaedic Foot & Ankle Society) Ankle-Hindfoot Scale.

Results: 68 patients were followed for an average of 15 months. In the superficial components group, the mean degree of plantar flexion was 48.5°, with 2.3° (range, 0-10°) less than the normal side, the mean degree of dorsiflexion was 14.1°, with 6.8° (range, 0-15°) less than the normal side. In the deep components group, the plantar flexion was 49.1°, the dorsiflexion was 14.0°, with 2.6° (range, 0-10°) and 6.9° (range, 0-14°) less than the normal side. In the nonrepaired group, the plantar flexion was 49.4°, the dorsiflexion was 14.4°, with 2.2° (range, 0-10°) and 6.4° (range, 0-20°) less than the normal side. The mean Philips and Schwartz score was 92.8 (range, 80-100) in superficial group, 93.7 (range, 70-100) in deep group, and 93.8 (range, 85-100) in the nonrepaired group, while the AOFAS score was 94.3 , 94.6, and 93.7, respectively. According to the intraoperative stress views, we found that the repair group, especially the deep components repair group, can reduce the talus tilt and rotation under valgus and lateral rotational stress. However, no statistically significant intergroup differences were evident in terms of clinical outcomes.

Conclusion: This study did not support regularly exposing and repairing the injured deltoid ligaments whether superficial or deep components, since both repairing and nonrepairing achieved similar results. Repairing injured deltoid ligaments may be helpful to early talus

stability postoperatively. For some cases in the deep components group, the augmentation of suture anchor replaced the syndesmosis screw and posterior malleolus fixation and improved the short-term outcome.

	Superficial group	Deep group	Non-repearing group
Mean degree of plantar flexion(FP)	48.5°	49.1°	49.4°
Difference from nomal of PF	2.3° (0-10°)	2.6° (0-10°)	2.2° (0-10°)
Mean degree of dorsiflexion(DF)	14.1°	13.8°	14.4°
Difference from nomal of DF	6.8° (0-15°)	7.2° (0-14°)	6.4° (0-20°)
Philips and Schwartz score	92.8 (80-100)	93.2 (88-100)	93.8 (85-100)
AOFAS Ankle-Hindfoot Scale	94.3 (82-100)	94.1 (85-100)	93.7(85-100)

See pages 47 - 108 for financial disclosure information.

The Diagnostic Accuracy of Mortise Radiographs and MRI in Predicting Deltoid Ligament Ruptures in Supination External Rotation Ankle Fractures

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Purpose: Supination external rotation (SER) ankle fractures represent the most common pattern of ankle injury, and operative indications for these injuries depend on the integrity of the medial structures. In the absence of a medial malleolus fracture, the status of the deep deltoid ligament should determine whether operative or conservative treatment is indicated. Despite the importance of assessing deep deltoid ligament injuries in these patients, the accuracy of common diagnostic tests has not been established. The objective of this study was to compare the ability of injury and stress radiographs and MRI to diagnose deep deltoid ligament ruptures in operative SER ankle fractures.

Methods: Patients who underwent open reduction and internal fixation of SER ankle fractures from 2010 to 2013 by a senior surgeon were identified from a prospective registry. Patients with medial malleolus fractures were excluded. Inclusion criteria consisted of all patients with an injury mortise ankle radiograph, manual stress test radiographs if the medial clear space (MCS) <5 mm on injury radiographs, preoperative ankle MRI, and intraoperative assessment of deep deltoid integrity by direct visualization. The MCS was considered positive for all values >5 mm on the injury or stress mortise radiographs. MRI analysis of the deep deltoid ligament injury was performed by two fellowship-trained musculoskeletal radiologists. Intraoperative direct visualization of the deltoid was performed using a medial ankle approach by a single surgeon who recorded the integrity of the deep deltoid.

Results: 53 patients met the inclusion and exclusion criteria. Based on intraoperative direct visualization, 46 patients (87%) had a complete rupture of the deep deltoid. Using intraoperative visualization as the gold standard, MCS measurements diagnosed a deep deltoid ligament rupture with 91% sensitivity, 14% specificity, and accuracy of 81%. MRI had a sensitivity of 80%, specificity of 100%, and accuracy of 83% to diagnose a deep deltoid rupture. In cases where the MCS was <5 mm on injury radiographs and stress tests were performed, MCS measurements were much less accurate than MRI in predicting deltoid ruptures (53% vs 80%, respectively). In contrast, an MCS measurement of greater than 5 mm on injury radiographs was a strong predictor of deltoid rupture (accuracy of 92%).

Conclusion: Diagnosing deep deltoid ligament injuries in SER ankle fractures often dictates treatment options; however, the ability of common diagnostic tests to predict these injuries is unknown. Using direct visualization of the deltoid ligament intraoperatively as the gold standard, these data support the diagnosis of deltoid ruptures when the MCS measurement is >5 mm on injury radiographs. However, when the MCS is <5 mm on injury radiographs, MRI has improved accuracy over stress tests. Given these data, we recommend proceeding with surgery when the MCS on injury radiographs is >5 mm without any additional stress

tests or advanced imaging. When the MCS is <5 mm, we recommend MRI analysis because of its increased accuracy and decreased false negatives compared to stress test. Understanding and improving our ability to diagnose deltoid ligament ruptures will contribute to effective treatment algorithms for patients with SER ankle fractures.

See pages 47 - 108 for financial disclosure information.

Medial Clamp Tine Positioning Using Intraoperative Fluoroscopy Affects Syndesmosis Malreduction

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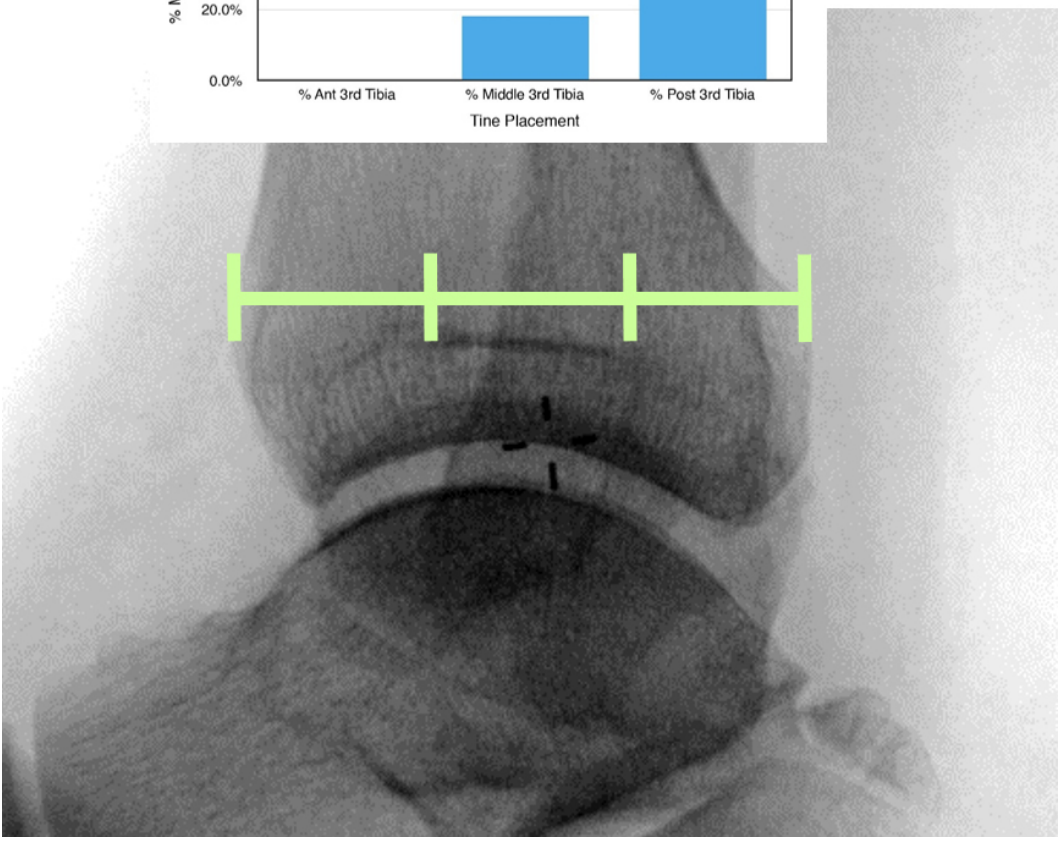
Background/Purpose: Treatment of ankle syndesmotic injuries requires precise anatomic reduction to provide optimal functional outcomes. Several recent studies have demonstrated unacceptably high malreduction rates. The ideal technique for reduction and intraoperative reduction assessment has been contested in the literature. The purpose of this study was to determine if the position of the medial clamp tine during syndesmotic reduction affected malreduction rates.

Methods: We prospectively enrolled 36 patients with malleolar ankle fractures and concomitant syndesmotic injuries into a study to assess multiple aspects of syndesmotic reduction and fixation. Patients had their malleoli fractures stabilized, and underwent stress examination of the syndesmosis. If the syndesmosis was unstable compared to the contralateral side, reduction and fixation was performed. Reduction was achieved using a reduction forceps, without visualization of the distal tibiofibular joint, by one of three orthopaedic traumatologists at a Level I center. The lateral clamp tine was placed on the fibular tubercle, or on a screw head on a posterolateral plate. The medial clamp tine was placed anteromedially on the distal tibia based on each surgeon's standard technique. Bilateral CT scans were obtained postoperatively. Various standardized measurements of syndesmotic reduction were performed based on several previous parameters described in the literature. Malreduction was defined as a difference of 2 mm between the injured and uninjured sides. Next, the true talar dome lateral flurosocopy view was evaluated and measured to determine the medial clamp tine positioning on the true talar dome lateral relative to AP dimension of the tibia. A Fisher exact test was performed to assess for statistical association between medial clamp tine placement on intraoperative fluoroscopy and malreduction.

Results: A significant association was found between medial clamp position and sagittal plane translational malreduction of the syndesmosis. In 10 patients, the tine was placed in the anterior third of the tibial line, and there were no malreductions; in 22 patients, the medial clamp tine position was located in the central third of the tibia, and 4 (18%) malreductions occurred. Of the 4 patients in whom the clamp tine was in the posterior third, 2 (50%) malreductions occurred (P = 0.05, Figure). There were no significant associations between medial clamp placement and coronal plane (overcompression) or rotational malreductions.

Conclusion: When using reduction forceps for syndesmotic reduction, the position of the fibular clamp tine is relatively constant, but the position of the medial clamp tine can be highly variable. The eccentric angle created with off-axis syndesmotic clamping is likely a major culprit in iatrogenic malreduction. A true talar dome lateral image during intraoperative fluoroscopy creates a reproducible template on which deliberate medial clamp tine positioning can be performed. Sagittal plane malreduction appears to be highly sensitive to clamp obliquity, which is directly related to the medial clamp tine placement.



See pages 47 - 108 for financial disclosure information.

The Failed Pilon: Factors Associated with Delayed Amputation, Arthroplasty, or Arthrodesis after Open Reduction and Internal Fixation

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Purpose: Pilon fractures are devastating injuries, with high reported rates of postoperative complications and persistent functional morbidity after open reduction and internal fixation (ORIF). The purpose of this study was to compare factors associated with tibial pilon fractures that failed ORIF, later requiring delayed amputation, arthroplasty, or arthrodesis.

Methods: Study design was a case control with 1:1 matching for controls, by date of surgery. Inclusion criteria included: age >18 years, OTA type 43B or 43C tibial plafond fractures treated with ORIF at a single institution. For the cases, "failure" was defined as amputation, arthrodesis, or arthroplasty performed at greater than 3 months post-ORIF. For controls, a minimum of 3 months of follow-up was needed. Demographic variables were collected, which included: age, gender, race, body mass index (BMI), marital status, diabetes, vascular disease, smoking, alcohol, Workers' Compensation. Injury variables were collected, which included: open versus closed injury, OTA type, vascular injury, radiographic severity score, radiographic alignment, bone loss, impaction, anterior plafond impaction, fibula fracture location. Operative variables were collected, which included: single versus two-stage treatment of the pilon component, and need for flap coverage. Complications of minor (requiring oral antibiotics) or major (requiring operative debridement or intravenous antibiotics) infection were recorded. Univariate analysis was performed for each variable, with odds ratios reported, and significance at $P < 0.05$. Results were entered into stepwise logistic regression for variables with $P < 0.1$.

Results: Between January 2000 and May 2014, 1560 43B or 43C injuries were treated with ORIF. 37 met the inclusion criteria for failure (21 fusion, 9 amputation, 7 arthroplasty) and 37 controls were matched. The average length to follow-up was 764 days (cases) and 452 days (controls). Factors associated with failure were: OTA type (C-type odds ratio [OR] 5.6, $P < 0.01$), two-stage management (OR 5.44, $P = 0.02$), minor infection (OR 7.9, $P = 0.01$), major infection (OR 12.6, $P < 0.01$), radiographic overall severity ($P < 0.001$), radiographic articular severity ($P < 0.001$), plafond impaction (OR 8.14, $P < 0.001$), and anterior plafond impaction ($P < 0.001$). Stepwise logistic regression demonstrated major infection ($P = 0.03$), overall radiographic severity ($P = 0.01$), and anterior impaction ($P = 0.006$) to be most predictive of pilon failure.

Conclusion: Multiple injury factors, including anterior impaction, overall radiographic severity, and major infection, were associated with failure of ORIF of tibial pilon fractures, which required delayed amputation, arthrodesis, or arthroplasty. Early recognition of the injury factors and early intervention, perhaps at the time of injury with a salvage procedure, may improve the reportedly high rates of poor outcomes following these injuries. In addition, patients with infections should be counseled about the severity of their injury.

Fixation of Tibial Pilon Fractures: Which Side of the Tibia Do I Plate?

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Purpose: Understanding fibular fracture morphology is crucial for the treatment of pilon fractures. Comminuted fibular fractures (compression failure) occur with the tibial component following a valgus force. Transverse fibular fractures (tension failure) occur with varus stress to the tibial component. No definitive guideline for determining the location of tibial fixation currently exists. We hypothesize that plate fixation on the anterolateral tibia for valgus fibular failures and medial tibial plating for varus fibular fractures will be superior and demonstrate fewer complications.

Methods: Pilon fractures were identified from our database and reviewed with the inclusion criteria for this retrospective study. Pilon fractures were classified with AO/OTA and included 43-A through 43-C fractures. Inclusion criteria included skeletal maturity, presence of an associated fibular fracture, and definitive tibial plating. Primary factors assessed included age, sex, weight, mechanism of injury, fibular fracture type (comminuted or transverse), tibial plate location (medial or lateral), location of open wound (if any), time to definitive fixation, time to full weight bearing, and complications. Patients were grouped based on the fibular component fracture type (comminuted vs transverse), and the location of plate fixation (medial vs lateral) was noted. Clinical outcomes were compared using a chi-square test for nominal data and t test for continuous variables.

Results: 407 patients were identified. 120 fractures in 119 patients (61 men and 58 women) met inclusion criteria with appropriate follow-up. 48 fractures resulted from a varus force (transverse fracture of the fibula) and 72 were due to valgus forces (comminuted fibula). In the transverse fibular fracture group (n = 48), 14.3% that were correctly plated medially developed mechanical complications. 83.3% that were incorrectly plated laterally developed mechanical complications ($P \leq 0.001$). For comminuted fibular fracture type (valgus), 35.1% of incorrectly medially plated fractures demonstrated mechanical complications versus 17.1% for fractures correctly stabilized with a lateral plate ($P = 0.083$). Time to weight bearing as tolerated (WBAT) was significant between groups plated medially and laterally for varus (transverse) fibula fractures ($P \leq 0.001$) and (valgus) comminuted fibular fractures ($P = 0.01$) in favor of the appropriately applied plate. Overall rate of nonunion/malunion was 25%, with the majority related to mechanical failures due to incorrect plate location.

Conclusion: Correctly assessing the fibular component for pilon fractures provides valuable information regarding deforming forces. Using this as a guide for correct tibial component plate location can minimize mechanical failures and malunion/nonunion. Soft-tissue injury remains an important factor in determining surgical approach; however, plates should be applied such that the tension band is re-established and can resist the original deforming forces as described by the fibular fracture morphology.

See pages 47 - 108 for financial disclosure information.

Predictors of Amputation in High-Energy Forefoot and Midfoot Injuries

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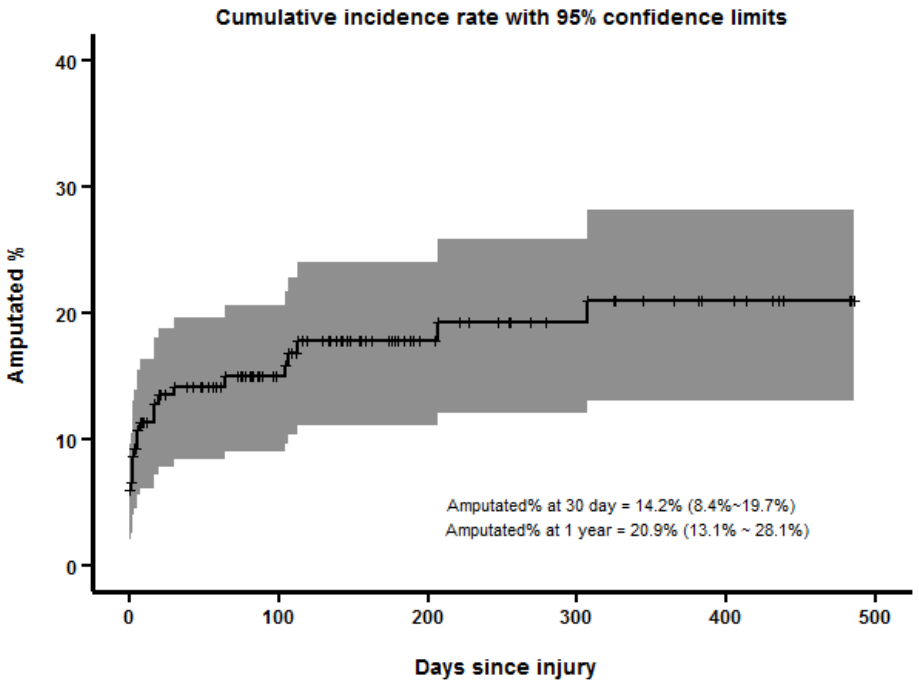
Purpose: High-energy forefoot and midfoot injuries are known to be high morbidity events but are poorly described in the literature. Patients with these injuries are challenging clinically as many will ultimately require a decision of limb salvage or amputation. The purpose of this study was to identify risk factors predictive of amputation in high-energy forefoot and midfoot injuries.

Methods: All patients presenting to our Level I trauma facility between January 2005 and December 2014 with a minimum of two foot fractures were reviewed, yielding 1970 unique patients. This cohort was then filtered for patients who sustained multiple fractures of the midfoot and forefoot with high-energy mechanisms, yielding 144 patients with 151 qualifying injured feet. Patient characteristics (age, comorbidities, tobacco use, body mass index [BMI]), fracture and dislocation patterns, and soft-tissue injury severity (open vs closed, Gustilo classification, location of wound, vascular injury, sensory loss) data were collected. Patients were grouped by mechanism into one of 5 categories: (1) falls from height, (2) restrained motorized collisions, (3) unrestrained motorized collisions, (4) direct-contact blunt trauma, and (5) industrial injuries. Operative reports were reviewed for the timing and levels of amputation (transmetatarsal through below-knee amputation [BKA]) at any time in their postoperative course. Cumulative incidence rate of amputation versus days since injury was estimated using a Kaplan-Meier survival analysis. Association between each variable and amputation was evaluated using a univariate Cox proportional hazard model. Statistical significance was set at a P value of <0.05.

Results: The 30-day amputation rate in this cohort was 14.2% (95% confidence interval [CI]: 8.4-19.7) and rose to 20.9% (95% CI: 13.1-28.1) at 1 year post injury (Fig. 1) after which the rate stabilized at that level. Of the 27 amputations, 23 (85.2%) ultimately proceeded to BKA. Variables predictive of amputation were the total number of fractures ($P = 0.01$), open injury ($P <0.001$) to either the plantar ($P <0.001$) or dorsal ($P <0.001$) surface of the foot, Gustilo grade ($P <0.001$), vascular injury ($P <0.001$), loss of sensation to any surface of the foot ($P <0.001$), and injury mechanism ($P = 0.04$). Specific fracture patterns that were predictive of amputation were fracture of all 5 metatarsals ($P <0.001$) and independently, fracture of the first metatarsal ($P = 0.002$). Variables of interest that were not statistically significant predictors of amputation included the presence of associated fractures of the distal tibia and plafond ($P = 0.35$), the presence of midfoot dislocations ($P = 045$), tobacco use ($P = 0.19$), and all patient comorbidities. Hazard ratios (HR; 95% CI) showed that open fractures were 17.3 (5.96–50.05) times more likely to progress to amputation. Each additional fracture of the foot increased the probability of amputation by 25% (1.05–1.49). Fracture of the first metatarsal specifically increased the probability of amputation by a factor of 3.4 (1.57-7.17) while fractures of all five metatarsals increased the probability of amputation by a factor of 9.8 (4.18-22.77). Patients who sustained direct blunt trauma (HR 11.39; 95% CI

1.49-87.17) and industrial (HR 11.73; 95% CI 1.22-112.83) mechanisms of injury were most likely to receive an amputation.

Conclusion: High-energy forefoot and midfoot injuries are associated with a high degree of morbidity; 20% of patients sustaining these injuries proceeded to amputation within 1 year. Using the findings of this hazard model, providers will be able to utilize the presenting characteristics of the injury to counsel patients regarding the severity of their injury and the possible need for subsequent amputation.



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A Randomized, Prospective Comparison of Bioabsorbable and Steel Screw Fixation of Lisfranc Injuries

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Purpose: The purpose of this study is to prospectively evaluate and compare the long-term clinical and radiographic outcomes of bioabsorbable (Smart Screw, Linvatec) and traditional steel screw fixation of the Lisfranc ligament complex in unstable Lisfranc injuries in a single surgeon's practice.

Methods: Between September 2008 and December 2013, 40 patients presented with acute, closed, unstable Lisfranc injuries. Patients that required a midfoot arthrodesis, such as those with chronic injuries or severe joint comminution, were excluded. On the day of surgery, 20 patients were randomized to receive 4.5-mm bioabsorbable screws while the remaining 20 were randomized to receive 4.0-mm steel screw fixation. All 20 patients that received steel screw fixation received additional surgery to remove this hardware by 9 months from their original surgery. Preoperative and postoperative function and pain was graded using the Foot and Ankle Ability Measure (FAAM) scoring system and a visual analog scale (VAS) of pain respectively. Radiographs were assessed for joint congruency, stability, and degenerative changes. Data regarding postoperative complications and revision surgeries were also recorded.

Results: All 40 patients (100%) with acute, closed, unstable, ligamentous Lisfranc injuries that randomly received either steel or bioabsorbable screw fixation returned for the final evaluation. All twenty patients who received bioabsorbable screws for Lisfranc fixation were evaluated with a mean follow-up time of 36.3 months. The mean FAAM score increased from 32.5 of 100 preoperatively to 91.2 of 100 at the time of final follow-up. The mean VAS pain score decreased from 4.7 of 10 preoperatively to 1.3 of 10 at final follow-up. One patient (5%) who received a single absorbable screw for Lisfranc fixation developed an inflammatory reaction at the head of the screw at 2 years after her original surgery. This portion of the screw had not completely absorbed by that time and was treated with removal of the screw head remnant. At the time of final follow-up, no patients that received absorbable screws developed posttraumatic instability but 2 of these 20 (10%) patients have developed posttraumatic midfoot arthritis. All twenty patients who received steel screws were evaluated with a mean follow-up time of 40.5 months. The mean FAAM score increased from 24.9 of 100 preoperatively to 89.6 of 100 at the time of final follow-up. This postoperative score is lower than that of the absorbable screw group, but not to a statistically significant degree ($P = 0.4$). The mean VAS pain score decreased from 6.5 of 10 preoperatively to 1.9 of 10 at final follow-up. This postoperative score is higher than that of the steel screw group, but not to a statistically significant degree ($P = 0.25$). Aside from hardware removal that was performed in all of these 20 patients by 9 months from their original surgery, none of these patients required subsequent procedures on their injured foot. None of these patients developed midfoot instability after hardware removal. At the time of final follow-up, 4 of these 20 (20%) patients have developed posttraumatic midfoot arthritis.

Conclusion: A comparison of outcomes from treating unstable ligamentous Lisfranc injuries with bioabsorbable and steel screws has not been previously reported in the orthopaedic literature. This study demonstrates that using either bioabsorbable or steel screws to treat these conditions results in a high rate of regaining normal midfoot function and stability. This study shows that using absorbable screws provides results that are equivocal to, if not better than, the traditional use of steel screws for treating unstable ligamentous Lisfranc injuries. In addition, the use of absorbable screws eliminates the need for an additional surgery to remove hardware. Studies with a larger patient population may be needed to further confirm these reported advantages when using absorbable screws to manage these injuries.

See pages 47 - 108 for financial disclosure information.