

Recent Advances for the Management of Foot and Ankle Trauma in Europe and the USA

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ABSTRACT

Introduction: Foot and ankle trauma are some of the most common injuries managed by orthopedic surgeons. Surgical fixation is well-established as the treatment of choice for managing these injuries. It allows for an anatomic reduction, it decreases instability, it permits early mobility of the extremity, and it lessens the development of post-traumatic arthrosis. Over the last few years newer techniques and implants have been developed to avoid creating these large surgical incisions and extensive surgical dissections. **Methodology:** This review paper will discuss newer treatment options available for the surgical management of acute foot and ankle trauma. Methods used to gather these newer techniques have been obtained through a PUBMED literature search performed over the last 8 years and are formatted to provide information regarding recent advances for the management of these injuries and discuss outcomes, when available, regarding the use of these newer approaches and implants. **Results:** This review paper has divided the manuscript into two sections consisting of the newer approaches for the management of injuries to the foot, consisting of care for Lisfranc injuries and talus and calcaneal fractures. The second half of the manuscript discusses the management of ankle fractures including an evaluation of stress tests, arthroscopy aided fixation, the use of fibular nails, and the newer advances available for the management of posterior malleolus and pilon fractures. **Conclusions:** Traditional teaching has relied on the use of open reduction internal fixation (ORIF) for the management of these injuries. However, these may require large incisions and extensive dissections to obtain adequate reductions. Over the last few years newer techniques and implants have been developed to avoid creating these large incisions and extensive surgical dissections. The new approaches and outcomes discussed in this review paper will hopefully provide surgeons managing these injuries with different options to consider for the management of foot and ankle injuries. Taking small steps to apply new methods of evaluations and fixation may allow those surgeons, who are hesitant, to feel more comfortable when attempting some of these newer approaches.

Keywords: Arthroscopy, Ankle, Pilon, Calcaneus, Talus Fractures, Nails, Lisfranc Injuries

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INTRODUCTION

Foot and ankle trauma are some of the most common injuries managed by orthopedic surgeons. An epidemiology study of adult fractures by Court-Brown and Caesar [1] found that at their institution 22.01% of all fractures involved the foot or ankle. These fractures were reported in the ankle (9.0%), metatarsals (6.8%), the toe phalanges (3.6%), calcaneus (1.2%), distal tibial (0.7%), the midfoot (0.4%), talus (0.3%) and sesamoids (0.01%). A more recent study, using information obtained from the National Trauma Data Bank from 2007 to 2011, identified a total of 280,933 foot and ankle fractures or dislocations [2]. In descending order, the percentage of injuries identified were seen in the ankle (55.7%), metatarsals (12.5%), calcaneus (9.3%), talus (7.9%), phalanges (5.5%), cuboid (2.7%), navicular (2.0%) and cuneiforms (1.7%). The remaining 2.8% of injuries were unspecified. This means that from 2007 to 2011 greater than 56,000 foot and ankle injuries were reported annually, with greater than 153 injuries occurring per day, in the United States.

When patients present with displaced fractures or fracture-dislocations of the foot or ankle, surgical fixation is well-established as the treatment of choice for managing these injuries. It allows for an anatomic reduction, it decreases instability, it permits early mobility of the extremity, and it lessens the development of post-traumatic arthrosis. Traditional teaching has relied on the use of open reduction internal fixation (ORIF) for the management of these injuries. However, these may require large incisions and extensive dissections to obtain adequate reductions. Over the last few years newer techniques and implants have been developed to avoid creating these large surgical incisions and extensive surgical dissections. These have included minimally invasive surgical (MIS) methods [3,4] the use of ring fixators [5], techniques utilizing intramedullary devices [6,7], arthroscopy-assisted fracture fixations [8] or percutaneous approaches that can be used as stand-alone methods or employed in combination with two or more of the afore mentioned techniques [9,10].

Despite the availability of these newer techniques and implants, some surgeons may be hesitant to try these newer techniques. Reasons for this hesitancy may include being unfamiliar with newer surgical approaches, concerns about the costs of these implants, unavailability of these new implants, prolonging the surgeries for these new approaches and a reluctance to try something new when they have had good successes and low complication rates using their previous methods of fixation. This review paper will discuss newer treatment options and implants available for the surgical management of acute foot and ankle

trauma. Historical references, especially those discussing classification of injuries and outcome scoring systems, have been kept. The methodology used to gather and present these newer techniques and implants, have been obtained through a PubMed literature search performed over the last 8 years and are formatted to provide information regarding recent advances for the management of acute foot ankle injuries and discuss outcomes, when available, regarding the use of these newer approaches and implants.

INJURIES OF THE FOOT

Lisfranc Injuries

In the foot, inspection of the skin, noting any abrasions, wounds, blisters, tenting of the skin or any subtle deformities should be performed. One such subtle finding recently described is the Lisfranc Jut Sign [11]. This has been described as a bony prominence, or "jut" on the medial border of the first tarsometatarsal joint, indicating a subtle Lisfranc injury. In this study, patients were identified with this injury presenting at an average of 9.9 weeks (range 6-18) from their date of injury and were followed for an average of 13.7 months (range 12-17). Outcomes were assessed radiographically, and any complications or reoccurrence of the "jut" were recorded. All underwent fixation and at final follow-up, none of the patients developed surgical site infections, wound dehiscence, loosening of implants, loss of reductions or a recurrence of the "jut". The recommendations from this study were that patients presenting with a history of low-energy trauma, a diagnosis of sprain, continued complaint of foot pain, and a "jut" on the medial border of the midfoot, be evaluated for a subtle Lisfranc injury.

Wong et al. evaluated the first tarsometatarsal (TMT) joint in patients presenting with Lisfranc injuries [12]. The authors performed a retrospective imaging review to analyze all surgically managed Lisfranc injuries to characterize how ligamentous injuries affected the first TMT joint. Using plain radiographs and computed tomography, injuries were assessed using the Hardcastle and Myerson Lisfranc classifications [13,14]. Seventy-one patients were evaluated with 61 patients (86%) identified with unstable first TMT joints. Of these, 25 patients (35%) had a medial capsular avulsion, and 33 patients (47%) demonstrated a fracture of either the medial cuneiform or base of the first metatarsal. This resulted in the authors identifying either medial-lateral or dorsal-plantar first TMT joint incongruence in 86% of patients with Lisfranc injuries. They suggested careful inspection of the TMT on plain and advanced imaging studies to identify four patterns of injury: joint incongruity, articular surface fractures, articular angulation and medial capsular avulsion fractures. The authors concluded that this information would provide surgeons treating Lisfranc

injuries to specifically evaluate the first TMT joint to access for any potential injuries.

The best approach for the management of isolated Lisfranc ligament injuries has been a topic of discussion for at least the past 20 years. Discussion has included using standard open reduction and internal fixation with screws alone or with plates, fixation using suture buttons or the use of a primary arthrodesis. Cho et al. [15] compared the results of using a conventional screw fixation versus a suture button for injuries involving the second tarsometatarsal joint. Clinical outcomes were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) and visual analog scale (VAS) scores. Fixations were evaluated using plain radiographs and foot pressure analysis. Sixty-three patients (32 screw, 31 suture button) were followed for a minimum of one-year. Clinical outcomes demonstrated better AOFAS and VAS scores in the suture button group at six-months but no difference was noted between both groups at one year. Radiographic outcomes demonstrated no diastasis or side-to-side differences between both groups and, and foot pressure analysis were equivalent. The authors concluded that the use of a suture button, for injuries involving the second tarsometatarsal joint, demonstrated good outcomes, was comparable to the use of a screw fixation and avoided the need for any secondary (removal) procedures.

Finally, evaluating the results of standard open reduction internal fixation (ORIF) versus primary arthrodesis (PA) in the management of Lisfranc injuries, Aneja et al. [16] followed 81 patients using the validated Foot and Ankle Ability Measure questionnaire at a follow-up range of 1 to 10 years. At final follow-up, the daily living subscores, sports subscores, perceived levels of activities of daily living, sports function and rates of reoperation were similar in both groups. The authors concluded that neither PA nor ORIF were superior for the management of Lisfranc injuries.

Talus Fractures

A retrospective review of patients who had undergone treatment of talar neck fractures was performed by Mechas et al. [17] to determine if talar neck fractures, with extension into the body, had higher rates of avascular necrosis (AVN) than fractures isolated to the neck. The authors classified fractures using the Hawkins [18] classification (with the addition of the Canale/Keely [19] and Vallier [20] modifications). Fractures were defined as extending into the body if the fracture extended proximal to a line subtended from the junction of the talar neck and the articular cartilage dorsal to the anterior point of the lateral talar process. Outcomes were assessed using plain radiographs. Both groups had similar demographics, and all patients were followed for an average of 15.4 months. Their results

showed that there were statistically significant differences in rates of AVN only between high-risk fractures (Type IIb, III, IV). In these high-risk fractures, those with extension into the body of the talus had an AVN rate of 63% versus 29% without an extension. Additionally, those with an extension also had higher rates of nonunions (26% versus 9%) and collapse (14% versus 4%). The authors concluded that careful evaluation of talar neck fractures is important when discussing potential outcomes with patients.

Calcaneus Fractures

The best treatment for displaced, intraarticular fractures of the calcaneus remains controversial. Most treatments have been divided into use of an extensile lateral approach (ELA) in conjunction with ORIF or the use of a sinus tarsi approach (STA) combined with percutaneous fixation. A recent study by Steinhausen et al. [21] discussed the use of a STA combined with fixation using a calcaneus nail versus ELA with plate fixation. They followed 76 patients with 82 fractures (Nail n=45, Plate n=37). Demographics were similar in both groups. The functional outcome was assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot scale. Their results demonstrated a significant difference in the number of total complications (ELA=51% STA=25%). The surgical duration was shorter in the nail group but Böhler's angle correction was similar in both groups. The nail group reached full weight-bearing earlier but had more mispositioned screws. Wound edge necrosis was more common in patients with ELA and plate fixation, but rates of infection were similar in both groups. The authors concluded that use of a calcaneal nail may be a viable method of treatment for displaced intraarticular calcaneal fractures.

Lastly, a recent study by the Major Extremity Trauma Research Consortium (METRC) [22] published their findings of a randomized controlled trial comparing high perioperative FiO₂ (fraction of inspired oxygen) of 80% compared with a standard 30% and its effect on surgical site infections (SSI) for calcaneal, tibial plateau, or pilon fractures. The FiO₂ of 80% was continued through the time the patient was in the recovery room. The primary outcome was a surgical site infection (SSI) with 182 days following definitive fracture fixation. The secondary outcomes were SSI within 90 days and 365 days, deep SSI, gram-positive deep SSI, gram-negative deep SSI and superficial SSI evaluated with 90, 182 and 365 days following definitive fixation. A total of 1,136 patients (575 treatments, 561 control) were evaluated. At 6 months significant differences in SSI were noted between the FiO₂ 80% treated group and the control groups, with a 7.0% SSI for the FiO₂ 80% versus 10.7% for the control group. The effect was noted at 90 days and continued through

365 days. This difference was noted primarily by fewer superficial infections in the FiO₂ 80% group but there were no differences noted for deep SSI between both groups. The authors believed that this produced some clinical benefit of at least reducing superficial SSI, was low cost and had few risks associated with this treatment.

ANKLE FRACTURES

Stress Tests

Determining stability is important in deciding which fractures are stable, and can be treated nonoperatively, versus unstable injuries needing surgical fixation. In a study by Gregersen et al. [23] they compared the outcomes of gravity stress radiographs [24] to weightbearing films, in 151 patients who presented with isolated Weber B/Lauge-Hansen SER2 or SER4a [23,25] ankle fractures. Both exams were performed 3-7 days after the patient's initial injury, anticipating a reduction in pain. Three patients were identified as unstable and were managed surgically. The primary outcome used to evaluate patients was the Manchester-Oxford Foot and Ankle Questionnaire (MOXFQ), which is used to assess symptoms and quality of life in patients with ankle pathology [26]. Secondary outcomes used to evaluate patients included the Olerud-Molander Ankle Score (OMAS) [27] and the American Foot and Ankle Society (AOFAS) ankle-hindfoot score [28]. At a 2-year follow-up, ankle radiographs were available for 123 patients. Good outcomes were noted in the weight bearing group treated non-operatively. Their results also showed that if that if only the gravity stress test had been used as an indicator for a surgical procedure, then sixty-three patients (42%) would have undergone surgical fixation of the ankle. Final outcomes demonstrated that if the weight-bearing films identify a stable mortise, then gravity stress tests were unnecessary.

Arthroscopy Aided Fixation

A recent adjunct described for the management of ankle fractures has been the use of arthroscopically aided open reduction internal fixation (AAORIF) techniques. In a recent analysis, Williams et al. [29] performed a systemic review of the literature using a PubMed database. They evaluated seventeen studies consisting of 2 systemic reviews, 1 meta-analysis, 2 randomized controlled trials, 5 retrospective studies, 6 care series and 1 case-controlled study. The results were mixed but the consensus was that the AAORIF is safe and may help better visualize associated intra-articular injuries. In their conclusions however, the authors stated that there are very few prospective randomized controlled studies available, and that overall, the literature has not shown significant improvements in anatomical reductions in the treatment of these intra-articular injuries, nor had it

demonstrated any improvement in outcomes over standard fixation methods.

Fibular Nails

Discussion for the use of fibular nails for the management of SER and PER injuries has recently increased in the literature. Kho et al. [30] compared young patients undergoing closed reduction and fibular nailing (IMN) (n=94) versus standard open reduction and fixation (ORIF) with a locked lateral plate (n=110). Demographics were similar for both groups and patients were followed for a minimum of three years. Radiographic outcomes were assessed for quality of the reduction, using the method described by McLennan and Ungersma [31], and the development of posttraumatic osteoarthritis. Clinical assessment was performed using the American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score [28] the Olerud and Molander score (OMAS) [27] the Foot and Ankle Outcome Score (FAOS) and visual analog scale (VAS) pain score. Radiologic outcomes demonstrated significantly higher rates of fair and poor reductions in the IMN group, especially in Weber C, pronation injuries, comminuted fractures and for trimalleolar injuries. In addition, post-traumatic osteoarthritis (PTOA) was more frequently observed in the IMN group (21.3%) versus the ORIF group (9.1%). However, overall complications occurred less frequently in the IMN group than the ORIF group. There were no significant differences in AOFAS, FAOS or VAS scores between both groups. The OMAS was higher in the IMN but was not statistically significant. Due to higher rates of malreductions and the development of PTOA, the authors recommended that until there is improvement in IMN techniques, surgeons consider using ORIF techniques for patients presenting with Weber C patterns, pronation injuries, comminuted fractures and trimalleolar injuries.

Posterior Malleolar Fractures

Different opinions still exist for the best treatment of fractures of the posterior malleolus (PM), especially when the fragment size is less than 25% of the articular surface. In a landmark article, Gardner et al. [32] challenged the recommendation that size be used to determine whether or not to fix the PM fragment. Subsequent studies have also shown that fixation of the PM fragment restores the anatomy of the tibiotalar and tibiofibular joints, reduces the fibula into the incisura, and restores ligamentous stability of the posterior inferior tibiofibular ligament (PITFL) [33], often avoiding the need for syndesmotic fixation. Continuing the recommendation for fixation, Pilskog et al. [34] retrospectively evaluated patients managed with traditional anterior approaches versus a posterior approach to compare outcomes and rates of complications. The posterior fixation group (n=43) were managed with or without a one-third

tubular plate while the anterior fixation group (n=43) were managed with traditional indirect reductions with screws alone. The primary outcome was the Self-Reported Foot and Ankle Score (SEFAS) [35] along with an evaluation of pain using the visual analog scale (VAS). The posterior group had less syndesmotic fixation (14%) compared to the anterior (49%) group ($p<0.01$), but patient reported outcomes, pain scores and range of motion were similar for both groups. A second study by Stringfellow et al. [36] also reported less syndesmotic fixation when the PM fragment was fixed (9.6% vs 34.9%) but also observed that the size of the PM fragments was noted to be larger on CT scans than plain radiographs. Using this information, Stringfellow et al. recommended using CT scans to evaluate all PM fragments.

Pilon Fractures

Tibial plafond fractures are difficult to manage due to the significant articular cartilage and soft tissue damage associated with this injury. Jo et al. [37] retrospectively reviewed 50 patients (52 fractures) who presented with pilon fractures, managed with a standard open reduction and internal fixation technique, focusing on fractures that presented with anterior impaction (AI) of the tibial plafond. Radiographs were reviewed and outcomes were evaluated using a Patient-Reported Outcome Measurement Information System (PROMIS) scores for depression, anxiety, physical function and pain interference. At a mean follow-up of 25 months, those patients with anterior impaction had significantly greater anterior subluxation, worse posttraumatic arthritis and higher rates of implant removal than those without anterior impaction. However, PROMIS scores for depression, anxiety, pain or physical function did not differ between AI and non-AI groups.

Avoiding large incisions for the management of these injuries is an attractive approach and Bouzid et al. [38] reported their results using minimally invasive reduction and fixation in 28 tibial plafond fractures (28 patients). Fractures were classified using the AO/OTA classification system and patients were followed for an average of 16 months with the primary outcome being the quality of the reduction on plain radiographs. There were 18 type A fractures and 10 type C fractures, all resulting from traffic accidents or falls from a great height. All patients underwent definitive fixation within 24 hours of their trauma. In their results they reported no skin complications. The quality of their reductions was reported as good in 24 patients with good outcome scores reported in 26 patients. The authors concluded that minimally invasive plate osteosynthesis (MIPO) techniques were a viable option in correctly selected patients.

Lastly, Bastías et al. [5] compared standard open reduction

internal fixation (ORIF) to minimally invasive hexapod ring fixation (HRF) supplemented with limited internal fixation. They reported on 53 patients (ORIF=30, HRF=23) treated for AO/OTA 43.C3 pilon fractures who were followed for at least two years. The outcomes evaluated were the quality of the radiographic reductions and complications noted in both groups. The overall rate of complications was similar in both groups however, superficial infections were higher in the HRF group (47.8%), related to the half-pin or the skinny wires used to secure the ring. Deep infections were noted only in the ORIF group (20%). Nonunions, reoperations and the development of posttraumatic arthritis were similar in both groups. The authors concluded that HRF was a safe and effective treatment with lower complications than patients managed with ORIF.

CONCLUSIONS

Injuries to the foot and ankle are common injuries. Traditional teaching has relied on the use of open reduction internal fixation (ORIF) for the management of these injuries. However, these may require large incisions and extensive dissections to obtain adequate reductions. Over the last few years newer techniques and implants have been developed to avoid creating these large surgical incisions and extensive surgical dissections. New techniques and implants are constantly being developed and one of the limitations of this review paper is that not all new implants and techniques can adequately and completely be discussed. Standard fixation techniques are still commonly used to manage all these injuries. However, surgeons tasked with managing these injuries may not be familiar with newer approaches, available implants and outcomes that occur managing these injuries. Additionally, and despite the availability of these newer techniques and implants, some surgeons may be hesitant to try something new. Some reasons for this hesitancy may include unfamiliarity with newer surgical approaches or implants, concerns about the costs of these implants, unavailability of these new implants, prolonging the surgeries to perform new approaches or a reluctance to try something new when they feel that they have had good success and low complication rates using their previous methods of fixation. This last reason is a difficult challenge to overcome. Future research may be directed towards identifying techniques and implants which will achieve good or excellent outcomes with high rates of reproducibility. The new approaches and outcomes discussed in this review paper will hopefully provide surgeons managing these injuries with different options to consider for the management of foot and ankle injuries. Taking small steps to apply new methods of evaluations and fixation may allow those surgeons, who are hesitant, to feel more comfortable when attempting some of these newer approaches.

AUTHOR CONTRIBUTIONS

DH: Conceptualization, Data Curation, Formal analysis, Preparation, Writing and Review of the Manuscript-original draft, Editing.

ADS: Investigation, Methodology, Resources, Writing-review and editing.

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CONFLICT OF INTEREST

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COMPETING INTERESTS

None.

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