Specialty Update

What’s New in Foot and Ankle Surgery

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This update summarizes recent research pertaining to foot and ankle surgery that was published or presented between August 2008 and July 2009. The sources of these studies include The Journal of Bone and Joint Surgery (American and British Volumes); Foot and Ankle International; the proceedings of Specialty Day at the Annual Meeting of the American Academy of Orthopaedic Surgeons (AAOS), held on February 28, 2009, in Las Vegas, Nevada; and the summer meeting of the American Orthopaedic Foot and Ankle Society (AOFAS), held on July 15 through 18, 2008, in Vancouver, British Columbia, Canada.

Ankle Fractures and Trauma

Since its inception, the Lauge-Hansen ankle fracture classification system has commonly been utilized by the orthopaedic community to correlate the mechanism of injury with the radiographic fracture pattern. Despite its enduring clinical use, the Lauge-Hansen classification system is often confusing and cumbersome and has lacked experimental reproducibility. Numerous investigators have been unable to specifically recreate the stage-4 supination-external rotation fracture pattern in an experimental setting. The lack of reproducibility has caused investigators to challenge the dogma that an external rotation force produces a fibular fracture pattern oriented from anteroinferior to posterosuperior only with the foot in a supinated position. Haraguchi and Armiger used a biomechanical cadaver model to prove their hypothesis that a pronated foot could produce fracture patterns traditionally ascribed to a supination-external rotation mechanism. According to the authors, the pattern of fibular fracture would largely be determined by the amount of laterally directed force (an abduction moment) applied to the foot in pronation. Fifteen cadaver specimens were mounted onto a load frame in a position of pronation-external rotation and were subjected to a large axial force with internal tibial rotation, and another eight specimens received a simultaneous laterally directed force to increase the abduction moment acting on the ankle joint. Eight of the fifteen specimens in the axial load group sustained oblique distal fibular fractures consistent with a traditional Lauge-Hansen supination-external rotation fracture pattern. Three of the eight specimens receiving the combined axial load with an abduction moment sustained a high fibular fracture pattern consistent with a traditional Lauge-Hansen pronation-external rotation mechanism. These results suggest that the pronation-external rotation ankle injury could account for fracture patterns originally attributed to a supination-external rotation mechanism. This may be of clinical value when attempting to “reverse the mechanism of injury” to reduce a displaced ankle fracture. The variable determining the type of fibular fracture pattern may be the magnitude of the abduction moment acting on the pronated foot. Additional testing is necessary to create a more straightforward system for the classification of ankle fractures based on applied loads.

Magnetic resonance imaging and ankle arthroscopy have recently drawn attention to the frequency of intra-articular injuries associated with acute ankle fractures. The frequency or degree of chondral injury, however, has not been correlated with the severity of the ankle fracture as classified according to the Lauge-Hansen criteria. Leontaritis et al. retrospectively reviewed their experience in the treatment of acute ankle fractures with use of open reduction and internal fixation as well as routine ankle arthroscopy. The authors correlated arthroscopic findings of intra-articular chondral injury with the severity of the ankle fracture pattern as staged with the Lauge-Hansen classification system. Among the eighty-four patients who met the inclusion criteria, the prevalence of associated chondral injury was 73% (sixty-one of eighty-four). Overall, fifty-one ankles (61%) sustained a chondral injury to the talar dome, five (6%) had lesions involving the tibial plafond, and ten (12%) sustained an injury to the medial and/or lateral malleolus. Fracture severity as determined by higher

Disclosure: The authors did not receive any outside funding or grants in support of their research for or preparation of this work. Neither they nor a member of their immediate families received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity.
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staging with the Lauge-Hansen classification also correlated with increased intra-articular injury. Type-IV supination-external rotation and pronation-external rotation fractures were found to be associated with a higher frequency of loose bodies and chondral lesions of the talar dome. Additionally, the type-IV fractures were 8.1 and 9.7 times more likely to be associated with two or more chondral lesions than their type-I and type-II fracture counterparts, respectively. These results demonstrate that articular cartilage injury of the ankle commonly occurs during acute ankle fractures, and the treating physician should anticipate more severe chondral damage with higher stages of ankle fracture as classified with the Lauge-Hansen system.

Open reduction and internal fixation of ankle fractures is associated with inherent surgical risks. Until now, the rate of complications and the risk factors associated with operative fixation of ankle fractures have not been investigated in a large population-based study. Using California’s discharge database, SooHoo et al. identified 57,183 patients who underwent open reduction and internal fixation of an ankle fracture during an eleven-year period. Pooling of the data during this time period allowed for an analysis of relevant demographic characteristics and hospital characteristics as well as short and intermediate-term complications. The overall complication rate was reported to be low in both the short term and the intermediate term. The exception was noted in patients with complicated diabetes and peripheral vascular disease, which were associated with significantly higher risks of infection and amputation in the short term and a higher risk of reoperation in the intermediate term. Strong predictors of intermediate-term conversion to ankle fusion or replacement were associated with open injuries and the severity of the ankle fracture. Severe ankle fractures, such as trimalleolar fractures, were associated with higher rates of revision when compared with isolated medial or lateral malleolar fractures. Hospital characteristics such as procedure volume, teaching status, and rural location had no significant effect on the complication rates. Interestingly, the overall rate of pulmonary embolism requiring readmission within ninety days following discharge was also very low (0.34%).

Early joint mobilization has become a commonly utilized postoperative modality following the stabilization of shoulder and elbow injuries. Despite its common application in the upper extremity, the value of early joint motion following operative fixation of ankle fractures is unclear. Thomas et al. performed a systematic review of the literature seeking evidence to support either early ankle motion or cast immobilization as the preferred postoperative treatment following open reduction and internal fixation of an ankle fracture. Their meta-analysis included nine randomized controlled trials comparing postoperative treatment in a nonremovable cast with early motion of the ankle joint. Outcomes according to the Olerud and Molander score were significantly improved in the early motion group at six weeks; however, no significant benefit remained at one year. Early motion was associated with a quicker return to work on the average and with a trend toward a lower risk of deep venous thrombosis but was also associated with an increased risk of wound infection. The results of that meta-analysis suggest that early motion may improve short-term function and allow earlier return to work at the cost of increasing the risk of wound infection. The postoperative regimen that is implemented remains a clinical decision that the surgeon must make on the basis of patient-related factors.

Calcaneal Fractures

Delayed subtalar arthrodesis frequently is required for salvage treatment in cases of symptomatic subtalar arthritis and foot deformity resulting from displaced intra-articular calcaneal fractures, irrespective of the manner in which the calcaneal fracture was initially treated. Radnay et al. investigated whether outcomes following subtalar arthrodesis were influenced by initial treatment of the calcaneal fracture with either open reduction and internal fixation or nonoperative treatment. Seventy-five fractures with symptomatic posttraumatic subtalar arthritis were retrospectively reviewed. Thirty-six fractures that were initially treated with operative fixation at their institution were compared with thirty-nine fracture malunions that initially were treated nonoperatively at an outside institution. In the subgroup initially treated with fracture fixation, the subtalar arthrodesis procedure was performed through an extensile lateral approach with removal of hardware, débridement of joint cartilage, and in situ fusion with allograft cancellous bone chips and 8.0-mm cannulated cancellous lag screws. In the malunion subgroup, subtalar arthrodesis was approached in a similar fashion, with the addition of a lateral wall exostectomy with or without a Dwyer-type calcaneal osteotomy for the correction of deformity. Better functional outcomes and fewer wound complications were found in the subgroup receiving subtalar fusion after initial open reduction and internal fixation of the displaced intra-articular calcaneal fracture. The authors concluded that initial open reduction and internal fixation of the fracture restores calcaneal shape, alignment, and height, which improves outcomes and facilitates future subtalar arthrodesis procedures that may be required to treat subtalar arthritis.

Percutaneous screw fixation of calcaneal fractures has gained momentum as a means to mitigate the potential wound complications associated with lateral plating through an extensile surgical approach. In a biomechanical cadaver model, Smerek et al. created Sanders type-2B calcaneal fractures in ten pairs of specimens. Ten fractures were stabilized with a titanium perimeter plate (DePuy, Warsaw, Indiana) that was contoured to the lateral calcaneal cortex and secured with eight 3.5-mm titanium cortex screws. The other ten specimens were stabilized with a standardized percutaneous screw.
configuration consisting of two 4.0-mm titanium partially threaded screws fixing the posterior facet, two 6.5-mm titanium cannulated partially threaded screws securing the posterior tuberosity to the anterior process, and one 4.0-mm titanium cannulated fully threaded “rafting” screw inserted from the plantar-lateral aspect of the posterior tuberosity to the subchondral surface of the posterior facet fragment. Biomechanical testing demonstrated that the mean load to failure and construct stiffness did not differ significantly between the two fixation groups. The specimens in the plate fixation group most commonly failed by means of pullout of screws from the constant fragment, whereas the specimens in the percutaneous fixation group most commonly failed by means of pullout of the two 6.5-mm cannulated screws from the anterior process fragment. These results suggest that percutaneous screw fixation of Sanders type-2B fractures has comparable strength in comparison with standard perimeter plating. Percutaneous techniques hold promise for being a reliable alternative to the extensile lateral surgical approach and may aid in reducing the rate of wound complications associated with open surgical treatment of these fractures.

Weber et al., in a retrospective review of their experience with the treatment of Sanders type-2 and type-3 calcaneal fractures, compared outcomes following lateral plating through an extensile approach with those following the use of a limited-incision technique with percutaneous fixation. The limited-incision technique involved a short lateral subtalar incision with percutaneous manipulation of the posterior tuberosity with use of a Schanz pin and manual disimpaction of the fracture fragments. The fracture fragments were fixed with transverse screws across the posterior facet and percutaneous screws directed from the posterior tuberosity into the anterior process and the subchondral bone of the posterior facet. Compared with lateral plating through the standard extensile lateral incision, the limited-incision technique resulted in a significant reduction in operating time, saving an average of fifty-two minutes per operation, while producing equivalent fracture alignment and joint reduction as judged clinically and radiographically. The extended approach and lateral plating resulted in more wound-healing complications and more cases of postoperative complex regional pain syndrome. Interestingly, the limited open approach required a higher number of subsequent minor procedures to remove symptomatic hardware. These results lend further support to fixation of calcaneal fractures through limited or percutaneous means in order to minimize potential wound complications and to reduce the prolonged surgical time associated with lateral plating through an extensile lateral approach.

**Lisfranc Joint Injury**

Investigational attempts to develop a cadaver model recreating Lisfranc joint injuries have concentrated on tarsometatarsal fracture dislocations and severe Lisfranc variants. In two related experiments, Panchbhavi et al. sought to develop a reliable cadaver model to produce diastasis characteristic of ligamentous Lisfranc injuries in order to subsequently test different fixation techniques. In the first experiment, a digitizer was used to record the three-dimensional position of screws placed into both the medial cuneiform and the base of the second metatarsal. The cadaver specimens were then loaded through the metatarsals with a force equal to half body weight with the ankle in 30° of plantar flexion before and after transection of the Lisfranc ligament. With this experimental setup, the authors were able to reliably create detectable displacement similar to the diastasis that is clinically observed in association with ligamentous Lisfranc injuries. In a second well-designed experiment, simulated cadaver Lisfranc injuries were stabilized either with a 3.5-mm-diameter cannulated screw or with a suture button (TightRope repair kit; Arthrex, Naples, Florida). Biomechanical testing demonstrated no significant difference in Lisfranc ligament displacement between the two fixation techniques. With equivalent fixation strength, the suture button may offer a more physiologic and nonrigid stabilization technique that may eliminate the need for subsequent hardware removal. These advantages of the suture button, however, may be offset by its significantly higher price in comparison with cannulated screws as well as by the paucity of evidence demonstrating its clinical efficacy.

Detecting midfoot instability following subtle Lisfranc injury historically has presented a diagnostic challenge. Weight-bearing radiographs producing a diastasis of ≥2 mm between the second metatarsal base and the medial cuneiform previously has been advanced as the imaging definition of instability; however, the examination is often limited by pain. Manual stress radiographic evaluation with the patient under anesthesia has therefore become the more accurate determinant of midfoot instability. Raikin et al. performed a retrospective investigation demonstrating the accuracy of magnetic resonance imaging for the detection of traumatic injury of the Lisfranc ligament and for the prediction of Lisfranc joint complex instability. Twenty-one Lisfranc injuries were evaluated with magnetic resonance imaging, and instability was confirmed through manual stress radiography with the patient under anesthesia. Magnetic resonance imaging correctly diagnosed 94% of the injuries as being either stable or unstable on the basis of the integrity of the plantar Lisfranc ligament, corresponding with a sensitivity of 94% and a specificity of 75%. All radiographs with weight-bearing radiographs were limited by pain and failed to produce a diastasis of ≥2 mm between the medial cuneiform and the second metatarsal base. These results suggest that magnetic resonance imaging is both an accurate modality to diagnose traumatic Lisfranc ligament injury and an accurate predictor of the resultant midfoot instability.
**Chronic Ankle Instability**

Recurrent lateral instability following an inversion ankle sprain is thought to be a risk factor for the development of ankle osteoarthritis. Sugimoto et al. performed an arthrosopic study of patients with prolonged lateral ankle instability to clarify risk factors for chondral injury as a potential precursor to ankle arthritis. Chondral lesions of some degree were found in 77% of the ankles overall. Chondral lesions were most frequently located in the medial half of the ankle and were localized to the tip of the medial malleolus in 58% of cases. The duration of instability was not a factor affecting the severity of chondral damage as observed arthroscopically. The risk factors associated with more severe chondral changes were increased age, a larger talo-tibial angle, and varus inclination of the tibiotalar joint. Of these risk factors, mechanical instability is most commonly corrected surgically through lateral ligament reconstruction and repair.

**Total Ankle Arthroplasty**

Tibiotalar arthrodesis for the treatment of severe ankle pain associated with arthritis has a strong clinical track record of providing pain relief and return to function. However, some reports have linked ankle arthrodesis to degeneration of adjacent joints, difficulty with specific activities, and painful malunion or nonunion. To our knowledge, Hintermann et al. were the first to report on the takedown of problematic ankle arthrodeses and conversion to a total ankle arthroplasty with use of an unconstrained three-component mobile-bearing prosthesis (HINTEGRA, Newdeal, Lyon, France). In a retrospective review of the conversion of twenty-nine painful ankle arthrodeses, the mean preoperative AOFAS hindfoot scores improved from 34.1 to 70.6 postoperatively, with an overall rate of patient satisfaction of 82.7% after 55.6 months of follow-up. The mean clinically measured ankle range of motion was 24.3°, corresponding with 55.1% of that of the contralateral, unaffected ankle. The tibial components had no demonstrable loosening or subsidence, but a higher risk of talar component failure was observed (as indicated by a 13.3% rate of radiographic failure). The rate of radiographic failure of the talar component compares favorably with rates that have been previously reported in the literature, which have exceeded 40% in association with the use of two-component constrained total ankle prostheses. These results suggest that takedown of a painful ankle arthrodesis and conversion to a total ankle arthroplasty is a technically demanding yet promising surgical option. Successful conversion to ankle replacement may be improved with use of unconstrained three-component total ankle designs, by careful preoperative planning to identify landmarks for osteotomies, and by correction of pre-existing hindfoot malalignment or ankle instability.

Hindfoot malalignment generally has been considered to be a relative contraindication to total ankle arthroplasty because of the theoretical risks of prosthesis edge-loading and potentially higher rates of failure. Hobson et al. reported on the short-term results of ninety-one ankle replacements that were performed with use of the Scandinavian Total Ankle Replacement (STAR; Waldemar LINK, Hamburg, Germany) in patients with normal hindfoot alignment and compared them with those of thirty-two ankle replacements that were performed with the STAR prosthesis in patients who had a concomitant hindfoot deformity of >10°. Correction of preoperative deformity typically occurred during implantation of the ankle prosthesis by means of intra-articular and extra-articular soft-tissue releases, ligament reconstruction, or bone cuts. No difference was detected in terms of the postoperative range of motion or complications; however, postoperative AOFAS scores were significantly higher in the group with preoperative deformity. Gross instability that was not adequately corrected with lateral ligament reconstruction was the most common mode of failure in the deformity group. The authors suggested that total ankle replacement in the setting of preoperative hindfoot deformity of as much as 30° can be performed safely. Definite conclusions cannot be extrapolated until more investigations are performed and long-term results demonstrate enduring success in this population with >10° hindfoot deformity. Surgical correction of hindfoot alignment and ankle instability as well as design features of newer implants incorporating features to augment coronal plane stability may prove to be instrumental in the success of total ankle replacement in the patient with hindfoot deformity.

**Arthrodesis**

Arthrodesis remains the most frequently performed procedure for the treatment of end-stage tibiotalar and subtalar arthritis. Two biomechanical studies were performed to compare fixation techniques used for ankle and tibiotalocalcaneal arthrodesis. Ogut et al. used cadaver lower extremities to compare relative initial ankle joint fixation stiffness after the application of five 6.5-mm screws placed in a “best-case scenario” configuration with that after the application of a standard ring external fixator (Smith and Nephew Orthopaedics, Memphis, Tennessee). No significant difference in bending stiffness was found in any of the four tested bending directions; however, the external fixator demonstrated 44% and 66% greater stiffness in plantar flexion and eversion, respectively. Additionally, no difference was found in terms of torsional stiffness in internal or external rotation; however, the screw configuration demonstrated an approximately 50% greater stiffness in both rotation directions. The comparable stiffness profile demonstrated in this biomechanical study suggests that external fixation may be utilized with confidence in cases of ankle arthrodesis in which screw fixation is not ideal, such as cases in which the patient has poor bone quality or a tenuous soft-tissue envelope. Santangelo et al. investigated the relative bending stiffness and torsional stiffness in cadaver legs following tibiotalocalcaneal arthrodesis with use of an Orthofix Sheffield Ring Fixator (Orthofix, McKinney, Texas) and
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an arthrodesis intramedullary nail (VersaNail; DePuy Orthopaedics, Warsaw, Indiana)\textsuperscript{17}. Biomechanical testing demonstrated no difference in bending stiffness, but the external fixator displayed higher torsional stiffness in both internal and external rotation in comparison with the intramedullary nail. Insufficient bending stiffness is probably more likely than insufficient rotational stiffness to contribute to failure of fusion clinically. As a result of these studies, early postoperative weight-bearing status may need to be restricted for external fixation in a fashion similar to restrictions for screw stabilization.

Progression of adjacent-joint degeneration following ankle arthrodesis has been well established as a late consequence of the transmission of gait forces to these surrounding joints. Sealey et al. performed a prospective study analyzing the radiographic progression of compensatory adjacent-joint motion and associated clinical function at six, twelve, and a mean of thirty-three months following forty-eight ankle arthrodeses\textsuperscript{16}. Adjacent-joint motion was derived from forced dorsiflexion and planar flexion lateral radiographs with use of reproducible anatomic landmarks. The medial column and the subtalar joint demonstrated a significant increase in motion in the sagittal plane postoperatively, indicating a compensatory increase through those joints following ankle arthrodesis. Interestingly, medial column and subtalar motion initially decreased at the six-month postoperative period and then progressively increased by 19\% at the time of the latest follow-up. A significant association also was found between improved quality of life and the increased compensatory motion of the hindfoot and midfoot. The increased subtalar motion was measured in the sagittal plane and appeared to result in impingement of the posterior aspect of the subtalar joint posterior facet. This study confirms the development of compensatory motion in adjacent joints following ankle arthrodesis, and this supra-physiologic motion may account for the documented increase in subtalar and midtarsal arthritis following this procedure.

Subtalar arthrodesis remains a reliable treatment option for severe subtalar arthritis that has failed to respond to nonoperative treatment. While several studies have investigated the clinical results of isolated subtalar fusion, few biomechanical studies have evaluated the optimal placement of arthrodesis screws. Chuckpaiwong et al. tested four different screw arthrodesis constructs in a cadaver model\textsuperscript{18}. The double-screw constructs outperformed single screws by significantly increasing the achieved compressive force across the subtalar joint by a factor of between two and three while significantly increasing torsional stiffness and reducing joint rotation. Among the double-screw constructs, a diverging pattern provided significantly higher torsional stiffness than did a double parallel orientation. The double diverging screw pattern involved placement of one screw from the posterolateral calcaneal tuberosity across the posterior facet of the subtalar joint into the talar dome while the second screw was initiated posteromedially on the calcaneal tuberosity and was targeted divergent to the first screw into the talar neck. The results of this biomechanical study support double diverging screw placement as the optimum configuration for isolated subtalar joint arthrodesis.

Computer-assisted surgery has been implemented in multiple orthopaedic subspecialties; however, its application has been infrequently applied to foot and ankle surgery. Easley et al. compared subtalar arthrodesis with and without computer-navigated assistance for the placement of two diverging arthrodesis screws in a pattern described in their biomechanical study\textsuperscript{19}. Computer assistance decreased the overall number of guidewire passes necessary to achieve optimal placement. Computer navigation allowed for a 95\% rate of ideal placement on the first insertion while also reducing mean fluoroscopy time by 87\%. In the group of surgeons who had previous experience performing conventional subtalar arthrodesis, computer assistance doubled the operative time in comparison with that required for conventional (fluoroscopy-guided) subtalar arthrodesis. Despite the computer-navigated placement of screws, no difference was found in terms of the frequency of screws breaching the talar dome or unintentionally penetrating the calcaneal or talar cortices or in terms of clinically suboptimal screw placement in comparison with conventional placement. This study suggests that computer assistance may have a role in subtalar arthrodesis, particularly for surgeons who are inexperienced with this procedure.

Diabetes and Charcot Arthropathy
Sammarco et al. reviewed their experience with the surgical correction of neuropathic midfoot collapse with use of a novel technique for arthrodesis\textsuperscript{19}. Twenty-two patients with midfoot collapse due to Charcot neuroarthropathy underwent surgical reconstruction and arthrodesis after the failure of nonoperative treatment. The reconstruction entailed limited exposure to the region of deformity, resection of osseous prominences, and preparation of the arthrodesis site with recreation of the midfoot arch, supplemented by hardware stabilization. The fixation technique involved retrograde intramedullary passage of an 8.0-mm screw through the metatarsophalangeal joint into the first metatarsal and across the fusion site. In the lesser metatarsals, a 4.5 or 5.5-mm-diameter screw was inserted in a similar fashion. Overall, sixteen of the twenty-two patients achieved complete fusion of the midfoot whereas another five had development of partial unions in which a single joint did not unite although the foot remained stable. All preoperative radiographic measurements (including the talar-first metatarsal angle, the talar declination angle, and the calcaneal-fifth metatarsal angle) improved significantly following surgery, and no recurrent dislocations were reported. Some loss of radiographic correction in the talar declination angle and the lateral-first metatarsal angle was noted in the more severe cases involving perinavicular
arthropathy with distal intermetatarsal fragmentation. The reported complication rate was relatively low for this challenging subset of patients, yet it remains a concern. The complications included one nonunion, six cases in which the patient required screw removal, seven broken intramedullary screws, three peroperative fractures, one case of osteonecrosis of the talus, and four cases in which plantar ulceration developed postoperatively. This series demonstrates that reconstruction of Charcot midfoot collapse with multiple intramedullary axial screw fixation is a viable surgical option. This technique, however, should be utilized with caution because of the risks inherent in this patient population.

Assal and Stern reported on the use of a similar technique to reconstruct severe diabetic neuropathic midfoot arch collapse associated with a rocker bottom deformity. Fifteen feet were reconstructed overall, of which thirteen had a nonhealing midfoot plantar ulcer with an average size of 2.8 × 2.8 cm. The technique first involved surgical reduction and alignment of the medial column. The talonavicular, naviculocuneiform, and medial cuneiform-first metatarsal joints were then decorticated for arthrodesis. Internal fixation of the medial column was then performed with use of a cannulated intramedullary screw, measuring 8 mm in diameter and 150 mm in length, that was placed antegrade from the posterior aspect of the talus into the first metatarsal. Supplemental fixation of the reconstruction was performed with use of a 6.5-mm antegrade intramedullary lateral column screw (inserted from the calcaneus into the fourth or fifth metatarsal), a single 6.5-mm subtalar fusion screw, and a 3.5-mm plate that extended from the talus to the second metatarsal. This procedure produced encouraging results as thirteen patients were able to walk with use of only a custom-made shoe with molded inserts and all plantar ulcers healed at an average of three months. An additional patient required a Charcot restraint orthotic walker for balance because of a contralateral transtibial amputation. Radiographic correction of the talus-first metatarsal angle was maintained postoperatively in the majority of patients, with the exception of four patients who had development of a nonunion. Only one of these four nonunions was symptomatic. One patient required a below-the-knee amputation because of a deep infection. These results indicate that bypassing the zone of fusion to improve fixation with strong hardware placed with minimal soft-tissue disruption can lead to successful outcomes with an acceptable complication rate.

Achilles Tendon Rupture
Operative repair of acute Achilles tendon ruptures has been associated with wound-healing problems and sural nerve injury. The Achillon suture system (Integra LifeSciences, Plainsboro, New Jersey) is a device that was developed to avoid these associated complications through the use of a minimally invasive repair technique. In the prospective randomized study by Aktas and Kocaoglu, the results and complications following the repair of acute Achilles tendon ruptures with use of a standard open technique involving end-to-end sutures were compared with those following minimally invasive repair with use of the Achillon suture system. Overall, the outcomes in terms of AOFAS scores, range of motion, calf girth, and return to sports activity were equivalent between the two groups. Additionally, no reruptures or sural nerve injuries occurred in either group. The lone significant difference between the two techniques resided in the frequency with which postoperative complications were encountered. Complications were observed with higher frequency in association with the open suturing technique, although most were considered minor. These results suggest that the Achillon suture system is safe and is likely as effective as the open suture technique for the repair of acute Achilles tendon ruptures.

Surgical repair of acute Achilles tendon ruptures has been associated with a lower risk of rerupture than nonoperative treatment has. However, some surgeons have advocated augmenting the tendon repair to further increase tensile strength. Pajala et al. performed a prospective randomized study comparing the results of augmented and nonaugmented techniques for the repair of an acute complete Achilles tendon rupture. Sixty patients were randomized to receive suture repair with use of a Krackow locking loop technique alone or the same repair augmented with a downturned gastrocnemius fascia flap. The postoperative results were similar between the groups in terms of subjective and objective outcomes, isokinetic strength scores, mean peak work-displacement relationships, and tendon elongation. The rerupture rate was 10% in each group. The surgical incision was significantly longer in the augmentation group (18 cm) than in the simple repair group (11 cm), and the tourniquet time was significantly greater in the augmentation group by an average of twenty minutes. Two deep infections occurred, both in the augmentation group. The equivalent results demonstrated between the two surgical techniques in this prospective randomized study support the repair of acute Achilles tendon ruptures without the use of augmentation as this adjunct provides no demonstrable additional benefit.

The postoperative regimen that is employed following the surgical repair of Achilles tendon ruptures varies widely and remains an area of controversy. Currently, there is little evidence to support definitive conclusions about the effect of early weight-bearing on recovery after the surgical repair of this injury. In a prospective randomized trial, Suchak et al. enrolled patients into either a non-weight-bearing protocol in which a fixed-hinge ankle-foot orthosis was worn or a weight-bearing-as-tolerated protocol in which the same orthosis was worn. At six weeks postoperatively, the weight-bearing-as-tolerated group reported fewer limitations of daily activities and demonstrated significantly better scores in terms of physical functioning, social functioning, role-emotional, and vitality outcome scores. These differences disappeared by six months as both groups had few
limitations. Both groups manifested heel-raise endurance impairment of 50% compared with the contralateral extremity at six months of follow-up. No reruptures were reported for either postoperative protocol. We can conclude from this study that early weight-bearing after surgical repair of an acute Achilles tendon rupture does not appear to increase the risk of rerupture or negatively impact recovery, whereas it improves health-related quality of life in the early postoperative period.

Comparison studies between operative repair and nonoperative treatment of Achilles tendon ruptures have demonstrated that operative repair is associated with a lower rerupture rate at the expense of an increased infection rate. However, the often-quoted higher rerupture rate associated with nonoperative treatment may not accurately reflect current functional early weight-bearing rehabilitation protocols. Sinclair et al. revisited the rate of rerupture following the treatment of acute complete Achilles tenotomy with use of a functional weight-bearing orthosis after operative repair or as nonoperative treatment. The nonoperative treatment group was provided with a Vacoped brace (OPED, Valley, Germany) and was allowed immediate full weight-bearing with protected ankle movement after three weeks. The operative repair group also was provided with the same brace shortly after surgery and was allowed to bear weight while protected motion was initiated once the surgical wound had healed. Eighty consecutive patients were followed prospectively after being given a choice of treatment based on evidence-based counseling. Fifty-one patients chose nonoperative treatment, and twenty-nine selected operative repair. The rerupture rates were 3.9% and 3.4% in the nonoperative and operative treatment groups, respectively, and the infection rate was 6.8% in the operative treatment group. The lower functional outcomes in the nonoperative treatment group were determined not to be significant as the patients in that group were an average ten years older. The results of this study suggest that the rerupture rate following nonoperative treatment of acute Achilles tendon tears is comparable with operative repair, possibly because of the benefits of early weight-bearing on tendon healing.

Achilles Tendinopathy

Extracorporeal shock wave therapy has demonstrated clinical success for the treatment of Achilles tendinopathy, yet the mechanism of this effect remains uncertain. Han et al. performed an elegant experiment investigating the potential biologic effects of extracorporeal shock wave therapy on normal and diseased tenocytes. Samples of diseased tendon were harvested during reconstructive efforts for Achilles tendinopathy and normal controls from healthy flexor hallucis longus tendons used for flexor hallucis longus transfer. The diseased and normal tenocyte cell samples were first cultured prior to treatment with shock wave therapy. The cells were subsequently analyzed for selected biologic markers for comparison with pretreatment levels. Tenocytes derived from degenerated Achilles tendons demonstrated higher levels of matrix metalloproteinases, which play a role in degrading the collagen matrix. Extracorporeal shock wave therapy decreased the expression of several matrix metalloproteinases and interleukin-6 (IL-6) in tendinopathy-affected tenocytes. The reduction in matrix metalloproteinases and IL-6 as demonstrated in this study may help to explain some of the clinical improvement observed in Achilles tendinopathy following treatment with extracorporeal shock wave therapy.

Elias et al. reviewed their surgical experience with the treatment of symptomatic chronic insertional Achilles tendinosis that had failed to respond to conservative treatment and demonstrated magnetic resonance imaging evidence of degenerative changes replacing >50% of the tendon. The surgical procedure involved splitting the Achilles tendon to allow for débridement, resection of the posterior calcaneal tuberosity (the Haglund exostosis) and insertional spur, reattachment of the Achilles tendon, and flexor hallucis longus transfer, all performed through a single longitudinal midline incision. The average preoperative AOFAS score improved significantly from 56.3 to 96.2 postoperatively, the average visual analog scale pain score improved from 7.5 to 0.3, and 95% of the patients rated the outcome as very good or good at twenty-seven months. Functional analysis with use of Biodex isokinetic dynamometry demonstrated that ankle torque and range of motion were equivalent to those of the contralateral, normal leg. This operative approach appears to be a safe and effective procedure that yields excellent functional and clinical outcomes for patients with advanced chronic insertional Achilles tendinosis that has failed to respond to nonoperative measures.

Hallux Valgus

Numerous methods for radiographic measurement of the hallux valgus angle and the intermetatarsal angle have been described; however, the most reliable and valid method has yet to be determined. Shima et al. selected twenty preoperative radiographs of feet with hallux valgus and twenty postoperative radiographs of feet with hallux valgus that had been treated with a proximal crescentic osteotomy and a modified McBride procedure. Three foot and ankle surgeons determined the hallux valgus angle and intermetatarsal angle with use of five different methods of measuring the longitudinal axis of the first metatarsal in order to determine intraobserver and interobserver agreement and correlation coefficients. The most reliable of the five methods defined the longitudinal axis of the first metatarsal by drawing a line connecting the centers of the first metatarsal head and articular surface of the first metatarsal base. The authors recommended the use of this method to most reliably evaluate radiographic correction of hallux valgus after treatment with a proximal crescentic osteotomy.
The scarf osteotomy was developed with the intention of creating a stable osteotomy that is capable of achieving large corrections of the intermetatarsal angle. Deenik et al. performed a prospective randomized study involving 136 feet to compare the scarf osteotomy with the chevron osteotomy for the correction of hallux valgus. No significant difference was detected between the two osteotomies in terms of radiographically measured correction of the hallux valgus angle, the intermetatarsal angle, or the distal metatarsal articular angle for deformities considered to be of mild or moderate severity. Insufficient numbers of patients with severe hallux valgus were enrolled for the investigators to draw definitive conclusions by comparing the two techniques. Interestingly, the scarf osteotomy group had a higher rate of complex regional pain syndrome (seven cases) than did the chevron osteotomy group (one case). The results of this study indicate that the scarf osteotomy is at least as effective as the chevron osteotomy for the correction of mild to moderate hallux valgus. Additional investigation is required to draw conclusions about the role of the scarf osteotomy in the treatment of severe hallux valgus.

The use of the opening-wedge osteotomy plate has surged in popularity for the surgical correction of hallux valgus associated with a moderate to large intermetatarsal angle. Randhawa and Pepper reviewed the short-term radiographic results for thirty-one feet following hallux valgus correction with use of the Arthrex opening-wedge metatarsal osteotomy plate (Opening Wedge Low Profile Plate and Screw System; Arthrex, Naples, Florida) combined with a modified McBride procedure\(^{29}\). Overall, the intermetatarsal angle improved from 18.4° preoperatively to 7.8° postoperatively. The average intermetatarsal angle correction increased with greater sizes of the plate’s central block (spacer). The mean intermetatarsal angle correction was 8.0° for the 3.5-mm-plate group, 9.0° for the 4.0-mm-plate group, and 14.9° for the 5.0-mm-plate group. Criticisms of the opening-wedge osteotomy plate such as nonunion of the osteotomy site or relative lengthening of the first ray were not addressed. This study is one of the first to evaluate radiographic results with use of this technique, and the results suggest that the opening-wedge plate allows for powerful correction of the intermetatarsal angle. Continued investigation will be necessary to elucidate the risks and long-term effects of its use.

Okuda et al. analyzed the relationship between the quality of sesamoid reduction under the first metatarsal head achieved by means of hallux valgus correction and the associated risk of postoperative recurrence of deformity\(^{30}\). Forty-three patients (sixty-five feet) with hallux valgus underwent correction with a combination of a proximal crescentic osteotomy and a modified McBride procedure and met the criteria for inclusion in the study. Postoperatively, the patients were evaluated radiographically with regard to the hallux valgus angle, the intermetatarsal angle, and the position of the medial sesamoid relative to the longitudinal axis of the first metatarsal. Of the sixty-five feet that underwent hallux valgus surgery, seventeen (26%) were considered to have lateral displacement of the medial sesamoid relative to the axis of the first metatarsal. Lateral displacement of the medial sesamoid in the early postoperative period subsequently correlated with both a greater hallux valgus angle and a greater intermetatarsal angle. Recurrence of the hallux valgus deformity occurred in sixteen feet (25%). Ten of the feet with recurrence were noted to have lateral displacement of the medial sesamoid in the immediate postoperative period. On the basis of the results of this study, incomplete reduction of the medial sesamoid can be associated with postoperative deterioration of the radiographic results and can increase the risk of recurrence of hallux valgus. The authors recommended intraoperative fluoroscopy to allow the surgeon to confirm adequate reduction of the sesamoids under the first metatarsal head. The authors noted that, if an incomplete reduction is identified, releasing the dorsolateral first metatarsophalangeal joint capsule and the collateral ligaments is an additional step that can be performed to ensure acceptable sesamoid alignment.

Advising patients when they can safely return to drive a car after surgical treatment of the foot and ankle presents unique medical, social, economic, and legal problems. Thus far, studies have only investigated brake-response timing after total knee and hip arthroplasty and after fixation of ankle fractures. Holt et al. performed a prospective observational study evaluating the effect of unilateral first metatarsal osteotomy on the right foot on emergency brake response time\(^{31}\). With use of a brake-reaction timer, the total brake-response time, reaction time, and brake time were recorded for twenty-eight patients at two and six weeks following a chevron, scarf, or basal first metatarsal osteotomy. At the second postoperative week, only 25% of the patients could complete the test; the remaining patients could not complete the test because of pain-related limitations. Those who could complete the test demonstrated slower times for each variable in comparison with the preoperative times, although the differences did not reach significance. By six weeks postoperatively, significant improvement was seen in each tested variable. Despite this improvement, the total brake-response time remained significantly slower at six weeks in comparison with the value for a control group. This information provides an evidence-based guideline for advising patients on when to safely resume driving following corrective osteotomy of the first metatarsal for the treatment of hallux valgus.

**Tibialis Anterior Tendon**

Rupture of the tibialis anterior tendon is a relatively infrequent occurrence that can present with pain and weakness of ankle dorsiflexion. Sparse evidence currently exists to guide surgeons in the treatment of either acute or chronic tibialis anterior tendon ruptures. Sammarco et al. retrospectively reviewed nineteen tibialis anterior tendon ruptures that were surgically...
Amputations

Pinzur et al. performed an investigation into the controversial topic of distal tibiofibular bone-bridging in transtibial amputation. The theoretical advantage of creating a bone bridge between the distal parts of the tibia and fibula is that it may support direct weight-bearing or at least distribute the mechanical load during walking and eliminate pain caused by pathologic fibular instability. Twenty nondiabetic patients with an average age of forty years underwent a unilateral transtibial amputation with this technique as a consequence of trauma. This bone-bridging group was compared with a group of fifteen patients who had undergone a unilateral transtibial amputation with use of a traditional posterior myocutaneous flap. All patients in the bone-bridging group had successful healing of the wound and union of the bone bridge. Only eight patients in the bone-bridge group completed a validated outcomes instrument, the Prosthesis Evaluation Questionnaire; their scores were found to be equivalent to those of the control group. Conclusions based on the results of this investigation, although limited by the small size of the study, suggest that distal tibiofibular bone-bridging in transtibial amputation offers no identifiable advantage over traditional techniques. Further studies need to be performed to provide objective data demonstrating the benefits of the bone-bridging technique before it can be recommended as a routine component of transtibial amputation.

Lesser-Toe Problems

The sliding oblique lesser metatarsal osteotomy (the so-called Weil osteotomy) has been used effectively to treat lesser-toe deformities such as subluxation or dislocation at the metatarsophalangeal joint as well as metatarsalgia. Results of the Weil osteotomy have been encouraging, except for the relatively high rate of complications such as floating toes and restricted motion at the metatarsophalangeal joint. Cadaver studies have demonstrated a plantar shift in the center of rotation of the metatarsophalangeal joint following this osteotomy, thereby converting the foot intrinsic muscles into dorsiflexors rather than plantar flexors; this possibly provides an explanation for the reported complications. Garg et al. reported on the results of a segmental osteotomy that has been previously demonstrated in cadaver studies to be an effective modification of the Weil osteotomy. This procedure involves an osteotomy that is similar to the Weil osteotomy, except that a second osteotomy cut is made parallel and proximally to remove a segment of bone and thereby prevent plantar displacement of the metatarsal head as occurs with the Weil osteotomy. The short-term results of the segmental osteotomy were reviewed for seventy-one metatarsals in forty-eight patients. The average postoperative AOFAS score was 87.6 points, with an overall satisfaction rate of 85.4%. However, the complication rates were higher than expected: 18.8% for transfer metatarsalgia, 27.1% for floating toes, 35.4% for toe weakness, 14.6% for infection, and 10.4% for wound-healing problems. The authors believed that their complication rate improved as experience was gained with the segmental osteotomy and after decreasing the amount of resected bone with the osteotomy cuts. While the segmental osteotomy may be technically easier to perform than the traditional Weil osteotomy, care should be taken to avoid excessive resection of bone.

Posterior Ankle Impingement

Scholten et al. reported on the results of hindfoot endoscopy for posterior ankle impingement. Fifty-five patients with posterior ankle impingement due to osseous or soft-tissue impingement underwent two-portal posterior endoscopic removal of bone fragments and/or scar tissue in the area of impingement. The average AOFAS hindfoot score improved from 75 points preoperatively to 90 points at an average of thirty-six months of follow-up. The median times for return to work and sporting activity were two and eight weeks, respectively. Patients with symptoms that were considered to be due to overuse were more satisfied and had higher AOFAS hindfoot scores than patients with a posttraumatic onset of symptoms. Only one complication, transient numbness along the posteromedial aspect of the heel, was reported. These results suggest that, in the hands of a surgeon who is experienced with this technique, two-portal posterior hindfoot endoscopy is a safe and effective alternative to open surgical treatment.
Paralytic and Cavovarus Foot Deformity
Provelengios et al. reported the long-term results of pantalar arthrodesis for the treatment of paralytic foot deformity.20 Twenty-four patients who underwent pantalar arthrodesis for the treatment of paralytic foot deformity as a consequence of poliomyelitis were available for follow-up at an average of 37.2 years postoperatively. Overall, the long-term results were encouraging as the average Short Form-36 (SF-36) score was 73 of 100 points. Although the majority of patients had some degree of ipsilateral knee pain requiring nonsteroidal anti-inflammatory medication, their symptoms did not prevent good function. Fifteen patients reported the ability to walk distances of >1 km, and nine could walk >5 km. The activities that were most limited by the pantalar arthrodesis were ascending hills, athletic activities, and driving a car. Thus, the pantalar arthrodesis appears to be a viable surgical option that can provide a strong and stable platform for walking for selected patients such as those with paralytic foot deformity.

The long-term results of joint-sparing procedures used for the correction of cavovarus foot deformity due to hereditary motor sensory neuropathy, or Charcot-Marie-Tooth disease, have been lacking in the literature. Ward et al. performed a retrospective review of twenty-five patients (forty-one feet) who underwent reconstruction of a flexible cavovarus foot deformity due to Charcot-Marie-Tooth disease, according to their algorithmic approach, from 1970 to 1994.20 The approach involves performing a plantar fasciotomy, transferring the peroneus longus to the peroneus brevis tendon, performing a closing-wedge dorsal first metatarsal osteotomy, and transposing the tibialis anterior to the lateral cuneiform if muscle strength was at least 4 of 5 preoperatively. After a mean duration of follow-up of 26.1 years, the correction of the cavus deformity was well maintained both clinically and radiographically, although some hindfoot varus recurred in most patients. Few patients demonstrated clinically relevant degenerative changes in the foot and ankle joints, and no patient underwent a subsequent triple arthrodesis. SF-36 scores were lower than age-matched norms, and gait (as measured with gait analysis) was slower. Overall, this algorithm of joint-sparing procedures demonstrates long-term maintenance of correction of the flexible cavovarus deformity due to Charcot-Marie-Tooth disease and results in lower rates of degenerative changes and reoperation than triple arthrodesis does.

Evidence-Based Orthopaedics
The editorial staff of The Journal reviewed a large number of recently published research studies related to the musculoskeletal system that received a Level of Evidence grade of I or II. Over 100 medical journals were reviewed to identify these articles, which all have high-quality study design. In addition to articles published previously in this journal or cited already in this Update, three additional level-I and II studies were identified that were relevant to foot and ankle surgery. A list of those titles is appended to this review following the standard bibliography. We have provided a brief commentary about each of the articles to help guide your further reading, in an evidence-based fashion, in this subspecialty area.

Upcoming Educational Events
There are several upcoming courses and events relevant to foot and ankle surgery sponsored or cosponsored by the American Academy of Orthopaedic Surgeons, the American Orthopaedic Foot and Ankle Society, and the Arthroscopy Association of North America (AANA).

The 2010 Advanced Foot and Ankle Course will be held on April 22 through 24, 2010, in Penn's Landing, Pennsylvania.

The twenty-sixth annual AOFAS Summer Meeting will be held on July 7 through 10, 2010, in National Harbor, Maryland.

The AOFAS/AANA Masters Experience: Foot and Ankle Arthroscopy course will be held on September 25 and 26, 2010, in Rosemont, Illinois.

The 2010 Complete Foot Care Course will be held on October 1 and 2, 2010, in Hershey, Pennsylvania.

References
What’s New in Foot and Ankle Surgery


low-energy radial shock-wave therapy received in three sessions starting four weeks after the eccentric training program was initiated. At the four-month follow-up, all outcome measures significantly favored the combined treatment approach. This difference, however, no longer existed at the time of the one-year follow-up. The combination of eccentric loading and repetitive low-energy radial shock-wave therapy appears to have a more significantly positive effect on noninsertional Achilles tendinopathy in the short term than either treatment alone.


Minimally invasive techniques to repair acute Achilles tendon ruptures are considered to reduce the risk of complications associated with standard open repair while also preventing tendon rerupture. In this randomized controlled trial, minimally invasive surgery was compared with nonoperative treatment of an Achilles tendon rupture, with both groups being managed with immediate full weight-bearing. The goal was to assess the overall risk of complications, other than rerupture. Surgical repair of the Achilles tendon was performed through a <5-cm posteromedial incision with use of a Bunnell-type stitch with PDS 1-0 suture. Postoperatively, the foot was placed in a plantar flexion cast for one week and then was converted to a tape bandage with progressively smaller-sized heel raises for six more weeks. The nonoperative treatment group was managed with a plantar flexion cast for one week, followed by a functional bracing system (Vacoped; OPED, Valley, Germany) for an additional six weeks. Full weight-bearing was permitted for both groups. The study demonstrated a 15% lower risk of complications (other than rerupture) in favor of the minimally invasive surgical treatment. This difference did not reach significance. We conclude that minimally invasive surgical repair of acute Achilles tendon ruptures may decrease the postoperative risk of complications seen with standard open repair and that it compares favorably with the risks associated with nonoperative brace treatment alone.