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SYMPOSIUM

Lisfranc Injuries in the Elite Athlete

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Abstract

The management of sports-related Lisfranc injuries is optimized by a detailed understanding of the relevant anatomy, mechanisms of injury, clinical diagnostic maneuvers, imaging, and treatment options for patients with this disabling injury. A lower energy ligamentous variant Lisfranc injury, which was first observed in professional football players, has recently been described. The treatment options for patients with a Lisfranc injury include nonsurgical management, open reduction and internal fixation, suture-button fixation techniques, and arthrodesis.

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Injuries to the Lisfranc joint complex have classically been associated with high-energy trauma, such as that which occurs during motor vehicle collisions, falls from a height, and industrial accidents.[1,2] Recently, there has been increased identification of a spectrum of Lisfranc injuries that result from lower-energy trauma, such as that which occurs in sports. Foot injuries represent approximately 16% of all sports-related injuries, with midfoot sprains occurring in 4% of collegiate football players each year.[3] Offensive linemen (29%) are the collegiate football players who most commonly sustain midfoot sprains, and the mechanism of injury for midfoot sprain in collegiate football players more commonly involves a twisting injury (50%) rather than axial loading (37%).[4] In a study of 15 patients who had subtle injuries of the Lisfranc joint, Faciszewski et al[5] reported that nine of the patients (60%) sustained injury via low-energy twisting mechanisms of injury, five of whom sustained injury while playing sports. Subtle Lisfranc injuries can have variable injury patterns and may be a challenge to diagnose, with delays in appropriate management resulting in persistent pain and disability. Treatment recommendations for patients who have a subtle ligamentous Lisfranc injury are based on joint diastasis and the instability pattern, with surgery performed to reduce the risk of joint degeneration and improve functional outcomes. Subtle ligamentous Lisfranc injuries are particularly relevant given the high demands an elite athlete places on the foot.

Video 21.1: Lisfranc Injuries in the Elite Athlete. Robert B. Anderson, MD (9 min)

Anatomy and Mechanism of Injury

Injuries to the Lisfranc joint complex may include disruption of the bony

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and/or soft-tissue structures of the midfoot, including the tarsometatarsal (TMT), intercuneiform, cubocuneiform, and naviculocuneiform joints. In an uninjured foot, the combination of osseous architecture and stout capsuloligamentous support allows the midfoot to function as a rigid lever arm during gait. The keystone configuration of the recessed second metatarsal base within the mortise of the cuneiforms forms the classic Roman arch structure, which provides maximal bony stability. Capsuloligamentous support provides secondary, indirect stability via the plantar and dorsal bridging ligaments and the transverse intermetatarsal ligaments.[6] The plantar midfoot ligaments are three times stronger than the dorsal ligaments, which likely accounts for the typical dorsal dislocation pattern observed in patients who have a Lisfranc injury. Only the first and second metatarsals are without intermetatarsal ligamentous connection. The Lisfranc ligament is located plantarly between the medial cuneiform and second metatarsal base. The Lisfranc ligament in conjunction with two stout Y-shaped plantar ligaments that connect the medial cuneiform and the second and third metatarsal bases form the Lisfranc ligament complex, which is key to the overall stability of the Lisfranc joint. Injury to both the two plantar ligaments and the Lisfranc ligament is required before transverse instability is observed, whereas disruption of the interosseous ligaments between the medial and middle cuneiforms results in longitudinal instability.[7,8] Injuries to the Lisfranc joint complex range from mild sprains with no displacement to severe fracture-dislocations.

Sports-related Lisfranc injuries may involve two separate mechanisms of injury, which result in a spectrum of injury patterns. The classic mechanism of injury involves direct axial loading of the midfoot combined with a twisting or bending moment, such as that which occurs when an athlete, whose foot is plantarflexed and in contact with the ground, has another athlete fall on his or her heel. This mechanism of injury may result in intermetatarsal or first intercuneiform diastasis with or without fractures of the metatarsals or tarsal bones. A less common mechanism of injury involves a noncontact injury that typically is associated with cleated footwear and the increased torsional forces that occur with the use of high-friction spikes on turf surfaces.[9,10] In this mechanism of injury, an athlete generates an axial force via his or her plantarflexed and slightly rotated foot. When the athlete's cleated foot engages with the turf, his or her midfoot is subject to forceful abduction and/or twisting, such as that which occurs with dynamic push-off or a sudden change of direction. These sports-related Lisfranc injuries, which include proximal or medial column instability patterns that extend through the first intercuneiform articulation and naviculocuneiform joint, were first described in professional football players.[9,10]

Clinical Evaluation

Physical Examination

Low-energy Lisfranc injuries may be difficult to diagnose and are commonly missed on initial physical examination.[11-13] The clinical evaluation of an athlete is informed by a detailed history that includes activity type and a description of the foot position at the time of injury. In patients who have a more subtle Lisfranc injury, midfoot swelling and an inability to bear weight may be the only initial findings. Additional findings may include tenderness of the dorsal midfoot, TMT joints, and medial naviculocuneiform joint. Midfoot pain may be substantially increased with attempted weight bearing. Gentle stressing of the forefoot into plantar flexion and abduction also may elicit pain. Patients with proximal Lisfranc injury variants may have an unstable first ray and difficulty with toe push-off. Comparison of the injured foot with the contralateral foot may reveal subtle first ray hypermobility. Plantar ecchymosis may be a late finding.

Imaging

Imaging should include standard AP, oblique, and lateral foot radiographs. Weight-bearing radiographs are strongly recommended because subtle joint diastasis is missed on initial non–weight-bearing radiographs in as many as 20% of athletes who have a Lisfranc injury.[14] Comparison radiographs of the injured foot with the contralateral foot may be helpful to assess consistent anatomic relationships. Single-limb standing radiographs are recommended as tolerated by the patient. Radiographs should be evaluated for joint diastasis, malalignment, and loss of longitudinal arch height. Fleck cortical avulsion fractures also may be present. Foster and Foster[15] reported that the most consistent radiographic finding in patients who had Lisfranc injuries was loss of alignment of the medial border of the second metatarsal and the medial border of the middle cuneiform. If initial imaging findings are negative but a high suspicion for midfoot injury exists, repeat radiographs may be obtained in 7 to 14 days; however, plain radiographs may not reliably detect malalignment of 1 to 2 mm.[16] Stress radiographs

under fluoroscopic guidance may be obtained but should not be considered sufficient to rule out midfoot injury. Stress radiographs are obtained by stabilizing the hindfoot and applying alternating supination/pronation as well as abduction/adduction stresses to the forefoot. Displacement of 2 mm or more is commonly reported as suggestive of instability, whereas cadaver model studies have reported that joint diastasis of as little as 1.3 mm may differentiate between an intact and a torn Lisfranc ligament.[17]

Both CT and MRI provide superior anatomic detail; however, because CT and MRI typically are static, non–weight-bearing imaging modalities, they may not identify subtle force-dependent joint diastasis. Despite these limitations, CT can be used to evaluate fracture comminution and displacement, and MRI can help identify ligamentous injury.[18,19] In a study on the utility of MRI for the diagnosis of subtle Lisfranc injury, Raikin et al[19] reported that, compared with intraoperative stress assessment, disruption of the Lisfranc ligament complex on MRI was the strongest predictor of instability, reliably identifying disruption in 90% of Lisfranc ligament complex injuries.

Treatment

The management of Lisfranc injury in athletes is based on the goal of attaining and maintaining anatomic alignment, which provides the best long-term outcomes.[14] According to Nunley and Vertullo,[14] nonsurgical treatment should be reserved for patients who have a nondisplaced stable Lisfranc injury. The authors proposed a classification system for Lisfranc injuries in athletes based on clinical examination findings, weight-bearing radiographic evaluation, and bone scintigraphy results. Stage I Lisfranc injuries are considered stable injuries, demonstrating no joint diastasis on radiographs and positive bone scintigraphy results. Stage II Lisfranc injuries involve rupture of the Lisfranc ligament, with 1 to 5 mm of joint diastasis and no longitudinal arch height loss. Stage III Lisfranc injuries involve 1 to 5 mm or more of joint diastasis and loss of longitudinal arch height. Nunley and Vertullo[14] recommended nonsurgical treatment for patients who had stage I Lisfranc injuries and surgical fixation for patients who had stage II or stage III Lisfranc injuries.

Surgical indications for sports-related Lisfranc injury do not include a specific threshold for joint diastasis and are based on instability as much as the amount of displacement. The stability of the TMT, intermetatarsal, intercuneiform, and naviculocuneiform joints should be assessed and addressed surgically if they are unstable. Lisfranc injuries, even those with a seemingly stable injury pattern, that fail to improve with nonsurgical treatment should raise concern for subtle instability that may require intraoperative assessment.

Nonsurgical Treatment

Nonsurgical management of Lisfranc injury in athletes is controversial. Curtis et al[20] recommended surgical intervention for all athletes and active patients; however, nonsurgical management has been successful in athletes who are returning to high-level sports activity.[4,14,21] Ideally, nonsurgical treatment in athletes is reserved for those with stage I Lisfranc injuries in whom minimal to no displacement is observed on CT. Nonsurgical treatment of 6 weeks of non–weight-bearing in a cast has shown excellent results.[14] In minimally symptomatic patients with a Lisfranc injury that appears stable, some studies have recommended 2 weeks of protected weight bearing in a cast or boot followed by a repeat physical examination and repeat weight-bearing radiographs. In these patients, if stability is maintained and the repeat physical examination is asymptomatic, then a graded return to activity with or without the use of an orthotic support for several months is allowed as tolerated.[14,22] Despite reported successes in the nonsurgical management of Lisfranc injuries, multiple studies have reported poor results in both athletic and nonathletic patients who underwent nonsurgical treatment for Lisfranc injuries that were unstable or in whom joint diastasis was present.[23-26]

Surgical Treatment

Surgery, if undertaken, should be performed as soon after injury as the soft tissues allow. In patients with severe Lisfranc injury, Trevino and Kodros[26] as well as Arntz et al[27] recommended performing surgery within the first 24 hours postinjury. A 1- to 2-week delay of surgery to allow for swelling to subside may be appropriate and does not appear to alter long-term outcomes;[18] however, surgical correction that is performed 6 weeks or more postinjury generally results in poorer outcomes.[18]

Regardless of which surgical treatment option is selected, the goal is to attain a stable, anatomic reduction of the Lisfranc injury. Closed reduction may be possible in some patients; however, several studies have reported that restoration of anatomic reduction and joint congruency is best achieved via open reduction.[28,29] Kirschner wire (K-wire) fixation has been described

for the definitive fixation of minimally displaced Lisfranc injuries;[30-32] however, because of the biomechanical superiority of screw fixation and the higher rate of complications after K-wire fixation, including loss of reduction, pin migration, and pin site infection, K-wire fixation has been largely abandoned.[23,28,32]

Current recommendations for the surgical management of Lisfranc injury support screw fixation after open reduction.[33] Surgical techniques for screw fixation and open reduction vary; however, many surgeons who perform Lisfranc fixation with isolated 3.5-mm, 4.0-mm, or 4.5-mm screws report excellent results.[22,27,34,35] Despite reported successes of screw fixation and open reduction, concern for chondral injury exists. Alberta et al[33] reported that a 3.5-mm screw can damage 2% to 3.6% of the articular surface of the TMT joint. However, Gaines et al[36] reported that a 4.0-mm cannulated screw can damage 3.2% to 5.3% of the articular surface of the TMT joint. The authors reported that more than one guidewire passage attempt led to fractures of the metatarsal base and cuneiform in more than 40% of the cadaver models in the study. Fixation with extra-articular plate constructs is advantageous because it avoids articular cartilage damage. Dorsal plating techniques have been reported to be at least as stable as transarticular screw constructs, and plantar plating techniques have been reported to provide even more stability, albeit at the cost of additional soft-tissue dissection and difficulty with hardware removal.[33,37] Locking plate technology has helped advance dorsal plating techniques and improved construct strength.[37] Although newer-generation plate and screw constructs are lower profile, dorsal plates increase the risk for hardware irritation and, therefore, delayed hardware removal. Hardware removal, if undertaken, typically occurs no earlier than 4 to 6 months after fixation.

Suture button fixation of Lisfranc injury has been performed in an attempt to provide a more physiologic fixation and decrease the need for delayed screw removal. However, in a recent cadaver model study, Ahmed et al[38] reported that, compared with 4.0-mm cannulated screw fixation, suture button fixation resulted in increased intermetatarsal stress widening; therefore, the authors recommended the continued use of screw fixation for the management of Lisfranc injuries. Fourth or fifth TMT joint injury, although less common in patients who have a low-energy Lisfranc injury, if unstable, may require percutaneous K-wire fixation for 6 weeks followed by hardware removal.

The role of primary arthrodesis in the management of Lisfranc injury is controversial. Ly and Coetzee[24] reported that arthrodesis resulted in lower complication and revision surgery rates compared with open reduction and internal fixation (ORIF). Conversely, Mulier et al[39] reported that, at a follow-up of 30 months, patients who underwent ORIF or partial arthrodesis had decreased rates of pain, forefoot stiffness, metatarsal arch loss, and complex regional pain syndrome without an increased risk for revision surgery compared with patients who underwent complete arthrodesis. Interestingly, degenerative joint changes were observed on the plain radiographs of 94% of the patients who underwent ORIF; because a substantial portion of these patients required eventual arthrodesis, the authors reported that partial arthrodesis may be the preferred surgical treatment option for patients with a Lisfranc injury in whom fracture comminution or substantially displaced ligamentous injuries are present. Although arthrodesis may result in improved pain and function in patients in whom Lisfranc injury is missed and in patients who have posttraumatic arthritis, the authors of this chapter do not prefer to use arthrodesis for the management of acute athletic Lisfranc injuries. Despite reports of professional athletes returning to a high of level play after arthrodesis of a Lisfranc injury, the authors of this chapter do not recommend arthrodesis for the treatment of elite athletes who have a Lisfranc injury, and believe that primary ORIF results in better overall pain and functional outcomes.[14,28]

The treatment recommendation of the authors of this chapter for elite athletes who have a Lisfranc injury includes a low threshold for an open, intraoperative evaluation of stability. The authors of this chapter perform internal fixation of all unstable segments, with dorsal bridge plating of the TMT joints to preserve joint surfaces. Care is taken to evaluate for subtle ligamentous injuries that extend to the proximal midfoot; fixation of these injuries includes intercuneiform stabilization with one or two screws. The authors of this chapter have reported that naviculocuneiform fixation is rarely necessary after fixation of the adjacent midfoot joints; however, they recommend observation of the medial naviculocuneiform column for collapse because it can deteriorate rapidly. The authors of this chapter avoid arthrodesis for the treatment of athletes who have a Lisfranc injury because of the risks previously discussed as well as the potential for symptomatic malunion or nonunion.

Postoperative Management

Postoperative management for patients with Lisfranc injuries includes 2 weeks of splint immobilization followed by the transition to a boot and initiation of a non–weight-bearing rehabilitation program. Weight bearing in a walking boot is begun at 6 weeks postoperatively. At 3 months postoperatively, patients are transitioned to normal shoe wear with molded orthotic support. Because of the prolonged healing time for ligaments, the authors of this chapter routinely retain fixation hardware for a minimum of 4 months. Despite lower profile plate and screw technology, the authors of this chapter have found that dorsal bridge plates can still become symptomatic and may require removal; however, plates or screws are less likely to become symptomatic if they break before removal. Intercuneiform screws are kept in situ indefinitely because of the concern for late joint diastasis. The authors of this chapter counsel patients on the relatively long postoperative recovery for Lisfranc injuries. In a study of 170 patients who underwent surgical treatment for a Lisfranc injury, Brunet and Wiley[40] reported an ongoing improvement in symptoms until 1.3 years postoperatively, with 80% of patients being pain free and most patients returning to their preinjury level of activity and sport. Although chronic discomfort and stiffness may occur in some patients, it rarely limits function.

Complications

Posttraumatic joint degeneration is the most common complication of Lisfranc injury. Delayed diagnosis of a Lisfranc injury and malunion increases the risk for posttraumatic arthritis. In a retrospective study of 92 patients with a Lisfranc injury who underwent ORIF, Kuo et al[23] reported that arthritis developed in 25% of the patients, 50% of whom required arthrodesis. Limited evidence on the long-term outcomes of athletes who undergo treatment for Lisfranc injury exists. Typically, sports-related midfoot injuries are low-energy injuries that include a higher rate of stage I and stage II Lisfranc injuries, in which substantially better outcomes are reported. In a study of 17 professional soccer and rugby athletes with a Lisfranc injury who underwent surgical treatment, Deol et al[41] reported that only one athlete retired as a result of injury. All of the other athletes had a mean time of return to sport training and full competition of 20.1 weeks and 25.3 weeks, respectively. The patients with ligamentous injuries had a slightly earlier mean time of return to competition compared with the patients who had bony injuries (22.5 weeks versus 26.9 weeks, respectively).

Summary

Lisfranc injuries in athletes are typically low-energy injuries that include variable instability patterns, which may add to the challenges of diagnosis and treatment. A high level of suspicion for Lisfranc injury as well as a careful physical examination, a thorough evaluation of imaging, and prompt treatment may allow athletes to return to a high level of competition and maximize functional outcomes. Typically, nonsurgical treatment is reserved for patients who have a stable stage I Lisfranc injury. Surgical treatment, which is recommended for patients who have displaced or unstable injury patterns, involves attaining a stable anatomic articular reduction of the Lisfranc injury without causing iatrogenic chondral injury. Arthrodesis should be reserved for patients who have complex high-energy fracture patterns with chondral injury and is rarely indicated in athletes who have a Lisfranc injury. Despite optimal treatment, elite athletes with a Lisfranc injury may have a prolonged postoperative recovery; therefore, athletes, sports teams, and athletic trainers should be aware of the severity of Lisfranc injury.

References

1. Hardcastle PH, Reschauer R, Kutscha-Lissberg E, Schoffmann W: Injuries to the tarsometatarsal joint: Incidence, classification and treatment. *J Bone Joint Surg Br* 1982;64(3):349-356. Medline
2. Myerson MS, Fisher RT, Burgess AR, Kenzora JE: Fracture dislocations of the tarsometatarsal joints: End results correlated with pathology and treatment. *Foot Ankle* 1986;6(5):225-242. Medline DOI
3. Garrick JG, Requa RK: The epidemiology of foot and ankle injuries in sports. *Clin Sports Med* 1988;7(1):29-36. Medline
4. Meyer SA, Callaghan JJ, Albright JP, Crowley ET, Powell JW: Midfoot sprains in collegiate football players. *Am J Sports Med* 1994;22(3):392-401. Medline DOI
5. Faciszewski T, Burks RT, Manaster BJ: Subtle injuries of the Lisfranc joint. *J Bone Joint Surg Am* 1990;72(10):1519-1522. Medline
6. Peicha G, Labovitz J, Seibert FJ, et al: The anatomy of the joint as a risk factor for Lisfranc dislocation and fracture-dislocation. An anatomical and radiological case control study. *J Bone Joint Surg Br* 2002;84(7):981-985. Medline DOI
7. Kaar S, Femino J, Morag Y: Lisfranc joint displacement following sequential ligament sectioning. *J Bone Joint Surg Am* 2007;89(10):2225-2232. Medline DOI
8. Pearce CJ, Calder JD: Surgical anatomy of the midfoot. *Knee Surg Sports Traumatol Arthrosc* 2010;18(5):581-586. Medline DOI
9. Anderson RB, Hammit MD: Recognizing and treating the subtle Lisfranc

injury. Presented at the 20th Annual Summer Meeting of the American Orthopaedic Foot and Ankle Society, Seattle, WA, July 29-31, 2004.

10. Ardoin GT, Anderson RB: Subtle Lisfranc injury. *Tech Foot Ankle Surg* 2010;9(3):100-106. DOI

11. Burroughs KE, Reimer CD, Fields KB: Lisfranc injury of the foot: A commonly missed diagnosis. *Am Fam Physician* 1998;58(1):118-124. Medline

12. Englanoff G, Anglin D, Hutson HR: Lisfranc fracture-dislocation: A frequently missed diagnosis in the emergency department. *Ann Emerg Med* 1995;26(2):229-233. Medline DOI

13. Perron AD, Brady WJ, Keats TE: Orthopedic pitfalls in the ED: Lisfranc fracture-dislocation. *Am J Emerg Med* 2001;19(1):71-75. Medline DOI

14. Nunley JA, Vertullo CJ: Classification, investigation, and management of midfoot sprains: Lisfranc injuries in the athlete. *Am J Sports Med* 2002;30(6):871-878. Medline

15. Foster SC, Foster RR: Lisfranc's tarsometatarsal fracture-dislocation. *Radiology* 1976;120(1):79-83. Medline DOI

16. Lu J, Ebraheim NA, Skie M, Porshinsky B, Yeasting RA: Radiographic and computed tomographic evaluation of Lisfranc dislocation: A cadaver study. *Foot Ankle Int* 1997;18(6):351-355. Medline DOI

17. Panchbhavi VK, Andersen CR, Vallurupalli S, Yang J: A minimally disruptive model and three-dimensional evaluation of Lisfranc joint diastasis. *J Bone Joint Surg Am* 2008;90(12):2707-2713. Medline DOI

18. Buzzard BM, Briggs PJ: Surgical management of acute tarsometatarsal fracture dislocation in the adult. *Clin Orthop Relat Res* 1998;353:125-133. Medline DOI

19. Raikin SM, Elias I, Dheer S, Besser MP, Morrison WB, Zoga AC: Prediction of midfoot instability in the subtle Lisfranc injury: Comparison of magnetic resonance imaging with intraoperative findings. *J Bone Joint Surg Am* 2009;91(4):892-899. Medline DOI

20. Curtis MJ, Myerson M, Szura B: Tarsometatarsal joint injuries in the athlete. *Am J Sports Med* 1993;21(4):497-502. Medline DOI

21. Shapiro MS, Wascher DC, Finerman GA: Rupture of Lisfranc's ligament in athletes. *Am J Sports Med* 1994;22(5):687-691. Medline DOI

22. Eleftheriou KI, Rosenfeld PF: Lisfranc injury in the athlete: Evidence supporting management from sprain to fracture dislocation. *Foot Ankle Clin* 2013;18(2):219-236. Medline DOI

23. Kuo RS, Tejwani NC, Digiovanni CW, et al: Outcome after open reduction and internal fixation of Lisfranc joint injuries. *J Bone Joint Surg Am* 2000;82(11):1609-1618. Medline

24. Ly TV, Coetzee JC: Treatment of primarily ligamentous Lisfranc joint injuries: Primary arthrodesis compared with open reduction and internal fixation. A prospective, randomized study. *J Bone Joint Surg Am* 2006;88(3):514-520. Medline DOI

25. Rajapakse B, Edwards A, Hong T: A single surgeon's experience of treatment of Lisfranc joint injuries. *Injury* 2006;37(9):914-921. Medline DOI

26. Trevino SG, Kodros S: Controversies in tarsometatarsal injuries. *Orthop Clin North Am* 1995;26(2):229-238. Medline

27. Arntz CT, Veith RG, Hansen ST Jr: Fractures and fracture-dislocations of the tarsometatarsal joint. *J Bone Joint Surg Am* 1988;70(2):173-181. Medline

28. Rammelt S, Schneiders W, Schikore H, Holch M, Heineck J, Zwipp H: Primary open reduction and fixation compared with delayed corrective arthrodesis in the treatment of tarsometatarsal (Lisfranc) fracture dislocation. *J Bone Joint Surg Br* 2008;90(11):1499-1506. Medline DOI

29. Pérez Blanco R, Rodríguez Merchán C, Canosa Sevillano R, Munuera Martínez L: Tarsometatarsal fractures and dislocations. *J Orthop Trauma* 1988;2(3):188-194. Medline DOI

30. Tan YH, Chin TW, Mitra AK, Tan SK: Tarsometatarsal (Lisfranc's) injuries—results of open reduction and internal fixation. *Ann Acad Med Singapore* 1995;24(6):816-819. Medline

31. Lee CA, Birkedal JP, Dickerson EA, Vieta PA Jr, Webb LX, Teasdall RD: Stabilization of Lisfranc joint injuries: A biomechanical study. *Foot Ankle Int* 2004;25(5):365-370. Medline

32. Stavlas P, Roberts CS, Xypnitos FN, Giannoudis PV: The role of reduction and internal fixation of Lisfranc fracture-dislocations: A systematic review of the literature. *Int Orthop* 2010;34(8):1083-1091. Medline DOI

33. Alberta FG, Aronow MS, Barrero M, Diaz-Doran V, Sullivan RJ, Adams DJ: Ligamentous Lisfranc joint injuries: A biomechanical comparison of dorsal plate and transarticular screw fixation. *Foot Ankle Int* 2005;26(6):462-473. Medline

34. DeOrio M, Erickson M, Usuelli FG, Easley M: Lisfranc injuries in sport. *Foot Ankle Clin* 2009;14(2):169-186. Medline DOI

35. Sangeorzan BJ, Hansen ST Jr: Early and late posttraumatic foot reconstruction. *Clin Orthop Relat Res* 1989;243:86-91. Medline

36. Gaines RJ, Wright G, Stewart J: Injury to the tarsometatarsal joint complex during fixation of Lisfranc fracture dislocations: An anatomic study. *J Trauma* 2009;66(4):1125-1128. Medline DOI

37. Cantu RV, Koval KJ: The use of locking plates in fracture care. *J Am Acad Orthop Surg* 2006;14(3):183-190. Medline DOI

38. Ahmed S, Bolt B, McBryde A: Comparison of standard screw fixation versus suture button fixation in Lisfranc ligament injuries. *Foot Ankle Int* 2010;31(10):892-896. Medline DOI

39. Mulier T, Reynders P, Dereymaeker G, Broos P: Severe Lisfrancs injuries: Primary arthrodesis or ORIF? *Foot Ankle Int* 2002;23(10):902-905. Medline DOI

40. Brunet JA, Wiley JJ: The late results of tarsometatarsal joint injuries. *J Bone Joint Surg Br* 1987;69(3):437-440. Medline

41. Deol RS, Roche A, Calder JD: Return to training and playing after acute Lisfranc injury in elite professional soccer and rugby players. *Am J Sports Med* 2016;44(1):166-170. Medline DOI

Video Reference

21.1: Anderson RB: Video. *Lisfranc Injuries in the Elite Athlete*. Charlotte, NC, 2016.