An Original Study

Effect of Simulated Lateral Process Talus "Fracture Excision" on Its Ligamentous Attachments

Phillip Langer, MD, Florian Nickisch, MD, David Spenciner, PE, ScM, and Christopher DiGiovanni, MD

Abstract

Recent epidemiologic studies highlight lateral talar process fractures as *snowboarder's fracture* or *snowboarder's ankle*. Snowboarding is the fastest growing sport worldwide, so lateral talar process fractures are increasing in frequency and mandating a more careful assessment of injury patterns, surrounding tissue involvement, and treatment strategy.

In this study, we evaluated the effects of lateral talar process fracture on the footprints of 3 lateral stabilizing ligaments of the ankle and subtalar joint—the lateral talocalcaneal ligament (LTCL), the anterior talofibular ligament (ATFL), and the posterior talofibular ligament (PTFL).

The musculotendinous structures from 10 fresh cadaveric limbs were removed and the distal fibula reflected to provide visualization of the lateral talar process and ligamentous attachments. Length and width of the LTCL, ATFL, and PTFL footprints on the lateral process of the talus were measured with calipers before and after removal of a 1-cm^3 simulated fracture fragment. Relative changes in the attachment site areas for the 3 ligaments were determined.

Mean pre-excision footprint areas were 80.57 mm^2 (LTCL), 224.38 mm^2 (ATFL), and 394.18 mm^2 (PTFL); mean postexcision footprint areas were 2.10 mm^2 (LTCL), 194.89 mm^2 (ATFL), and 335.18 mm^2 (PTFL); and mean decreases calculated as percentages of the original areas were 97.5% ± 3.5% (LTCL), 11.7% ± 13.0% (ATFL), and 14.3% ± 12.3% (PTFL).

Removal of a 1-cm^3 bony fragment from the lateral talar process involves 3 of the major lateral stabilizing ligaments: approximately 100% of LTCL and approximately 10% to 15% of ATFL and PTFL.

Dr. Langer is Assistant Team Physician and Orthopedic Surgeon of the NFL Atlanta Falcons and the NHL Atlanta Thrashers, Atlanta Sports Medicine & Orthopedic Center, Atlanta, Georgia.
Dr. Nickisch is Assistant Professor of Orthopaedic Surgery, University of Utah Orthopaedic Center, Salt Lake City, Utah.
Mr. Spenciner is Test Facility Manager, CORO Laboratory, Department of Orthopedics, and Dr. DiGiovanni is Associate Professor and Chief, Division of Foot and Ankle, Department of Orthopedics, Brown Medical School/Rhode Island Hospital, Providence, Rhode Island.

Address correspondence to: Christopher DiGiovanni, MD, Division of Foot and Ankle, Department of Orthopedics, Brown Medical School/Rhode Island Hospital, Providence, RI 02903 (tel, 401-277-0790; fax, 401-277-0799; e-mail, yodigi@aol.com).

Am J Orthop. 2009;38(5):222-226.

There has been an increase in attention regarding injury of the lateral process of the talus. This escalation appears to coincide with the apparent association of this injury with snowboarding, the fastest rising winter sport in the United States.[1] Historically, fractures of the lateral process of the talus were considered unusual, with fewer than 65 cases reported in the English-language literature.[2] However, a recent prospective study of more than 3000 snowboarding injuries found that fractures of the lateral process of the talus accounted for 15% of all ankle injuries and 32% of ankle fractures.[3] The incidence of these fractures has triggered epidemiologic studies and led to coinage of 2 terms for lateral talar process fracture[3,4]: *snowboarder's fracture*[5] and *snowboarder's ankle*.[6]

In a recent study,[7] the ligamentous anatomy of the lateral ankle and subtalar joints was described relative to the lateral process of the talus as a means of expanding the understanding of the potential clinical relevance of fractures at this level. Contrary to previous anatomical, clinical, and case reports, these dissections clarified that only the lateral talocalcaneal ligament (LTCL), the anterior talofibular ligament (ATFL), and the posterior talofibular ligament (PTFL) attach to the lateral process of the talus. The lateral root of the extensor retinaculum, cervical ligament, and interosseous ligament, which have been shown to be lateral stabilizers of the subtalar joint,[8,9] were in anatomical proximity to the lateral process of the talus but did not insert on it. Therefore, these structures are not directly affected by lateral talar process fractures.

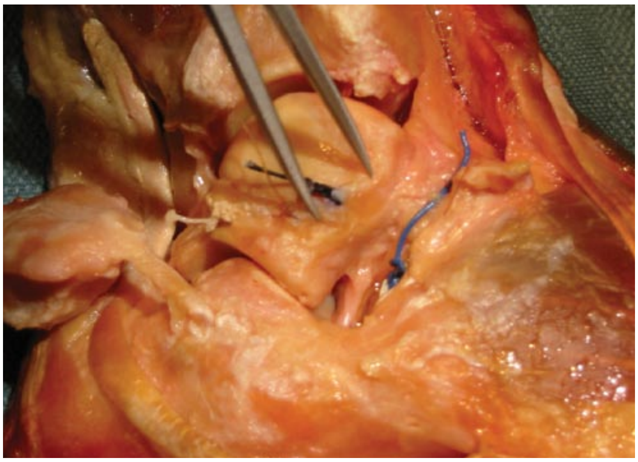

Figure 1. Measurement of length of anterior talofibular ligament insertion.

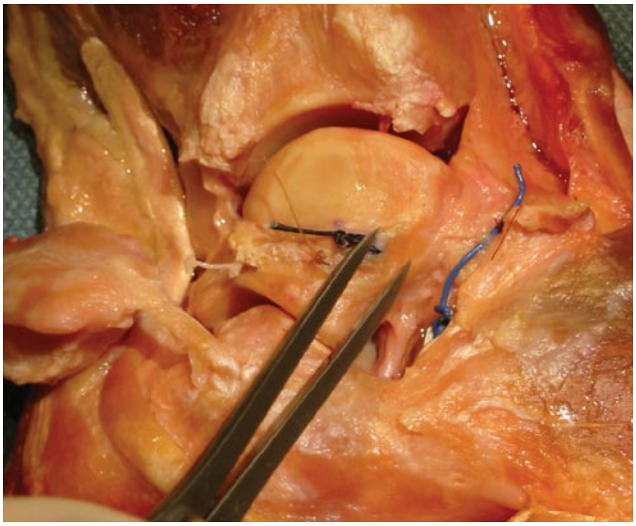

Figure 2. Measurement of width of anterior talofibular ligament insertion.

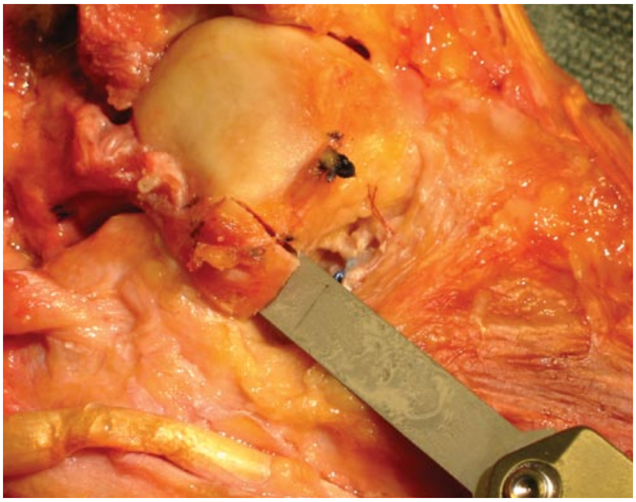

Figure 3. Three cuts made with 1-cm chisel (Synthes, Paoli, PA) relative to apex of lateral talar process and subtalar joint to create standardized fracture fragment.

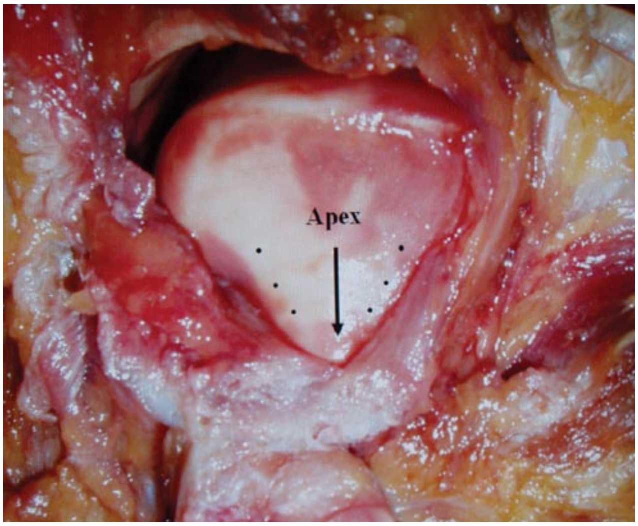

Figure 4. Apex of lateral process of talus.

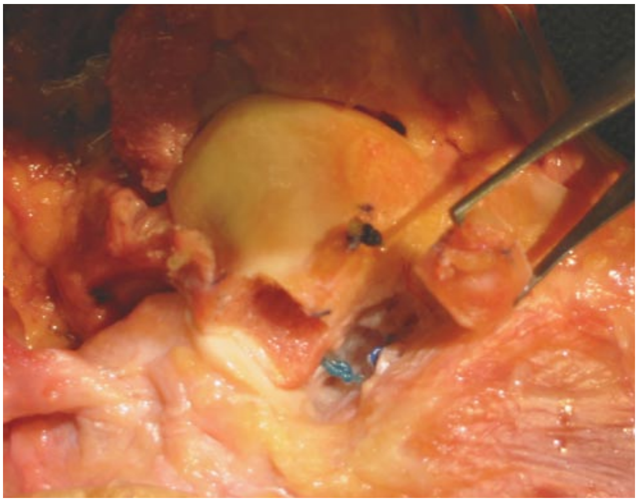

Figure 5. Excision of simulated 1-cm^3 fracture fragment.

Despite the recent interest in fractures of the lateral process of the talus, treatment recommendations have been based on retrospective summaries of small case series.[10,11] One centimeter has been arbitrarily recommended as the fracture size that requires invasive treatment modalities.[12,13] Fractures with single fragments larger than 1 cm or displaced more than 2 mm are treated with open reduction and internal fixation. Fractures smaller than 1 cm are typically excised or treated closed, depending on the level of comminution.[12,14] These recommendations are based on the belief that removal of fragments smaller than 1 cm may result in subtalar joint instability, abnormal subtalar joint mechanics, and persistent symptoms.[14,15] There has yet to be a scientific investigative study to substantiate or refute these beliefs.

In this study, we evaluated the impact of excising a 1-cm^3 fragment (simulated fracture) of the lateral process of the talus on the footprints of the major lateral stabilizing structures of the ankle and subtalar joint, specifically the 3 ligaments that attach to this site: LTCL, ATFL, and PTFL. The results of this study may provide the anatomical foundation for clinical recommendations for this injury. In light of the proven association between this fracture and snowboarding, possible implications of this work could include altered treatment recommendations, which may accelerate a return from injury to competitive or recreational participation in this sport.

Material and Methods

Ten fresh-frozen cadaveric lower limbs from 7 donors (mean age, 74 years; 6 male, 1 female) were used. After thawing, all musculotendinous structures were carefully removed from the field to enable adequate visualization of the lateral talar process and ligamentous attachments. Methodical dissections were performed to identify LTCL, ATFL, PTFL, interosseous ligament, lateral root of the inferior extensor retinaculum, and cervical ligament. ATFL and PTFL were transected off the fibula at their respec-

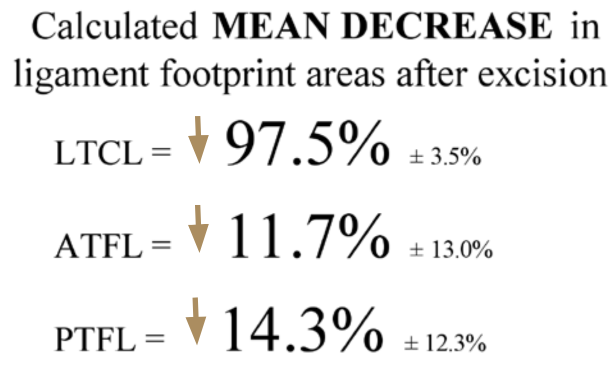

Figure 6. After excision, mean decrease in attachment area of lateral talocalcaneal ligament (LTCL), anterior talofibular ligament (ATFL), and posterior talofibular ligament (PTFL), calculated as percentage of original area.

tive origins. The distal fibula was reflected to enable adequate visualization of the lateral talar process and the ligamentous attachments of LTCL, ATFL, and PTFL. The calcaneofibular ligament was carefully dissected free from the LTCL, and the fibula was reflected from the field to accurately visualize the LTCL.

LTCL, ATFL, and PTFL were transected at a level just proximal to their respective attachment sites on the lateral process of the talus. Consequently, only the footprints of the origin of the LTCL and insertions of the ATFL and PTFL remained on the lateral talar process. Analog calipers (KM 53-042; KMedic Corp, Northvale, NJ) were used to measure length and width of the LTCL, ATFL, and PTFL footprints on the lateral process of the talus (Figures 1, 2). The interobserver variance when using these calipers to measure the attachment areas of LTCL, ATFL, and PTFL was relatively low (<5 mm^2 for LTCL and PTFL, 5-10 mm^2 for ATFL).[11] Length and width measurements of the ligament attachments were used to calculate the respective areas of LTCL, ATFL, and PTFL attachments. When calculating the areas of each attachment, we assumed an elliptical footprint and used the formula for an elliptical area (Area = $\pi \cdot a \cdot b$, where a and b are the major and minor radii of the ellipse). Measurements used to calculate the areas of the LTCL, ATFL, and PTFL attachment sites were taken by both observers in a non-blinded fashion.

With a 1-cm chisel (Synthes, Paoli, PA), 3 cuts were made relative to the apex of the lateral talar process and subtalar joint: 1 cm superior and parallel; 1 cm medial and perpendicular; and 1 cm posterior and perpendicular (Figure 3). The analog calipers were used to gauge the size of each cut. The cuts were made by the same examiner in an effort to standardize the osteotomies. The apex of the lateral talar process was defined using an orthogonal plumb line that bisected the transverse connection between 3 arbitrary points along the lateral talar articular surface margin of its fibular facet[7] (Figure 4). The apex was then identified as the most inferior point on the talus just above the intersection of the plumb line with the talocalcaneal articulation.[7] The resultant fragment was removed from the lateral process of the talus (Figure 5). Width, length, and depth of each removed fragment of bone were measured with a ruler (resolution, 0.5 mm) to verify that each edge of the fragment was 1 cm and that the volume was 1 cm^3. After excision of the “simulated fracture” fragment, the analog calipers were used to measure length and width of the remaining LTCL, ATFL, and PTFL footprints on the lateral process of the talus. These measurements were used to calculate the respective areas of the LTCL, ATFL, and PTFL attachments after removal of the simulated fracture fragment, assuming an elliptical footprint.

After the attachment insertion dimension of LTCL, ATFL, and PTFL on the lateral process of the talus was measured, mean footprint areas before and after excision of the fragment were calculated. Values obtained after excision were then subtracted from those obtained before excision. Mean change in area was reported as a percentage of the original areas. Paired *t* tests were used to determine if the differences before and after excision for each ligament were statistically significant ($P<.05$).

Results

Mean pre-excision widths and lengths were, respectively, 3.6 mm and 7.33 mm (LTCL), 5.3 mm and 13.4 mm (ATFL), and 5.5 mm and 23.0 mm (PTFL). Mean pre-excision footprint areas were 80.57 mm^2 (LTCL), 224.38 mm^2 (ATFL), and 394.18 mm^2 (PTFL). Mean postexcision widths and lengths were, respectively, 0.72 mm and 0.78 mm (LTCL), 5.3 mm and 11.85 mm (ATFL), and 5.15 mm and 20.65 mm (PTFL). Mean postexcision footprint areas were 2.10 mm^2 (LTCL), 194.89 mm^2 (ATFL), and 335.18 mm^2 (PTFL). Mean decreases in attachment areas after excision were 70.63 mm^2 (LTCL, $P<.001$), 29.49 mm^2 (ATFL, $P = .01$), and 59.00 mm^2 (PTFL, $P = .02$) (Figure 6).

Discussion

First introduced in the United States in 1965, snowboarding did not develop as a mainstream winter sport until the 1970s. Statistical projections demonstrate that snowboarders now make up 20% of the visitors to US ski resorts[1] and that snowboarding is the fastest growing sport worldwide.[1] As the popularity of snowboarding continues to escalate, there will likely be a similar increase in the incidence of lateral process fractures. It is therefore important to delineate the implications of treatment modalities to maximize outcome after this injury. One centimeter has been arbitrarily recommended as the fracture size that mandates invasive treatment modalities.[12,13] In this study, we found that, after excision of a 1-cm^3 simulated fracture fragment from the lateral process of the talus, mean decrease in ligament footprint attachment sites, calculated as a percentage of the original areas, was approximately 100% of the LTCL origin and 10% to 15% of the ATFL and PTFL insertions.

Hawkins[16] described a radiographic classification of lateral process of the talus fractures that includes 3 different patterns: type I, a single large fragment involving the talofibular articulation and the subtalar joint; type II, a comminuted fracture involving both articulations; and type III, a nonarticular chip fracture. Treatment modalities differ with each fracture type. Acute, nondisplaced fractures are nearly universally managed with short leg cast immobilization for 6 to 8 weeks.[12,13] Likewise, Hawkins type III fractures may be treated nonoperatively or may be excised to prevent joint irregularity or loose bodies.[12,13] For Hawkins type II, most authors recommend primary excision of the small fragments to avoid the subsequent subtalar arthritic changes that have been found in the series of reported cases to date.[10-13] Yet, the Hawkins type I fractures with fragments larger than 1 cm in diameter or displaced more than 2 mm are usually anatomically reduced and internally fixed because it is believed that removal may result in subtalar joint instability, abnormal subtalar joint mechanics, and persistent symptoms.[14,15] Before this study, there had been no scientific investigation to substantiate or refute this belief.

The results of this study provide an anatomical foundation for future investigative efforts regarding treatment and clinical results for this unique injury. The decrease in ligament insertion areas seen in this study may lead to instability of the ankle or subtalar joints; however, a biomechanical study is necessary for confirmation. The excised fragment in our study is designed to simulate a Hawkins type I fracture—currently anatomically reduced and internally fixed. Yet, despite the intent to simulate a specific type, we believe our results provide a broader insight into the impact of disruption of these specific ligaments through loss of integrity of the lateral talar process, independent of type according to the Hawkins classification. What we have demonstrated is that 3 important ligaments are disrupted by excision of a substantial fragment from the lateral process of the talus. Yet, the integrity of these ligaments could be compromised by removal of lesser fragments and a fracture of the lateral process of the talus that involves the apex. The potential impact of this study is that it provides the first anatomical evidence that type of fracture management chosen (fragment excision vs internal fixation, hence, removing or restoring such ligament integrity) could compromise the lateral stabilizers of the ankle and subtalar joint. In light of the association of this fracture with snowboarding, possible implications could include altered treatment recommendations, such as excision of type I fractures, which may accelerate a return from injury to competitive or recreational participation in this sport by eliminating the need for activity restrictions currently needed to achieve bony union after open reduction and internal fixation. However, before any treatment alterations can be made, the implications regarding optimal treatment of lateral talar process fractures require more clinical trials. Should fractures of the lateral process of the talus continue to represent a substantial percentage of ankle injuries in snowboarders, the pressure to optimize and expedite treatment will likely increase, especially if snowboarding continues to gain in popularity among elite athletes.

Under way are studies assessing the effect of fracture management on the biomechanics and contact stresses of the ankle and subtalar joint.

This study is not without limitations. Three cuts were used relative to a predefined apex and the subtalar joint to remove a 1-cm^3 simulated fracture fragment from the lateral process of the talus. We assumed an "average" fracture size and shape when deciding the depth and direction of each osteotomy. This size was chosen, however, because 1 cm is the fracture size believed to be the threshold for invasive treatment modalities.[12,13] Additional limitations may derive from difficulty in determining a discrete edge for each ligamentous attachment before and after excision of the fracture fragment. However, the measurements used to calculate the areas of the LTCL, ATFL, and PTFL attachment sites were taken by 2 orthopedic surgeons in a non-blinded fashion. An elliptical footprint was assumed before and after excision, despite an obvious alteration to each ligamentous attachment, because it was nearly impossible to determine the exact geometric shape of the LTCL, ATFL, and PTFL footprints that remained. As our objective was to determine anatomical changes after excision of a simulated fracture fragment, an elliptical cross-section was used. Last, the sample size was small, and additional samples may permit a better description of the natural anatomical variations (eg, LTCL deficiency) that may be present. Nonetheless, differences in the mean footprint areas of LTCL, ATFL, and PTFL after excision of the fragment from the lateral talar process were found to be highly significant.

> **"...this study provides the first anatomical evidence that type of fracture management chosen...could compromise the lateral stabilizers of the ankle and subtalar joint."**

Conclusions

As interest surrounding lateral talar process fractures heightens with the continued rapid growth in popularity of snowboarding, careful assessment of injury patterns, surrounding tissue involvement, and treatment strategy is required. It was determined that removal of a 1-cm^3 "fracture fragment" from the lateral talar process compromised 3 of the major lateral stabilizing ligaments (LTCL, ATFL, PTFL). Mean decreases in ligament footprint attachment areas, calculated as a percentage of the original areas, were approximately 100% of the LTCL origin and 10% to 15% of the ATFL and PTFL insertions.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

References

1. Chan GM, Yoshida D. Fracture of the lateral process of the talus associated with snowboarding. *Ann Emerg Med*. 2003;41(6):854-858.
2. Mills HJ, Horne G. Fractures of the lateral process of the talus. *Aust N Z J Surg*. 1987;57(9):643-646.
3. Ganong RB, Heneveld EH, Beranek SR, et al. Snowboarding injuries: a report on 415 patients. *Phys Sportsmed*. 1992;20:114-122.
4. Bladin C, Giddings P, Robinson M. Australian snowboard injury data base study. A four-year prospective study. *Am J Sports Med*. 1993;21(5):701-704.
5. Kirkpatrick DP, Hunter RE, Janes PC, Mastrangelo J, Nicholas RA. The snowboarder's foot and ankle. *Am J Sports Med*. 1998;26(2):271-277.
6. Bladin C, McCrory P. Snowboarding injuries. An overview. *Sports Med*. 1995;19(5):358-364.
7. DiGiovanni CW, Langer PR, Nickisch F, Spenciner D. Proximity of the lateral talar process to the lateral stabilizing ligaments of the ankle and subtalar joint. *Foot Ankle Int*. 2007;28(2):175-180.
8. Kjaersgaard-Andersen P, Wethelund J, Helmig P, Søballe K. The stabilizing effect of the ligamentous structures in the sinus and canalis tarsi on movements in the hindfoot. An experimental study. *Am J Sports Med*. 1988;16(5):512-516.
9. Stephens MM, Sammarco GJ. The stabilizing role of the lateral ligament complex around the ankle and subtalar joints. *Foot Ankle*. 1992;13(3):130-136.
10. McCrory P, Bladin C. Fractures of the lateral process of the talus: a clinical review. "Snowboarder's ankle." *Clin J Sport Med*. 1996;6(2):124-128.
11. Mukherjee SK, Pringle RM, Baxter AD. Fracture of the lateral process of the talus. A report of thirteen cases. *J Bone Joint Surg Br*. 1974;56(2):263-273.
12. DiGiovanni CW, Bernirschke SK, Hansen ST. Foot injuries. In: Browner BD, Jupiter JB, Trafton PG, Levine AM, eds. *Skeletal Trauma*. 3rd ed. Philadelphia, PA: Saunders; 2003:2400-2402.
13. Heckman JD. Fractures of the lateral process of the talus. In Bucholz RW, Heckman JD, eds. *Rockwood & Green's Fractures in Adults*. 4th ed. New York, NY: Lippincott-Raven; 1996:2311-2313.
14. Tucker DJ, Feder JM, Boylan JP. Fractures of the lateral process of the talus: two case reports and a comprehensive literature review. *Foot Ankle Int*. 1998;19(9):641-646.
15. Giannestras NJ, Sammarco GJ. In: Rockwood CA Jr, Green DP, eds. *Fractures in Adults*. Vol 1. Philadelphia, PA: Lippincott; 1975:1746-1749.
16. Hawkins LG. Fracture of the lateral process of the talus. *J Bone Joint Surg Am*. 1965;47:1170-1175.