SUBTALAR JOINT ATHLETIC INJURIES

Thomas O. Clanton, MD, and Lawrence Berson, MD

Considerable attention has been given to the subtalar joint as an area of injury and pathology.[1, 7, 9, 13, 21, 22,27] Subtalar injuries frequently occur in combination with other injuries, especially sprains of the lateral ankle ligaments. Because lateral ankle sprains rank as the most common source of time-loss injury in sports,[7] it follows that subtalar injuries affect a significant portion of the athletic population. In the past the most commonly reported conditions affecting the subtalar joint were dislocation, instability, tarsal coalition, or sinus tarsi syndrome. With the advent of magnetic resonance (MR) imaging and subtalar arthroscopy, more specific diagnoses can be made.[13, 32, 54] Interosseous ligament tears, loose bodies, arthrofibrosis, and early degenerative changes of the subtalar joint are better defined with these studies.[13, 32, 54] Ongoing research is gradually clarifying the enigmatic symptoms attributed to this anatomic region. This article reviews the anatomy, biomechanics, and diagnostic techniques used for the subtalar joint, along with some specific diagnoses.

ANATOMY

The subtalar joint can be divided into anterior and posterior articulations. The sinus tarsi laterally connects with the tarsal canal medially to separate these articulations. The anterior articulation includes portions of the anterior inferior talus, the posterolateral navicular bone, the anterior calcaneus, and the calcaneonavicular *(spring)* and bifurcate ligaments. The posterior articulation is composed of the posterior facets of the talus and calcaneus. These facets are concave and convex, respectively, which increases the stability of this joint. The posterior articulation is stabilized medially by the deltoid ligament and laterally by the calcaneofibular ligament (CFL), the lateral talocalcaneal ligament (LTCL), the

From the Department of Orthopaedic Surgery, University of Texas Medical School at
    Houston (TOC); and the Foundation for Orthopaedic, Athletic, and Reconstructive
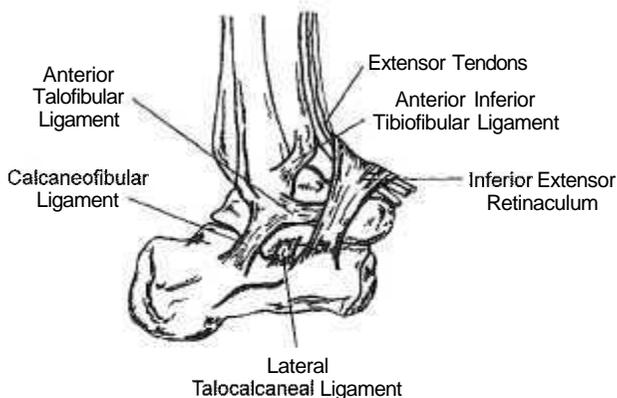   Research, Houston, Texas (LB)

Figure 1. The anatomy of the lateral ankle and hindfoot complex.

cervical ligament (CL), and the interosseous talocaicaneal ligament (ITCL)[5] (Figs. 1 and 2). The inferior extensor retinaculum (IER) extends into the sinus tarsi and contributes additional stability to the subtalar joint (see Fig. 2). Harper clarified the lateral ligamentous anatomy of the subtalar joint through literature review and an anatomic study, and categorized the structures as superficial, intermediate, and deep.[16]

Lateral Ligamentous Support of the Subtalar Joint
1. Superficial layer
    Lateral root of the inferior extensor retinaculum
    Lateral talocaicaneal ligament
    Caicaneofibular ligament
2. Intermediate layer
    Intermediate root of the inferior extensor retinaculum
    Cervical ligament
3. Deep layer
    Medial root of the inferior extensor retinaculum
    Interosseous talocaicaneal ligament

From Harper MC: The lateral ligamentous support of the subtalar joint. Foot Ankle Int 11:354-358, 1991; with permission.

The IER and CL are generally thick, strong, well-defined structures that may be difficult to separate. The LTCL is relatively small and poorly defined. Note that individual variability may contribute to differences in instability patterns from similar injury mechanisms.

BIOMECHANICS

The complicated bony and ligamentous anatomy of the subtalar joint produces an equally complicated kinematic picture. The anatomy has been reviewed thoroughly by Harper and the biomechanics by Sarrafian and Inman.[16, 19, 44] Harper clarifies the role of the CL and ITCL holding the talus and calcaneus together.[16] The CL is often difficult to separate clinically from the surrounding roots of the IER. Biomechanically, the CL functions to allow controlled inversion
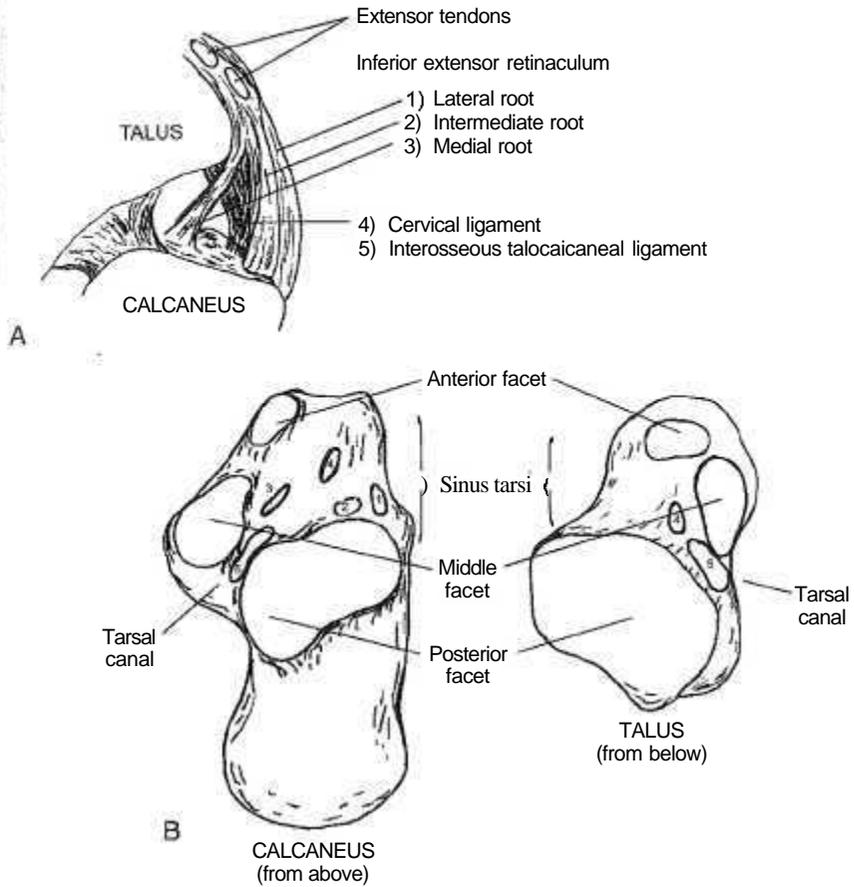
Figure 2. The anatomy of the subtalar joint. *A,* Frontal section through the sinus tarsi-tarsal canal region identifying inferior extensor retinacular roots, cervical ligament, and the interosseous talocaicaneal ligament. *B,* Open-book view of the anatomy of the subtalar joint. The inferior extensor retinacular attachments on the calcaneus and the talar and calcaneal attachments of the cervical and interosseous talocaicaneal ligaments are numbered to correspond to *A.*

and to prevent excessive motion.[53] The central fibers of the ITCL lie along the axis of rotation of the subtalar joint, called the axis of Henke.[19, 53] The fibers pass from the medial side of the neck of the talus through the posterolateral wall of the calcaneus. The rotational movement around this oblique axis is a complicated, triplanar motion, best characterized by Manter.[33] Supination consists of adduction, inversion, and slight plantar flexion, and pronation is composed of abduction, eversion, and slight dorsiflexion. Inman[19] has pointed out that the screw-like movement may also include forward translation during supination and backward translation with pronation. A normal range of motion for the subtalar joint has been defined, but the degree to which variations occur, and

allow laxity, is unclear.[8, 19] Clinically, when laxity becomes symptomatic and pathologic, it is termed instability.[8]

Under experimental conditions, abnormal joint kinematics are observed after sectioning of the caicaneofibular ligament and are observed to increase on sectioning the interosseous ligament.[18, 24, 25, 29] In an anatomic study, Taillard et al progressively inverted the heel and found rupture of the lateral ligaments in the following order: CFL, LTCL, and ITCL.[48] The ITCL was not damaged, unless the LTCL and CF had already ruptured. This study underscores the rarity of an isolated lesion of the ITCL. Kjaersgaard-Andersen et al evaluated the stabilizing effect of the cervical and interosseous ligaments.[25] When these ligaments were cut, motion in the hindfoot increased only slightly (2.6° maximum); however, because of the small total range of motion in the subtalar joint (estimated to be 24°), this increase in motion is significant. Such small motion increases are difficult to detect in a clinical situation but nevertheless may contribute to instability symptoms or the sinus tarsi syndrome.

PHYSICAL EXAMINATION

Clinical symptoms of sinus tarsi syndrome typically include complaints of pain on the lateral side of the foot that increase by palpation over the sinus tarsi. This may be the only sign or symptom present in the individual with sinus tarsi syndrome. Pain here also may occur after lateral ankle sprains, with subtalar arthritis, or with peroneal tendon pathology. Differential injections of the peroneal tendon sheath and the sinus tarsi may help to clarify the diagnosis.

When patients experience inversion instability, it is impossible to distinguish clinically if the instability is coming from the tibiotalar or talocaicaneal portion of the ankle joint complex. Symptoms are especially noteworthy when the patient describes the feeling as occurring when walking on uneven or irregular ground, such as a plowed field or slanted roof. Increased internal rotation of the calcaneus and excessive distal displacement of the calcaneus, in relation to the talus, and compared with the unaffected side, have been described as physical examination findings in subtalar testability.[22] Increased subtalar tilt, as opposed to talar tilt, is another postulated objective finding on examination; however, in practical terms, it is virtually impossible to distinguish instability signs at the subtalar joint from those coming from the ankle joint. For this reason, considerable research attention has been directed toward objective radiographic methods for corroborating the diagnosis.

RADIOGRAPHIC EVALUATION

Rubin and Witten were the first to describe a method of assessing subtalar instability using conventional tomography.[43] The method was not actually used to make the diagnosis of subtalar instability until 1977.[3] Laurin et al developed a special radiographic technique for evaluating subtalar instability.[30] The radiographic tube was tilted 45°, the patient's leg was internally rotated 45°, and forced inversion stress was applied to the ankle. Heilman and Clanton modified the Broden view to a stress radiographic method for evaluating subtalar instability.[9, 18] Heilman and coworkers confirmed the validity of the method experimentally, and Clanton used the method to diagnose a female basketball player with subtalar instability—the first successful clinical use of an office diagnostic test for subtalar instability. Other radiographic methods for making

ymptomatic and

cs are observed
d to increase on
dy, Taillard et al
ligaments in the
aged, unless the
the rarity of an
d the stabilizing
ligaments were
num); however,
(estimated to be
n increases are
y contribute to

e complaints of
over the sinus
dual with sinus
ins, with subta-
ijections of the
e diagnosis.
e to distinguish
tlcaneal portion
rthy when the
ven or irregular
[rotation of the
relation to the
bed as physical
tilt, as opposed
an; however, in
ity signs at the
ason, consider-
raphic methods

essing subtalar
t actually used
t al developed
ty.30 The radio-
tated 45°, and
nton modified
ating subtalar
of the method
nale basketball
e of an office
ds for making

the diagnosis were also described by Clanton.[9] Kato described a dorsoplantar radiograph to demonstrate instability of the subtalar joint.[23] Traction was applied to the foot through a footplate, and radiographs were used to compare the distances displaced by the calcaneus versus the talus. Kato believed this method was exact and reproducible and enabled the differentiation of subtalar instability from sinus tarsi syndrome. Ishii et al conducted a controlled clinical study of a method of radiological assessment specific for subtalar instability.[20] Through a lateral radiographic view of the ankle, with the foot manually positioned in forced dorsiflexion and supination, the influence of associated talocrural instability was avoided. The comparative positions between the stressed and unstressed views of the lateral process of the talus in relation to the posterior articular facet of the calcaneus showed a statistically significant correlation with the clinical entity of subtalar instability. Yamamoto et al used the Telos device to evaluate subtalar instability using a 40° Brodén-like projection.[55] Low interobservation and intraobservation error was shown with this method. Karlsson et al defined subtalar instability as ≥ 2 mm separation of the talocaicaneal surfaces compared with the other ankle.[21] The current authors have had success using the 40° Broden view to evaluate subtalar instability (Fig. 3).

Helical computed tomography (HCT) is another radiographic technique that has recently been used to evaluate subtalar instability.[52] Patients with chronic instability and positive Brodén stress test results were evaluated with HCT. None of the patients demonstrated subtalar tilt on HCT. The authors subsequently concluded that the Brodén stress view may not reliable for evaluating patients with subtalar instability.[52]

Magnetic resonance (MR) imaging is gradually becoming the accepted method for imaging soft-tissue pathology owing to its specificity and sensitivity. Several MR imaging studies have clarified the anatomy of the lateral ankle and subtalar region.[26, 32, 36] Structural alterations in the ITCL are evident with injury to the subtalar joint.[36] The trilayered IER, CL, and ITCL all can be delineated clearly in the uninjured state with new generation MR imaging coils.[26, 32] Furthermore, tears of the CFL, ITCL, and CL can easily be detected.[50] ITCL tears seen on MR images correlated with symptoms of giving way, pain, and limited ankle motion, and CL tears revealed on MR images correlated with symptoms of giving way and pain. Tochigi et al concluded that MR imaging could be used to evaluate acute ankle sprains and determine the extent of injury.[50]

There are instances when the diagnosis is unclear after the initial evaluation of the patient with lateral ankle and hindfoot pain. When routine radiographs are negative and further investigation seems warranted, these authors will often recommend a Technetium bone scan to distinguish between a bone and soft-tissue source for the pain (Fig. 4). Occult bony problems then can be clarified with computed axial tomography (CAT scan), which provides more bony detail than MR imaging.

SUBTALAR ARTHROSCOPY

Another diagnostic alternative to radiology that is gaining popularity is arthroscopy of the subtalar joint. Despite increased interest, the number of reports remains small. The subtalar joint is divided into anterior and posterior portions by the sinus tarsi and tarsal canal, with the posterior joint accessible to arthroscopy. Parisien and Vangsness presented their technique of subtalar joint arthroscopy in 1985.[10] They used two portals, one 2 cm anterior and one 2 cm posterior to the tip of the lateral malleolus. They used a 2.7 mm arthroscope to
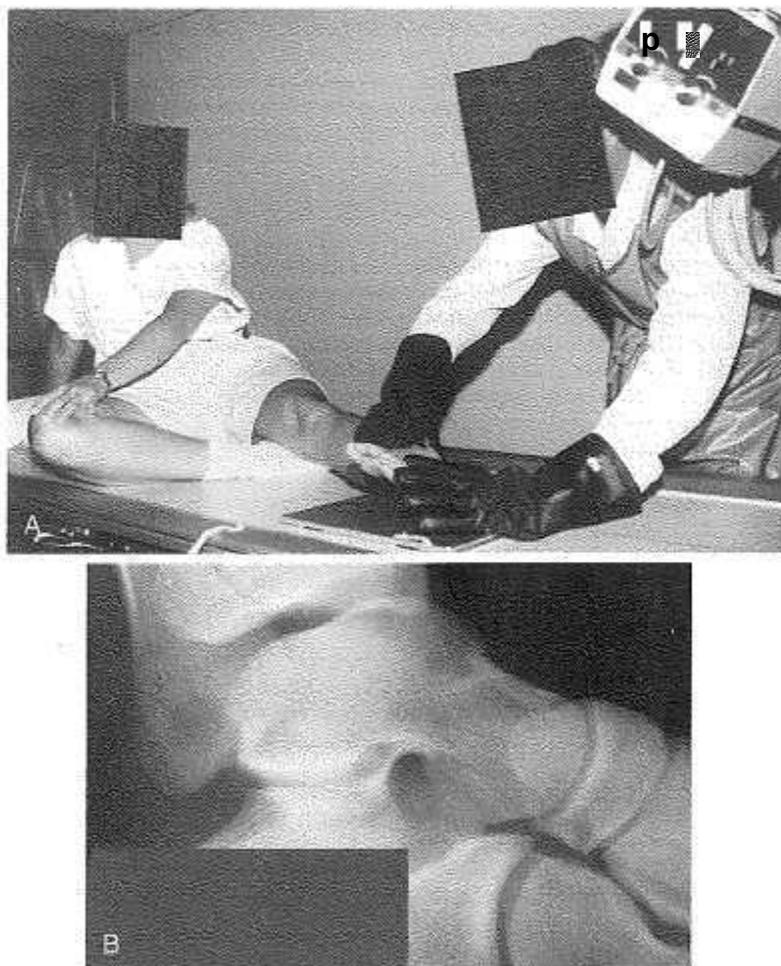
Figure 3. Demonstration of method for performing stress Broden view. *A,* Clinical appearance. *B,* Norma! radiograph showing parallelism of posterior facets. *(Part A from* Clanton TO: Instability of the subtalar joint. Orthop Clin North Am 20:583-592, 1989; with permission.)

visualize most of the posterior facet, interosseous ligament, synovial lining, and posterior recess in their cadaver specimens. The following year Parisien reported three clinical cases of subtalar arthroscopy,[39] adding that the posterior portal should be close to the Achilles' tendon to avoid the sural nerve and short saphenous vein. The procedures performed were lysis of adhesions, lavage, synovial biopsy, and diagnosis of chondromalacia. In 1994, Frey et al evaluated the portals for subtalar arthroscopy and found that the sural nerve and small saphenous vein were at risk when using posterior portal placement." Anterior portal placement created a minor risk to the dorsal intermediate cutaneous branch of the superficial peroneal nerve. The best visualization of the posterior
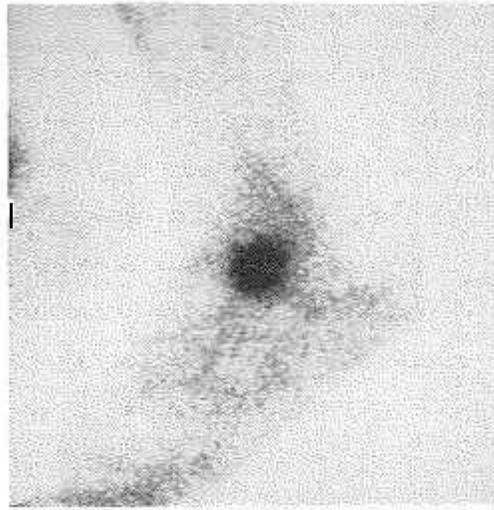
Figure 4. Technetium bone scan showing increased uptake in subtalar joint.

facet was obtained by placing the arthroscope in the posterior portal, whereas the best access to the posterior facet occurred by placing the arthroscope in the anterior portal and the instruments in the posterior portal. The middle portal provided best access to the sinus tarsi. In 1994, Williams and Ferkel reported on 50 cases of subtalar arthroscopy, the largest extinct series.[54] Subtalar arthroscopy was combined with ankle arthroscopy for chronic pain, swelling, buckling, locking, and chronic lateral pain after inversion injury. They diagnosed synovitis, degenerative joint disease, chondromalacia, nonunion of a posterior talar process fracture, arthrofibrosis, loose bodies, and osteochondritis dissecans of the talus. Normal subtalar joints were present in 21 patients who experienced pain after an inversion injury, and it was concluded that chronic ankle pain after an inversion injury generally does not originate from the subtalar joint. In 1999, Frey et al reviewed a series of 49 subtalar arthroscopies.[13] Fourteen of the patients had been diagnosed with sinus tarsi syndrome, and all their diagnoses were changed after arthroscopy. Frey and colleagues recommended subtalar arthroscopy as a diagnostic tool. The postsurgical diagnoses were interosseous ligament tears, arthrofibrosis and degenerative changes, Subtalar arthroscopy was also recommended for evaluating subtalar instability, furthermore suggesting that arthroscopy may be the most accurate way of evaluating instability and even defined it as an excessive medial glide of the calcaneus, out from under the talus. Their suggested indications for subtalar arthroscopy include the following:

1. Removal of loose bodies
2. Evaluation of chondral and osteochondral fractures
3. Excision of intra-articular adhesions
4. Appraisal of articular cartilage damage after hindfoot fractures
5. Chronic pain in the sinus tarsi
6. Subtalar instability
7. Interosseus talocaicaneal ligament (ITCL) injuries
8. Osteoarthritis
9. Arthrodesis of the subtalar joint.

The advantages of subtalar arthroscopy over standard techniques are decreased morbidity and more rapid rehabilitation. According to Frey's results, arthroscopic débridement gave 94% good and excellent results, with only minor complications. Transient neuropraxia of the superficial peroneal nerve was the most common complication.

SINUS TARSI SYNDROME

Sinus tarsi syndrome was first described by O'Connor, in 1958.[37] Since then, numerous cases have been reported.[7] Most patients with this diagnosis have had previous ankle sprains or trauma to the foot. The diagnostic criteria are pain at the lateral ankle, tenderness to palpation of the sinus tarsi, pain relief with anesthetic injection of the sinus tarsi, and negative radiographic studies. Taillard et al recommend arthrography for assisting in this diagnosis.[48] Positive arthrogram findings are blockage of the lateral recess at the sinus tarsi, and loss of the normal microrecesses along the interosseous ligament, occurring from marked synovial hyperplasia. Nonoperative treatment consists of multiple injections of anesthetic and cortisone into the sinus tarsi, combined with physical therapy. Surgical treatment involves excision of the tissue filling the lateral half of the sinus tarsi. In a review of the literature, the results of this procedure have been more than 90% good or excellent.[7]

SUBTALAR INSTABILITY

Subtalar instability has recently received much attention.[7, 9, 13, 16, 21, 22, 49] The incidence remains unknown but has been projected to be as high as 10% of patients with symptoms of chronic lateral ankle instability.[42] The mechanism of injury can be extrapolated from the causative mechanism in medial subtalar dislocation.[4, 28, 51] The mechanism of injury has been described as an inversion force, with progressive injury to the talonavicular ligament and the talonavicular capsule, followed by tears of the CFL and LTCL. Patients complain of *giving way* and recurrent ankle sprains. Stress radiographs may be necessary to make the diagnosis if there has been a spontaneous reduction (Fig. 5).

Treatment of chronic ankle or subtalar instability begins with a good physical therapy program that incorporates strengthening exercises for the invertors and evertors, Achilles' tendon stretching, and proprioceptive reeducation. Most patients respond well to this approach. Nonoperative treatment also is the mainstay for acute injury to the lateral ankle complex. Despite an adequate exercise program, patients with residual instability symptoms will require surgical intervention.

Many surgical methods for correcting ankle and subtalar instability have been described.[29, 45, 49] Chrisman and Snook recognized subtalar instability intraoperatively and modified the Elmsie procedure to address this disorder.[6] Schon et al reviewed various methods of reconstruction for subtalar instability,[45] including the Larsen procedure, a modified Elmslie repair, triligamentous reconstruction, and cervical ligament reconstruction. Most of these techniques are nonanatomic modifications of lateral ankle ligament reconstructions, The CL reconstruction is anatomic and uses half the peroneus brevis through bony runnels. The tunnels are created in the anterior calcaneus, near the origin and insertion of the cervical ligament. No objective results of stability, however, were discussed in Schon's paper, and the present authors' experience has been too

re decreased
sults, arthro-
only minor
erve was the

ʰ Since then,
sis have had
a are pain at
a relief with
dies. Taillard
itive arthro-
d loss of the
rom marked
injections of
cal therapy.
half of the
e have been

, 21, 22, 49 The
as 10% of
chanism of
ial subtalar
n inversion
lonavicular
f giving way
o make the

ood physi-
e invertors
ation. Most
also is the
n adequate
quire surgi-

bility have
bility intra-
der.⁶ Schon
y,⁴⁵ includ-
econstruc-
re nonana-
The CL
ugh bony
origin and
ever, were
been too

Figure 5. Abnormal stress radiographs showing subtalar instability in collegiate basketball player. *A,* AP radiograph showing subtalar tilt rather than talar tilt. *B,* Forty-degree stress Broden view with loss of parallelism of posterior facets. (Part *A from* Clanton TO: Instability of the subtalar joint. Orthop Clin North Am 20:583-592, 1989; with permission.)

limited to advocate this method. Smith and Miller have modified the Chrisman-Snook procedure for a more anatomical reconstruction of the caicaneofibular ligament.⁴⁶ They reported 2.8° of subtalar tilt in operated ankles compared with 7.2° in nonoperated ankles. Thermann et al used the Chrisman-Snook procedure

for the treatment of isolated or combined subtalar instability.[49] Postoperatively, medial displacement of the calcaneus decreased from 9 mm to 2 mm and the talocaicaneal tilt from 11° to 3°. Thermann and coworkers also reported 91% good or excellent results. Karlsson et al[21] anatomically reconstructed the CFL, LTCL, CL, and augmented the repair with a part of the IER. They reported 82% satisfactory results.

Only a small number of reports on subtalar instability deal with reconstructions of the interosseous ligament. Kato described a technique for reconstruction of the ITCL using a portion of the Achilles' tendon placed through tunnels anterior to the talar trochlea medially to the lateroplantar corner, and beneath the sulcus of the calcaneus.[23] Displacement values on stress radiographs decreased from 4.9 mm to 2.3 mm, and 93% of patients were satisfied. Pisani's technique of reconstructing the ITCL using a split peroneus brevis tendon graft through tunnels in the anterior process of the calcaneus to the neck of the talus[41] reportedly produced 91% satisfaction, even though 15% of patients complained of subjective instability. Objectively, patients were stable, and Pisani accounted for this difference by suggesting that it might be caused by a loss of the normal proprioceptive mechanism in the subtalar joint.

The recent popularity of the Brostrom reconstruction technique for lateral ankle instability led these authors to evaluate it for subtalar instability. The Brostrom reconstruction is found to be more than adequate when the CFL ligament is imbricated with the anterior talofibular ligament and the Gould[15] modification (using the IER to reinforce the repair and augment subtalar stability) is added. This seems to be a very direct and effective method of restoring subtalar stability without a large operation that requires multiple drill holes and the sacrifice of a tendon.

SUBTALAR DISLOCATION

Dislocations of the subtalar joint are uncommon injuries that are increasing in prevalence.[1] The cause of injury usually is the result of a violent force, such as a motor vehicle accident, but may occur from a fall or a twisting athletic injury.[51]

Medial subtalar dislocations are more common than lateral subtalar dislocation (Fig. 6). Medial subtalar dislocation occurs with forced inversion, with the sustentaculum tali acting as a fulcrum for the posterior part of the talar body. First the talonavicular joint dislocates, followed by rotatory subluxation of the talocaicaneal joint. If the force continues, dislocation will occur.[4] Lateral subtalar dislocation occurs with forced eversion. The anterior process of the calcaneus acts as the fulcrum for the anterolateral corner of the talus. First, the head of the talus displaces through the talonavicular capsule; then the calcaneus dislocates laterally from the talus, with the head of the talus palpable medially and the calcaneus laterally.[1]

Treatment of subtalar dislocation is closed reduction under anesthesia and the application of a below-knee cast for 3 to 4 weeks; however, occasionally, circumstances will be encountered that require open reduction. The potential structures preventing reduction are the posterior tibial tendon in lateral dislocations and the posterior process of the talus, peroneal tendons, and extensor retinaculum in medial dislocations.[1] When associated with fractures, excision of smaller fragments or open reduction and internal fixation of larger fragments may be required. In simple dislocations the prognosis is only fair because most patients will lose subtalar motion and develop arthrosis. These problems are
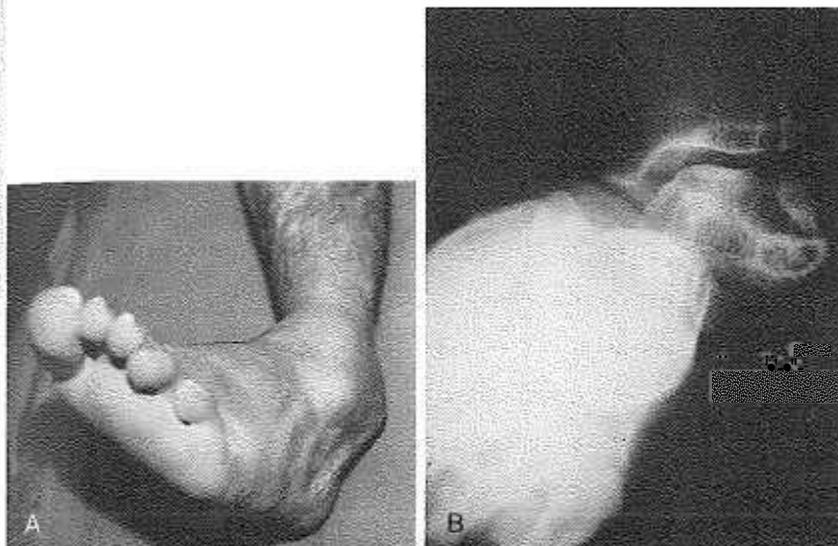
Postoperatively,
2 mm and the
reported 91%
ucted the CFL,
reported 82%

ith reconstruc-
reconstruction
rough tunnels
, and beneath
diographs de-
isfied. Pisani's
tendon graft
of the talus[41]
ts complained
ani accounted
of the normal

ue for lateral
[stability. The
hen the CFL
the Gould[15]
btalar stabil-
of restoring
rill holes and

re increasing
iolent force,
a twisting

alar disloca-
on, with the
talar body.
ation of the
ral subtalar
e calcaneus
head of the
s dislocates
lly and the

sthesia and
ccasionally,
e potential
ral disloca-
extensor
excision of
fragments
ause most
oblems are

Figure 6. A, Clinical appearance and (B) AP radiographic views of medial subtalar dislocation in high school baseball player.

worse when the dislocation is associated with fractures. Other prognostic factors include severity of injury and length of immobilization. Recurrent dislocations or instability are exceedingly rare.[10]

TARSAL COALITION

A tarsal coalition can present with subtalar pain in the adolescent athlete.[34] The onset of coalition symptoms usually occurs between the ages of 11 and 20, when participation in organized athletics increases.[34] The estimated incidence of tarsal coalition is 0.03% to 0.4% to less than 1%, in the general population.[27] Tarsal coalitions have been found in up to 63% of patients who sustain ankle sprains.[47] The incidence of bilateral occurrence ranges from 22% to 80%.[27] The most common coalitions are calcaneonavicular and talocaicaneal. The incidence of calcaneonavicular and talocaicaneal coalitions can be considered equal.[11, 27]

Coalitions usually cause pain with activity. As the child grows older, the motion becomes more limited, and stress on the foot increases. The athletic child with this condition often presents with repeated ankle sprains.[47] Subtalar motion is limited, and the foot is usually painful directly over the coalition.[12-27] A valgus heel, flattening of the arch, and forefoot abduction are typical; however all patients do not have flat feet.

Diagnosis can be obtained using standard radiographs and a CAT scan. Lateral radiograph often will demonstrate dorsal talar beaking or narrowing of the talocaicaneal joint. The Harris-Beath axial view can identify a talocaicaneal synostosis. Calcaneonavicular bars are best visualized on the 45° oblique view of the hindfoot. When suspicion is high, the CAT scan provides the best diagnostic confirmation (Fig. 7), Treatment of symptomatic tarsal coalitions begins with
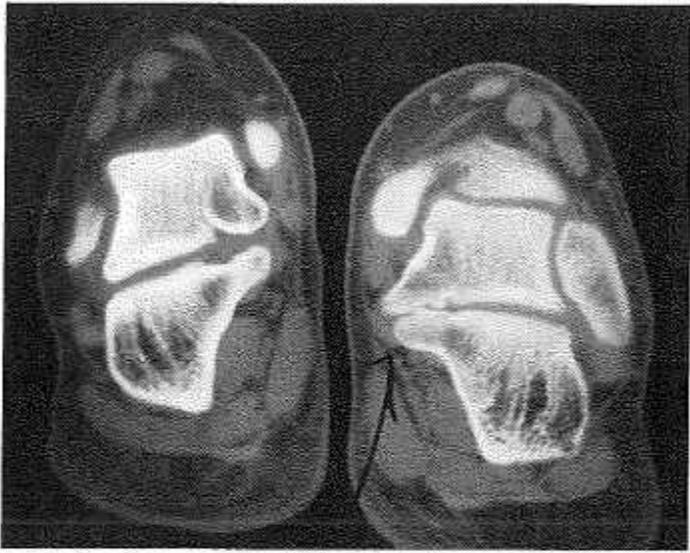
Figure 7. CT scan showing talocaicaneal coalition in 19-year-old tennis player.

immobilization. A large number of people with tarsal coalitions exist in the undiagnosed and minimally symptomatic population. A patient with an acute exacerbation of symptoms may return to the earlier state of peaceful coexistence with their anatomical variation by simply giving the foot a period of rest from stress. When this is not successful, the best alternative is excision of the coalition, when possible.

Elkus reported successful bar resection in 25 patients, including eight cases of talocaicaneal resection.[12] O'Neill and Micheli reported similar success in 16 adolescent athletes (20 feet) treated with resection of the coalition in 18 feet.[38] Morgan and Crawford operated on eight patients with coalitions, and seven returned to competitive athletics, with five patients having excellent results.[34] These authors have had similar results in athletic patients and recommend bar resection for those who fail nonoperative treatment,

STRESS FRACTURES

Stress fractures in the vicinity of the subtalar joint are rare. When they occur, however, diagnosis of stress fractures can be difficult, unless such a possibility is included in the differential diagnosis for lateral ankle and hindfoot pain in the athlete. Pain is clearly the most common presentation, but there also may be swelling, warmth, and restriction in subtalar movement. Routine radiographs are notoriously negative, and a bone scan, a CAT scan, or an MR image are necessary for the definitive diagnosis. Rest or sometimes immobilization provide adequate treatment.

For example, Motto reported a stress fracture of the lateral process of the talus in a competitive tennis player.[35] The patient presented with lateral ankle pain and reduced subtalar motion. Diagnosis was confirmed with a CAT scan.

The fracture healed after prescribing limited activity and bracing. Bradshaw reported on four stress fractures of the talar body in athletes.[2] Diagnosis was confirmed with a CAT scan, showing a fracture line through the posterolateral aspect of the body of the talus and extending into the subtalar joint. The author recommends 6 weeks of nonweight-bearing ambulation as treatment. Although stress fractures rarely cause subtalar pain, it is important to consider this diagnosis in the appropriate setting, when more common causes are ruled out.

CONCLUSIONS

With increased clinical and basic science research focussed on the topic of subtalar injuries, an understanding of specific causes has increased. What was once known as *sinus tarsi syndrome* now is becoming several more specific diagnoses. The use of MR imaging and arthroscopy is making more accurate and specific diagnoses possible. The complex anatomy is more understandable with recent categorization. Biomechanical studies have added to our knowledge base and have determined that the CFL is the most important lateral stabilizer of the subtalar joint. The other supporting ligaments play a secondary role, with varying contribution to stability, depending on mechanism and type of injury. The Broden 40° stress view appears to be a useful office method for screening of subtalar instability, but it is certainly not infallible. MR imaging offers another modality to evaluate ligamentous and chondral injuries of the subtalar joint. Bone scans and arthroscopy can add to the diagnostic armamentarium. Treatment options for subtalar injuries have expanded with the use of subtalar arthroscopy and more anatomical reconstructions. With more specific diagnoses and appropriate treatment of these injuries, better outcomes should be obtained.

ACKNOWLEDGMENT

References

1. Bohay DR, Manoli A: Subtalar joint dislocations. Foot Ankle Int 16:803-808, 1995
2. Bradshaw C, Khan K, Brukner P: Stress fracture of the body of the talus in athletes demonstrated with computer tomography. Clin J Sport Med 6:48–51, 1996
3. Brantigan JW, Pedegana LR, Lippert FG: Instability of the subtalar joint: Diagnosis by stress tomography in three cases. J Bone Joint Surg Am 59:321-324, 1977
4. Buckingham WW, Jr: Subtalar dislocation of the foot. J Trauma 13:753-765, 1973
5. Cahill DR: The anatomy and function of the contents of the human tarsal sinus and canal. Anat Rec 153:1–17, 1965
6. Chrisman OD, Snook GA: Reconstruction of lateral ligament tears of the ankle: An experimental study and clinical evaluation of seven patients treated by a new modification of the Elmslie procedure. J Bone joint Surg Am 51:904–912, 1969
7. Clanton TO: Athletic injuries to the soft tissues of the foot and ankle. *In* Coughlin MJ, Mann RA (eds): Surgery of the Foot and Ankle, ed 7. St Louis, Mosby-Yearbook, 1999, pp 1090-1209
8. Clanton TO: Etiology of injury to the foot and ankle. *In* Drez D, Jr, DeLee JC (eds): Orthopaedic Sports Medicine. Philadelphia, WB Saunders, 1992, pp 1642-1704
9. Clanton TO: Instability of the subtalar joint. Orthop Clin N Amer 20:583-592, 1989

10. Dendrinos G, Zi G, Terzopoulos H: Recurrence of subtalar dislocation in a basketball player. Am J Sps Med 22:143–145, 1994

11. Ehrlich MG, Elmer EB: Tarsal coalition. In Jahss MH (ed): Disorders of the Foot and Ankle, ed 2, Philadelphia, WB Saunders, 1991, pp 921–938

12. Elkus RA: Tarsal coalition in the young athlete. Am J Sports Med 14:477–480, 1986

13. Frey C, Feder KS, DiGiovanni C: Arthroscopic evaluation of the subtalar joint: Does sinus tarsi syndrome exist? Foot Ankle Int 20:185–191, 1999

14. Frey C, Gasser S, Feder K: Arthroscopy of the subtalar joint. Foot Ankle Int 15:424–428, 1994

15. Gould N, Seligson D, Gassman J: Early and late repair of lateral ligament of the ankle. Foot Ankle Int 1:84–89, 1980

16. Harper MC: The lateral ligamentous support of the subtalar joint. Foot Ankle Int 11:354–358, 1991

17. Harris R, Beath T: Etiology of peroneal spastic flatfoot. J Bone Joint Surg Br 30:624–634, 1948

18. Heilman A, Braly W, Bishop JO, et al: Anatomic study of subtalar instability. Foot Ankle 10:224–228, 1990

19. Inman VT: Biomechanics of the subtalar joint. In The Joints of the Ankle. Baltimore, Williams & Wilkins, 1976, pp 57–66

20. Ishii T, Miyagawa S, Fukubayashi T, et al: Subtalar stress radiography using forced dorsiflexion and supination. J Bone Joint Surg Br 78:56–60, 1996

21. Karlsson J, Eriksson BI, Renstrom P: Subtalar instability of the foot. A review and results after surgical treatment. Scand J Med Sci Sports 8:191–197, 1998

22. Karlsson J, Eriksson BI, Renstrom P: Subtalar ankle instability. Sports Medicine 24:337–349, 1997

23. Kato T: The diagnosis and treatment of the instability of the subtalar joint. J Bone Joint Surg Br 77:400–406, 1995

24. Kjaersgaard-Andersen P, Wethelund J, Nielsen S, et al: Lateral talocalcaneal instability following section of the calcaneofibular ligament: A kinesiological study. Foot Ankle 7:355–361, 1987

25. Kjaersgaard-Andersen P, Wethelund J, Helmig P, et al: 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 16:512–516, 1988

26. Klein MA, Spreit AM: MR imaging of the tarsal sinus and canal: normal anatomy, pathologic findings, and features of the sinus tarsi syndrome. Radiol 186:233–240, 1993

27. Kulik SA, Clanton TO: Tarsal Coalition. Foot Ankle Int 17:286–296, 1996

28. Lancaster S, Horowitz M, Alonso dislocations: A prognosticating classification. Orthopedics 8:1234–1240, 1985

29. Larsen E: Tendon transfer for lateral ankle subtalar joint instability. Acta Orthop Scand 59:168–172, 1988

30. Laurin CA, Ouellet R, St-Jacques R: Talar and subtalar tilt: An experimental investigation. Can J Surg 11:270–279, 1968

31. Louwerens JWK, Ginai AZ, Van Linge B, al: Stress radiography of the talocrural and subtalar joints. Foot Ankle Int 16:148–, 1995

32. Mabit C, Boncoeur-Martel MP, Chaudruc JM, et al: Anatomic and MRI study of the subtalar ligamentous support. Surg Radiol Anat 19:111–117, 1997

33. Manter J: Movements of the subtalar and transverse tarsal joints. Anat Rec 80:397–410, 1941

34. Morgan RC, Crawford AH: Surgical management of tarsal coalition in adolescent athletes. Foot Ankle 7:183–193, 1986

35. Motto SG: Stress fracture of the lateral process of the talus—a case report. Br J Sports Med 27:275–276, 1993

36. Neri M, Grandi A, Querin F, et al: Diagnostica per immagini della sottoo-astragalica: tomografia computerizzata e risonanza magnetica Chirurgia del Piede 15 319–325, 1991

37. O'Connor D: Sinus tar syndrome: A clinical entity. J Bone Joint Surg Am 40:720–729, 1958

38. O'Neill DB, Micheli L: Tarsal coalition: A followup of adolescent athletes. Am J Sports Med 17:544–549, 1989

39. Parisien JS: Arthroscopy of the posterior subtalar joint: A preliminary report. Foot Ankle 6:219-224, 1986
40. Parisien JS, Vangsness T: Arthroscopy of the subtalar joint: An experimental approach. Arthroscopy 1:53-57, 1985
41. Pisani G: Chronic laxity of the subtalar joint. Orthopedics 19:431-437, 1996
42. Renstrom AFH: Persistently painful sprained ankle. Journal of the American Academy of Orthopedic Surgeons 2:270-280, 1994
43. Rubin G, Witten M: The subtalar joint and the symptom of turning over on the ankle: A new method of evaluation utilizing tomography. Am J Orthop 4:16-19, 1962
44. Sarrafian SK: Biomechanics of the subtalar joint complex. Clin Orthop 290:17-26, 1993
45. Schon LC, Clanton TO, Baxter D: Reconstruction for subtalar instability: A review. Foot Ankle 11:319-325, 1991
46. Smith PA, Miller SJ, Berni AJ, et al: A modified Chrisman-Snook procedure for reconstruction of the lateral ligaments of the ankle: Review of 18 cases. Foot Ankle Int 16:259-266, 1995
47. Snyder RB, Lipscomb AB, Johnston RK: The relationship of tarsal coalitions to ankle sprains in athletes. Am J Sports Med 9:313-317, 1981
48. Taillard W, Meyer JM, Garcia J, et al: The sinus tarsi syndrome. Int Orthop 5:117-130, 1981
49. Thermann H, Zwipp H, Tscherne H: Treatment algorithm of chronic ankle and subtalar instability. Foot Ankle Int 18:163-169, 1997
50. Tochigi Y, Yoshinaga K, Wada Y, et al: Acute inversion injury of the ankle: Magnetic resonance imaging and clinical outcomes. Foot Ankle Int 19:730-734, 1998
51. Tucker DJ, Burian G, Boylan JP: Lateral subtalar dislocation: Review of the literature and case presentation. J Foot Ankle Surg 37:239-247, 1998
52. Van Hellemondt FJ, Louwerens JW, Sijbrandij ES, et al: Stress radiography and stress examination of the talocrural and subtalar joint on helical computed tomography. Foot Ankle Int 18:482-488, 1997
53. Viladot A, Lorenzo JC, Salazar J, et al: The subtalar joint: Embryology and morphology. Foot Ankle 5:54-66, 1984
54. Williams MM, Ferkel RD: Subtalar arthroscopy: Indications, technique, and results. Arthroscopy 14:373-384, 1998
55. Yamamoto H, Yagishita K, Ogiuchi T, et al: Subtalar instability following lateral ligament injuries of the ankle. Injury 29:265-268, 1998

Address reprint requests to

Thomas O. Clanton, MD
Department of Orthopaedic Surgery
University of Texas Medical School at Houston
6431 Fannin, Room 6156
Houston, TX 77030