Considerable attention has been given to the subtalar joint as an area of injury and pathology. 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, 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. Interosseous ligament tears, loose bodies, arthrofibrosis, and early degenerative changes of the subtalar joint are better defined with these studies. 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
cervical ligament (CL), and the interosseous talocalcaneal 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.\(^6\)

**Lateral Ligamentous Support of the Subtalar Joint**

1. **Superficial layer**
   - Lateral root of the inferior extensor retinaculum
   - Lateral talocalcaneal ligament
   - Calcaneofibular ligament

2. **Intermediate layer**
   - Intermediate root of the inferior extensor retinaculum
   - Cervical ligament

3. **Deep layer**
   - Medial root of the inferior extensor retinaculum
   - Interosseous talocalcaneal ligament


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.\(^6\)\(^9\)\(^4\) Harper clarifies the role of the CL and ITCL holding the talus and calcaneus together.\(^6\) The CL is often difficult to separate clinically from the surrounding roots of the IER. Biomechanically, the CL functions to allow controlled inversion...
Inferior extensor retinaculum

1) Lateral root
2) Intermediate root
3) Medial root
4) Cervical ligament
5) Interosseous talocalcaneal ligament

Calcaneus

TCL

(Figs. 1-2). Harper and literature note that may be reviewed from the joint.

and to prevent excessive motion. The central fibers of the ITCL lie along the axis of rotation of the subtalar joint, called the axis of Henke. 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. Supination consists of adduction, inversion, and slight plantar flexion, and pronation is composed of abduction, eversion, and slight dorsiflexion. Inman 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. Clinically, when laxity becomes symptomatic and pathologic, it is termed instability.

Under experimental conditions, abnormal joint kinematics are observed after sectioning of the caicaneofibular ligament and are observed to increase on sectioning the interosseous ligament. 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. 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. 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 talocalcaneal 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. 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. The method was not actually used to make the diagnosis of subtalar instability until 1977. Laurin et al developed a special radiographic technique for evaluating subtalar instability. 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. 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
SUBTALAR JOINT ATHLETIC INJURIES

Symptomatic and asymptomatic" injuries are observed and are believed to increase on aging. Taillard et al. reported ligaments in the aged, unless the rarity of an injury and the stabilizing ligaments were determined (estimated to be >45° rotation of the talus); however, symptom increases are believed to contribute to the diagnosis.

The complaints of instability over the sinus tarsi region are dual with sinus tarsi syndrome, with subta- lar instabilities. The method of Broden view was used to differentiate subtalar instability from sinus tarsi syndrome. Ishii et al. conducted a controlled clinical study of the method of radiological assessment specific for subtalar instability. Yamamoto et al. used the Telos device to evaluate subtalar instability using a 40° Broden-like projection. Low interobservation and intraobservation error was shown with this method. Karlsson et al. defined subtalar instability as >2 mm separation of the talocalcaneal surfaces compared with the other ankle. 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. Patients with chronic instability and positive Broden stress test results were evaluated with HCT. None of the patients demonstrated subtalar tilt on HCT. The authors subsequently concluded that the Broden stress view may not reliable for evaluating patients with subtalar instability.

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; structural alterations in the ITCL are evident with injury to the subtalar joint. The trilayered IER, CL, and ITCL all can be delineated clearly in the uninjured state with new generation MR imaging coils. Further-more, tears of the CFL, ITCL, and CL can easily be detected. 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.

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. 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...
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, 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.

Subtalar joint athletic injuries were discussed in the text. It was mentioned that subtalar arthroscopy was used 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. 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. Since then, numerous cases have been reported. 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. 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.

SUBTALAR INSTABILITY

Subtalar instability has recently received much attention. The incidence remains unknown but has been projected to be as high as 10% of patients with symptoms of chronic lateral ankle instability. The mechanism of injury can be extrapolated from the causative mechanism in medial subtalar dislocation. 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. Chrisman and Snook recognized subtalar instability intraoperatively and modified the Elmslie procedure to address this disorder. Schon et al reviewed various methods of reconstruction for subtalar instability, 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
Since then, arthroscopic procedures have had limited success, with pain at the joint being a frequent complaint. Taillard et al. reported a 65% failure rate. Arthroscopic debridement and loose bodies removal from the joint resulted in limited or no clinical improvement. Infrapatellar and peroneal tendinitis are common sources of pain, and treatment with anti-inflammatory medication and physiotherapy is indicated.


In 1928, Smith and Miller reported good functional results with the Chrisman-Snook procedure for treating instability of the subtalar joint. The procedure involved a capsular and ligamentous repair, and the authors reported excellent results in the treated group. However, the procedure was later modified by Smith and Miller to improve the anatomical reconstruction of the calcaneofibular ligament.

The Chrisman-Snook procedure has been used successfully to treat chronic subtalar instability. Thermann et al. reported good results with this procedure in their study. They found that the procedure resulted in a decrease in pain and an increase in functional ability in most patients. However, the procedure requires a significant amount of time and skill, and its success is dependent on the patient's adherence to postoperative rehab.

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 calcaneofibular ligament. 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. Postoperatively, medial displacement of the calcaneus decreased from 9 mm to 2 mm and the talocalcaneal tilt from 11° to 3°. Thermann and coworkers also reported 91% good or excellent results. Karlsson et al. 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. 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 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 Broström reconstruction is found to be more than adequate when the CFL ligament is imbricated with the anterior talofibular ligament and the Gould 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. 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.

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 talocalcaneal joint. If the force continues, dislocation will occur. 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.

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 anterior process of the talus, peroneal tendons, and extensor retinaculum in medial dislocations. 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, Pisani reported 91% of feet resorbed the CFL, while Gould reported 82%.

With reconstruction alone, reoperation through tunnels beneath the CFL, and beneath the talus, radiographs demonstrated satisfactory. Pisani's techniques tended to tendon graft passage and access to the CFL of the talus. Patients complained of the normal of the normal outcome for lateral stability. The Gould technique for lateral stability. The a twisting

TARSAL DISLOCATION

Tarsal dislocation, with the talus displaced, the tendon, the talar body, and the calcaneus, occurs at the talocalcaneal head of the talus and the subtalar joints. The ankle sprains occur in the general population. The estimated incidence of tarsal coalition in the general population is 0.03% to 0.4%. The incidence of bilateral occurrence ranges from 22% to 80%. The most common coalitions are calcaneonavicular and talocalcaneal. The incidence of calcaneonavicular and talocalcaneal coalitions can be considered equal.

Coalitions usually cause pain with activity. As the child grows older, subtalar motion becomes more limited, and stress on the foot increases. The athletic child with this condition often presents with repeated ankle sprains. Subtalar motion is limited, and the foot is usually painful directly over the coalition. 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 demonstrate dorsal talar beaking or narrowing of the talocalcaneal joint. The Harris-Beath axial view can identify a talocalcaneal synostosis. Calcaneonavicular bars are best visualized on the 45° oblique view of the hindfoot. When suspicion high, the CAT scan provides the best diagnostic confirmation (Fig. 7). Treatment of symptomatic tarsal coalitions begins with immobilization. Recurrent dislocations or instability are exceedingly rare.
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 talo-caicaneal resection. O'Neill and Micheli reported similar success in 16 adolescent athletes (20 feet) treated with resection of the coalition in 18 feet. Morgan and Crawford operated on eight patients with coalitions, and seven returned to competitive athletics, with five patients having excellent results. 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. 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. 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.

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