0198-0211/96/1705-0286$03.00/0
FOOT & ANKLE INTERNATIONAL


# Foot Fellow's Review

## Tarsal Coalition

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**ABSTRACT**

**Tarsal coalition is a bridging between the tarsal bones of the foot. The bridge may be composed of bone, cartilage, fibrous tissue, or a combination of these. When symptomatic, patients usually present with hindfoot pain and frequent sprains as children, adolescents, or young adults. The classical appearance is a rigid flatfoot with heel valgus and abduction of the forefoot. Flexible cavus feet have been reported. The incidence in the general population is less than 1%, and the most common types are talocalcaneal and calcaneonavicular coalitions. The cause is attributed to failure of segmentation and differentiation of the primitive mesenchyme. Calcaneonavicular coalitions can be diagnosed with an oblique radiograph of the hindfoot. Most talocalcaneal coalitions require computerized tomography for diagnostic confirmation. Magnetic resonance imaging may be useful for cartilaginous and fibrous coalitions. Casting is the usual initial treatment for the symptomatic individual. With treatment failure, in the absence of degenerative changes, resection of the coalition can be performed with good results. Isolated subtalar fusion may be performed for failed talocalcaneal resections. Failed subtalar fusions and failed calcaneonavicular resection may be treated with triple arthrodesis.**

### INTRODUCTION

Tarsal coalition is a common problem in pediatric, adolescent, and adult foot and ankle patients. It is an important diagnosis to consider when frequent sprains, hindfoot and midfoot pain, and flatfoot deformities are encountered. New imaging modalities have increased our diagnosis of this condition. In recent years, treatment has progressed from nonsurgical treatment to a more aggressive surgical treatment. The goal of treatment is painless functional hindfoot motion without deformity. In this Review, current ideas concerning tarsal coalition are examined and our conclusions and preferred treatment are presented.

### DEFINITION OF TARSAL COALITION

Tarsal coalition is a congenital bridging of two or more tarsal bones of the foot. It is the most common cause of peroneal spastic flatfoot, which is a complex of pain, rigid valgus deformity of the hindfoot and forefoot, and peroneal muscle spasm.[37] A foot with tarsal coalition may not have valgus deformity or peroneal spasm but may be in a neutral[20-22,26,48,57] or varus position.[1,18,48,50] The terms rigid flatfoot,[27] rigid flatfoot followed by the etiology,[22] and rigid valgus foot followed by the etiology[23] have been used. Because of the varieties of foot position in this condition, tarsal coalition is the most useful term.

Although tarsal coalition is the most common cause of peroneal spastic flatfoot, or rigid flatfoot, there are many other causes. Any abnormality of the subtalar joint that decreases motion may cause a peroneal spastic flatfoot.[11,42] These include posterior or middle facet fracture of the calcaneus and talus, inflammatory arthritis, and calcaneal tumor.[11] The abnormalities may also present with subtalar pain, decreased subtalar motion, or peroneal spasm. Mosier and Asher[37] have compiled an extensive differential diagnosis list for peroneal spastic flatfoot.

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## TYPES AND LOCATIONS OF COALITIONS

Calcaneonavicular and talocalcaneal coalitions are the focus of this article. Harris[20,21] reported that the coalition may be composed of bone (synostosis) and be complete or incomplete. The complete coalition is completely ossified; incomplete coalition is incompletely ossified with bridging of cartilage (synchondrosis), fibrous tissue (syndesmosis), or a combination of these.[20,21] We prefer to use the terms ossified, nonossified, and partially ossified. An ossified coalition is composed completely of bone. A nonossified coalition is composed of fibrous and/or cartilaginous tissue. A partially ossified coalition refers to a mixture of bone with fibrous and/or cartilaginous tissue. It is helpful to estimate the percentage of facet involvement.

Coalitions may develop between any two adjacent tarsal bones. Talocalcaneal and calcaneonavicular coalitions—the most common—are about equal in incidence.[15] Talonavicular and calcaneocuboid coalitions are much less common.[55] Talocalcaneal coalitions can develop between either the middle, posterior, or anterior facets, or a combination of these. Coalition between the middle facets is the most common; coalition between the posterior facets is the next most common.[3,27,36,48,57,58]

## ETIOLOGY AND HEREDITY

Pfitzner suggested that accessory ossicles were incorporated into the adjacent normal tarsal bones. In his extensive anatomical dissections, he observed sesamoid bones and accessory ossicles at areas where coalitions had occurred.[37,44] Other authors have supported his theory. Leboucq, Solger, and, later, Jack believed the cause of tarsal coalition was failure of segmentation of primitive mesenchyme.[15,54] Supporting their theory of etiology of tarsal coalition, Harris, in 1955, demonstrated this failure of segmentation and differentiation in embryos.[19,21] This is currently the most widely accepted theory of the etiology of tarsal coalition.

Hereditary transmission of tarsal coalition was studied most comprehensively by Leonard[31] in 1974. He evaluated the first-degree relatives (parents and siblings) of 31 patients with tarsal coalition. Of these, 98 first-degree relatives (39%) had tarsal coalitions demonstrated by radiographs. He concluded that tarsal coalition is a unifactorial disorder of autosomal dominant inheritance, with nearly full penetrance. In reviewing Leonard's study, Ehrlich and Elmer[15] found no genetic difference between the various coalition types.

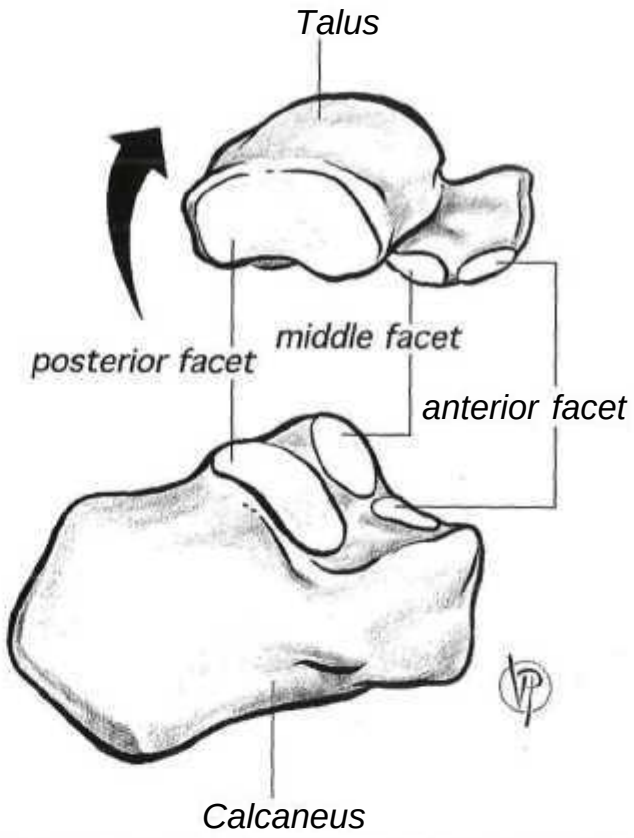


**Fig.** 1. Illustration of the lateral talus and calcaneus demonstrates the anterior, middle, and posterior articular facet joints. The talus is slightly rotated to better demonstrate the middle and anterior facets.

## ANATOMY

The talocalcaneal joint is composed of the posterior, middle, and anterior articular facets (Figs. 1 and 2). The middle and anterior facets may be separate, partially fused, or completely fused.[3,10]

On a lateral x-ray, the middle and posterior facets are normally visible, while the anterior facet is obscured due to its obliquity and inclination (Fig. 3). If a lateral x-ray is slightly rotated with too high a centering point, the middle facet will be superimposed on the calcaneus, and thus not visible.[3] This may appear as a false coalition. The anterior facet may be better visualized on a lateral oblique x-ray[3,25] or with lateral plane tomography, as described by Conway and Cowell.[9]

The anterior process of the calcaneus is aligned obliquely with the navicular. Though they are juxtaposed, the calcaneus and navicular share no true joint.

## INCIDENCE

Numerous studies have estimated the incidence of tarsal coalition in the general population. Notably, the incidence of peroneal spastic flatfoot is not the same as the incidence of tarsal coalition. Tarsal coalition can

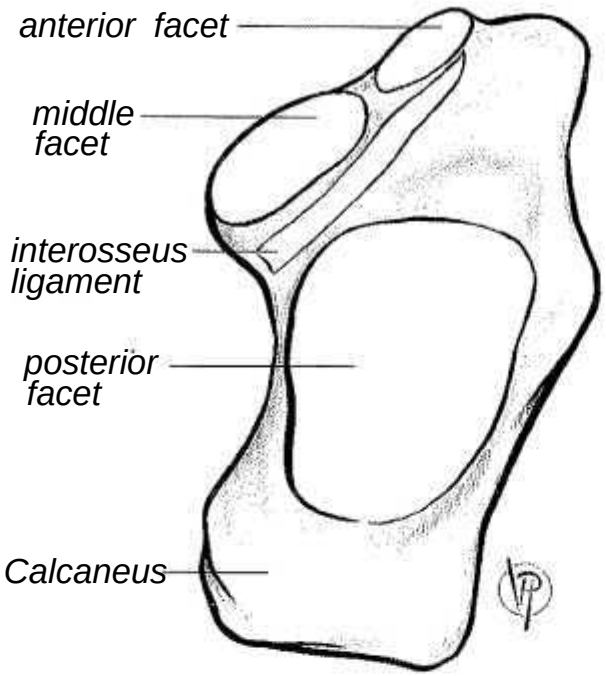


Fig. 2. Illustration of the calcaneus from above with the talus removed demonstrates the anterior, middle, and posterior articular facets.

be symptomatic or asymptomatic. The incidence of tarsal coalition has been found to be between 0.03 and 0.4%[22,44,45]; other authors have confirmed incidences of less than 1 %.[15,55,63]

Fig. 3. Normal lateral radiograph shows the posterior articular facet joint (arrows) and the middle articular facet joint (arrowheads), which are usually parallel and angled 45° to the long axis of the calcaneus. The anterior articular facet joint is more horizontal and cannot be seen because of its medial obliquity and superimposition on the anterior process of the calcaneus.

The number of asymptomatic coalitions has never been studied extensively in a large population. In Jack's[26] group, 26% were asymptomatic. All of Leonard's[31] first-degree relatives (76% of his total group) were asymptomatic. Jayakumar and Cowell,[27] from their experience reviewing families with inherited talocalcaneal coalitions, noted that many adults have asymptomatic talocalcaneal coalitions. Previously asymptomatic talocalcaneal coalitions may become symptomatic in adults with traumatic injury.[48]

The incidence of bilaterality varies between studies and type of coalition. Leonard[31] reported greater than 80% bilaterality in all of his patient groups. The incidence of bilateral talocalcaneal coalitions is reported to range from 22% to 60%,[11,30,46,55,57,58] and calcaneonavicular coalitions from 40% to 68%.[11,18,45,53,57] Ehrlich and Elmer[15] concluded from their literature review that more than 50% of patients with tarsal coalition are bilateral.

Most studies seem to indicate either equal gender incidence[4,9,31] or male predominance.[18,30,48,55,58]

Fifteen percent of the group studied was black. There does not appear to be a race predilection.[45]

Stormont and Peterson[55] reviewed the literature from 1927 to 1981. They reported incidences of 48.1 % for talocalcaneal, 43.6% for calcaneonavicular, 1.3% for talonavicular, 1.3% for calcaneocuboid, and 5.7% for "other" coalitions.[55] They noted limitations due to selection bias, diagnostic variations, and difficulty with radiographic documentation, and in their own study group reported 53% calcaneonavicular and 37% talocalcaneal coalitions. For practical purposes, the incidences of calcaneonavicular and talocalcaneal coalitions can be considered equal as found by Ehrlich and Elmer.[15]

As noted above, the middle facet in talocalcaneal coalitions is the most commonly involved facet, followed by the posterior facet.[3,27,36,48,57,58] Anterior talocalcaneal facet coalition is much less common. Two of the first reported osseous coalitions were found in combination with calcaneonavicular coalitions.[9,10] Before surgical excision of a calcaneonavicular coalition, the coexistence of other coalitions must be ruled out.[11,13,37] CT scanning can be used to rule out coexisting talocalcaneal coalitions.[18,56]

## PATHOMECHANICS

With a tarsal coalition present, normal external rotation of the calcaneus through the subtalar joint is blocked. Compensatory motion must occur in the ankle joint or distal to the subtalar joint, causing progressive laxity. The calcaneus is forced into valgus. The forefoot is abducted, the arch flattens, and the navic-

ular overrides the talus to cause talar beaking. Because the subtalar joint cannot invert, peroneal tendon excursion is limited, and eventually the tendon is shortened. If an attempt is made to invert the foot, the peroneal muscles contract, resulting in peroneal spasm. Tarsal coalition is only one cause of peroneal spasm. Any disturbance of the subtalar joint that limits subtalar motion can cause peroneal spasm.[11,27]

As dorsiflexion occurs in the normal foot, the calcaneus glides forward on the talus until it is limited by the capsular ligaments. At maximum dorsiflexion, the calcaneocuboid and talonavicular joints glide upward and the navicular joint moves slightly cephalad to the talar head.[7,42,62] Fluoroscopic studies of patients with subtalar arthrodesis show that, instead of a gliding motion at the midtarsal joint, a hinge motion occurs. With dorsiflexion, the midtarsal joint widens interiorly and narrows superiorly. The navicular joint impinges and overrides the anterior aspect of the head of the talus,[42] thereby causing elevation of the talonavicular ligament and talar neck periosteum. This represents a situation analogous to tarsal coalition.[37,42]

The talar beak indicates increased stress across this joint, but it does not predict degenerative articular changes.[57] Talar beaking is regarded as a talonavicular ligament traction spur and not a degenerative change.[20,22]

## SYMPTOMS

Pain is usually the most common complaint of patients with tarsal coalition. It usually occurs after some particular exertional event, prolonged activity, or trauma.[11,37] The most common presentation among college-age athletes is repeat ankle sprains.[53]

For talonavicular coalitions, ossification occurs when patients are between the ages of 3 and 5 years. For calcaneonavicular coalitions, it occurs between 8 and 12 years, and between 12 and 16 years for talocalcaneal coalitions. At birth and in early childhood, the coalition is fibrous or cartilaginous. Motion occurs between the bones involved in the coalition, and the foot is asymptomatic. As the coalition ossifies, subtalar motion is restricted, and the foot becomes symptomatic, frequently with only minor trauma or activity.[13,26,27] There is a correlation between type of symptom and age at ossification.[26,53,60] However, Scranton[48] has noted that a coalition can become symptomatic at an older age when "awakened" by traumatic events. It has not been shown whether female patients with tarsal coalition are symptomatic earlier than males.

The calcaneonavicular coalition is usually painful directly over the coalition at the anterolateral foot or sinus tarsi.[16] The talocalcaneal coalition may be painful over the talonavicular joint, but usually the pain is present deep in the subtalar joint[13,16] and often it is poorly localized.[37]

The differential diagnosis of rigid flatfoot includes fracture of the calcaneus or talus, inflammatory arthritis, osteomyelitis, and tumors. Each can be diagnosed with characteristics specific for the etiology.

## PHYSICAL EXAMINATION

### Appearance

Tarsal coalition appears as a valgus heel, flattening of the medial longitudinal arch, and abduction of the forefoot on weightbearing that is unchanged with nonweightbearing.

Rigid flatfoot should be distinguished from flexible flatfoot. Flexible flatfoot, usually asymptomatic, indicates loss of the longitudinal arch on weightbearing and reformation of the arch when nonweightbearing. This condition is commonly found in both children and adults.[34]

The amount of heel valgus, arch flattening, forefoot abduction, and subtalar motion varies dramatically in tarsal coalitions.[1,16,40,48,55,58] Talocalcaneal coalitions usually eliminate subtalar motion, and are more likely to produce severe valgus hindfoot. Patients with talocalcaneal coalition with a neutral heel position and no subtalar motion have been reported.[48] Calcaneonavicular coalitions also present most commonly with a valgus hindfoot and loss of subtalar motion, but there may be little loss of subtalar motion and no significant valgus malalignment.[20-22,26,48,57] Other studies have reported patients with calcaneonavicular coalition and a varus heel.[1,18,48,50]

### Tenderness

Calcaneonavicular coalitions may have tenderness over the anterolateral foot directly over the coalition. In talocalcaneal coalition, tenderness is usually localized over the middle facet distal to the medial malleolus.[37]

Middle facet talocalcaneal coalition may cause medial neurovascular bundle impingement and produce pain and numbness. Tenderness and a positive Tinel test may be present directly over the middle fact and the course of the nerves. A bony eminence from talocalcaneal coalition was responsible for 32% of tarsal tunnel syndrome cases in one series.[59] Tarsal tunnel syndrome caused by middle facet coalition irritation is an indication for resection of the coalition.[12,27]

### Peroneal Spasm

Peroneal spasm may or may not be present in patients with tarsal coalition.[16,18,26,48,55,58] It has been

noted that the peroneal tendons are adaptively shortened and do not cause the deformity. Electromyographic studies have shown that there is no spasm, and the foot deformity persists even after selective blocks of the peroneal nerve.[22] It has also been reported that spasm occurs in every case at some point.[21]

### Subtalar Motion

Because it is difficult to accurately demonstrate subtalar motion, the heel-tip test has been used to evaluate restricted tarsal motion.[28] The patient stands while the examiner supinates the foot by raising the medial border of the forefoot. The lateral border of the foot and heel remain flat on the floor. Since supination of the foot causes external rotation of the tibia, this will be visible by external rotation of the patella. This measurement can be quantified. If there is a condition that restricts tarsal motion, the tibia and patella will not rotate. The authors tested nine patients with known talocalcaneal coalition and measured 8.4° of rotation, as compared with 27° in 60 normal control feet.[28]

### Other Findings

Other physical findings may be important in ruling out the diagnosis of tarsal coalition, and considering other diagnoses in the causes of the rigid flatfoot. Previous evidence of skin trauma to the hindfoot may make trauma of the calcaneus or talus, or penetrating trauma, a more likely diagnoses. Deformity, erythema, and effusion of the subtalar joint with involvement of other joints in the foot or ankle, or in the body, may suggest a diagnosis of inflammatory arthritis, such as rheumatoid arthritis or Reiter's syndrome. Osteomyelitis of the talus or calcaneus, with involvement of the subtalar joint, may be a cause of rigid flatfoot, and may present with erythema, fluctuance, or drainage. A palpable mass of the hindfoot would most likely indicate that a neoplasm is the cause of rigid flatfoot.

## DIAGNOSTIC EVALUATIONS

### Plain Radiographs

Radiographic evaluation for tarsal coalition should be performed in a systematic manner, from basic radiographs to more complex imaging studies. A basic foot series should consist of AP, lateral, oblique, and axial hindfoot views (Harris-Beath view).[11]

The AP view is the least useful, but may demonstrate a talonavicular coalition. It can rule out other causes of peroneal spastic flat foot, e.g., tumor.

The lateraf is a useful view, but it must be interpreted carefully with relation to the anatomy of the talocalcaneal facets. When viewed from **a** sagittal plane, the middle and posterior facets are essentially parallel, and form a 45° angle with the long axis of the calcaneus. The anterior facet is more horizontal (Fig. 3). If the hindfoot is slightly rotated, or the x-ray beam is not perpendicular to the hindfoot, the middle facet is not visible due to its superimposition on the main mass of the calcaneus.[3] This may incorrectly appear as a talocalcaneal coalition. Shaffer and Harrison[49] have coined the term "tarsal pseudocoalition" for an apparent bony bridge between the talus and calcaneus when the iateral radiograph is taken slightly rotated. This artifact results from the overlap of the anterior edge of the lateral process of the talus and the posterior margin of the sustentaculum tali of the calcaneus[49] (Fig. 4). Therefore, the lateral view is not reliable for a definitive diagnosis of talocalcaneal coalition. However, it is useful for identifying secondary signs of tarsal coalition,[3,9,20] which include talar beaking, narrowing of the posterior subtalar joint space, rounding of the lateral process of the talus, and failure to visualize the middle subtalar joint (Fig. 5). These secondary signs are indicative of limited subtalar motion and are not specific for tarsal coalition.[3,9,20] Another sign of talocalcaneal coalition is an abnormal appearance of the anterior talocalcaneal joint, as compared with the opposite side, on the lateral oblique view with flattening or concavity of the underside of the talar neck on the side of the coalition.[3] Once these secondary signs are recognized, further studies should be performed to determine the exact cause.[37]

The "anteater nose" may be visualized on the lateral radiograph[36] (Fig. 6). A consistent sign of calcaneonavicular coalition, anteater nose has been reported in 100 out of 125 patients with calcaneonavicular coali-

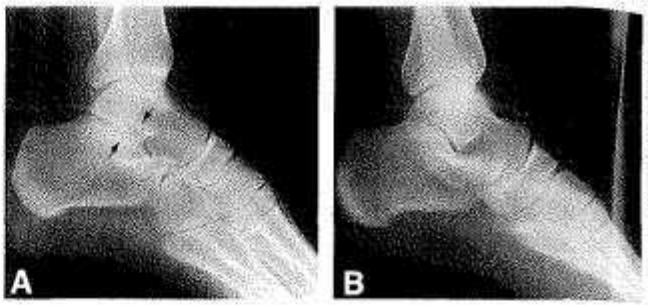


**Fig. 4.** *A,* Laterai radiograph of a normal hindfoot with slight abduction shows "tarsal pseudocoalition." The apparent bony coalition (arrows) is a positional artifact from overlap of the anterior edge of iateral articular surface of the talus with the posterior margin of the sustentaculum tali of the calcaneus. S, True lateral radiograph of the same foot shows disappearance of the artifactual bony coalition.

Fig. 5. Lateral radiograph shows secondary signs of a patient with talocalcaneal coalition. A talar beak is apparent on the dorsum of the talus (white arrow). The lateral process of the talus is broad and rounded (black arrow). The posterior facet articular joint is narrowed (black arrowheads), as is the middle facet articular joint (white arrowheads).

tion.[39] Gonzalez and Kumar[18] noted the anteater nose in all of their 75 calcaneonavicular coalitions.

The uncommon posterior facet coalitions may also be visualized on the lateral radiograph. This is demonstrated by a bony mass in the area of the os trigonum, accompanied by talar beaking.[3]

The oblique view is the best view for detection of the calcaneonavicular coalition.[11,51] A 45° lateral oblique radiograph usually gives the best visualization of the coalition, but because a false coalition can be noted from overlapping structures, oblique views of varying angles may be needed, starting with 45°. Osseous coalitions are easily noted and are about 1 cm in width. Secondary signs that suggest a calcaneonavicular coalition include proximity of the calcaneus to the navicular, irregularity of the cortical surface of the navicular at the site of the coalition, hypoplasia of the talus, and flattening of the calcaneus as it approaches the navicular.[11,27] Twenty-seven out of 31 calcaneonavicular coalitions were found to have a distinct gap between the calcaneus and navicular, and only four were noted to have a solid bridge of bone.[1]

Fig. 6. Lateral radiograph demonstrates an elongation of the anterior process of the calcaneus, or "anteater nose," which is a consistent sign of calcaneonavicular coalition.

If a coalition is suspected and not demonstrated on plain radiographs, axial views of the hindfoot may be taken. This view was first described by Korvin[29] in 1934, and popularized by Harris and Beath[22] in 1948. The radiograph is taken with the patient standing on the cassette, bending forward at the ankle about 10°. The x-ray beam is projected downward and forward through the heel, and through the subtalar joint. Harris and Beath originally described a beam angle of 45°,[22] but later recommended several projection angles at 30°, 35°, and 40°.[21] This radiographic view demonstrates the posterior and middle talocalcaneal facets. Cowell recommended first taking a 45° angled axial view. If the facets are not well visualized at this angle, he advised taking a standing lateral x-ray, and measuring the angle that the facets form with the horizontal axis. This angle is then used to take the axial view. Usually the posterior and middle facets are parallel, but occasionally they occur at different angles. If this is the case, the middle and posterior facet angles should be measured separately, and two separate axial views should be taken at these different angles.[10,27]

In a normal axial view, the middle and posterior talocalcaneal facets are at different levels but parallel to each other. Since the middle facet is the most common site of talocalcaneal coalition, abnormalities are usually seen on the medial side. If the coalition is bony, the joint is obliterated. If the coalition is cartilaginous or fibrous, then the facet is irregular and angled inferior medial. In the case of middle facet coalition, the posterior facet would appear horizontal and the middle facet angled.[11,27] When the angle of these facets is more than 20°, a middle facet coalition is probable, even if the facet appears to be open.[12]

When the anterior talocalcaneal facet is viewed axially, it is downward, medial, and obscured by the head of the talus. Other views and studies are needed to visualize this facet. The lateral oblique view has

been described by Isherwood[25] for evaluation of the anterior talocalcaneal facet. The lateral tomogram has been described to evaluate this facet more clearly, and is discussed below.

### Bone Scan

Radionuclide scanning of the foot using $^{99m}$technetium methylene diphosphonate is a useful noninvasive screening procedure for coalitions that are difficult to diagnose radiographically. The subtalar accumulation probably results from increased stresses on the articular surfaces adjacent to the fusion, and the talar accumulation probably results from increased stresses at the talonavicular joint.[17] The bone scan may be useful as a screening procedure when the plain radiographs are unremarkable.[14]

### Plain Tomograms

Beckly and associates[3] advise caution in evaluating anterior facet coalition with lateral plain tomography, because tomograms that are not perpendicular to the joint may yield false-positive results.

### Computerized Tomography

The computerized tomography (CT) is the gold standard of imaging because of its ability to demonstrate the anatomy better than other modalities, its usefulness in surgical planning, and its ability postoperatively to document resection of the bar. It is the single most reliable test for evaluating talocalcaneal coalitions. Calcaneonavicular coalition is best detected on oblique x-rays without CT.[23]

CT scanning can also evaluate the amount of degenerative arthritis in the joints, determine the extent of the coalition to be excised, and determine whether resection is feasible. Although not routine, the CT scan may be used after surgery to evaluate the adequacy of resection, the amount of subtalar joint remaining, and the reformation of the coalition.[32]

CT may demonstrate various appearances of the tarsal coalition depending on its composition. If the coalition is ossified, it will be represented on CT as cortical bridging and/or marrow continuity. If the coalition is not ossified, and composed of fibrous and/or cartilaginous tissue, it will appear on CT as joint space narrowing, joint irregularity, cortical enlargement of the sustentaculum tali or the adjacent talus, and abnormal angulation of the joint in an inferior medial inclination. A partially ossified coalition may be seen where the area between the two sides of the facet contains ossified material, and represents a mixture of fibrous, cartilaginous, and bony tissue. In cases where the entire facet is not involved in the coalition process, the CT scan can quantify its involvement.[6,23,61]

For a coronal technique, the patient lies supine with the hips and knees flexed and feet plantarflexed 20° at the ankles. The coronal CT view is the best view for the talocalcaneal coalitions.[52]

Long axis or sagittal plane views, with the patient supine and the feet oriented perpendicular to the scanning table, are useful for demonstrating calcaneonavicular coalition.[47]

Computerized tomography with talocalcaneal arthrography is only recommended if plain CT is equivocal.[61]

### Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is particularly useful in the immature skeleton before ossification of the tarsal bones is complete. Bony coalition may show continuity of the marrow space (high signal), or if there is cortical bridging (diffuse low signal). Coalitions composed of cartilage appear as continuity of the bright joint cartilage without a joint space. Fibrous coalition appears as an intermediate to low signal bridging the affected bones. The T1 -weighted sequence of the MRI has been reported to be more useful than CT, and could distinguish between osseous and fibrocartilaginous coalitions.[38] It could also demonstrate changes at the tibiotarsal joint and remainder of the subtalar joint associated with the coalition.[33] MRI may be the more reasonable test to order since both tests are expensive and time consuming, but the MRI may be better for patient evaluation if there is a question of a nonossified coalition. It may be useful in establishing an early diagnosis of a nonossified coalition in a young symptomatic patient.[43]

## TREATMENT

### Calcaneonavicular Coalition

*Nonoperative treatment.* Most authors recommend nonsurgical treatment initially for calcaneonavicular coalition.[10,16,21,22,26,36,37,41,51,56] Manipulation,[2,26,37] peroneal nerve blocks,[56] and short leg orthoses are not recommended. Minor symptoms may be treated with a Thomas heel, medial heel wedge, or arch supports.[37]

If symptoms are severe, most authors recommend short leg walking cast immobilization with the foot in neutral or slight varus.[10,16,26,36,37,41,56] If positioning of the foot and application of the cast are uncomfortable, a general anesthetic may be necessary. The cast is left on for 3 weeks, then replaced for another 3 weeks if

necessary.[37] Decreased activity and anti-inflammatory medication may also help improve the discomfort.[5]

Nonsurgical treatment is seldom indicated.[4,11,36] Resection of calcaneonavicular coalitions is recommended before degenerative changes can occur.[11,16,57] The procedure is simple, inexpensive, and without significant complications.[57]

*Surgical indications and contraindications.* Resection is indicated in a young patient with foot pain and limited subtalar motion. Resection in a foot with a cartilaginous bar is more likely to give a near-normal foot, since no other associated degenerative changes have occurred. Contraindications to resection include age, i.e., older individuals who have established degenerative changes, and associated talocalcaneal coalition.[9,11,13,27] An osseous bar is a relative contraindication to resection. Once degenerative changes occur, there is little hope for obtaining a near-normal foot with resection. The patient should be 14 years or younger to be a candidate for resection.[12]

Some authors[18,36,41,57] believe that frank osteoarthritic changes in other tarsal joints is a contraindication to resection, but do not consider an osseous bar or a talar beak a contraindication. Swiontkowski et al.[57] concluded that a talar beak represents increased stress across the talonavicular joint, rather than early degenerative arthritis. Two patients with talar beaking underwent successful resection of their calcaneonavicular coalition after intraoperative inspection revealed no degenerative changes.[57] Documented talonavicular arthritis is considered a contraindication.[36,41] Excision of the coalition can be performed in older patients as the initial procedure, but persistent pain may require a triple arthrodesis.[18]

*Technique.* The technique for resection of the calcaneonavicular coalition with interposition of the extensor digitorum brevis muscle has been described elsewhere.[11] A recent trend has been toward early motion, and away from interposing the extensor digitorum brevis muscle in the defect created by resection of the coalition.[8] Ehrlich and Elmer[15] have reported taking a larger rectangle of bone and not placing the extensor digitorum brevis muscle in the defect.

*Results.* Numerous studies indicate successful results after resection of calcaneonavicular coalitions except in the presence of frank degenerative changes. Relief of symptoms, improved function, and satisfactory results have been reported.[11,12,16,18,24,27,36,41,50,55,57]

Long-term follow-up of calcaneonavicular coalition resections shows similar results (73-77% satisfactory and 23-27% unsatisfactory).[1,18,24]

The amount of reformation of the coalition varies among studies, which indicate from 23% to 48% partial reformation[11,18,27] and from 0 to 10% complete reformation.[11,41,57] Mitchell and Gibson,[35] using no interpositional material, reported a significant recurrence of the coalitions in one third of their patients, and only a slight recurrence in another third.

If the foot has degenerative arthritis at the associated tarsal joints, or if resection of the coalition fails, there is uniform agreement to treat the foot with a triple arthrodesis. In these circumstances, triple arthrodesis has produced good results.[9-11,13,15,24,26,27,36,37,56,57]

### Talocalcaneal Coalition

*Nonoperative treatment.* There is almost total agreement that the initial treatment for talocalcaneal coalitions should be nonsurgical.[9,13,16,21,26,27,30,36,40,48,58] Many adults are asymptomatic with talocalcaneal coalition, even with complete coalition and degenerative disease of the talonavicular joint.[27] Improvement with nonsurgical treatment varies between 22% and 46%.[27,30,48,58] Other authors have noted no significant benefit from nonsurgical treatment.[9,46]

As with calcaneonavicular coalitions, manipulation with casting, peroneal muscle injections, and peroneal nerve blocks is not recommended, and may be harmful.[2,26,37,56] Minor symptoms can be treated with a medial heel wedge, Thomas heel, or medial arch support.[37] A Plastizote shoe insert is an acceptable approach for mild symptoms. For more severe pain, stiffness, and rigid planovalgus foot, a short leg walking cast in neutral position should be used for 3 weeks, followed by a shoe insert. If the symptoms recur after cast removal, repeat the cast for 3 more weeks. If the symptoms are relieved in the cast, but recur after removal, an ankle-foot orthosis to limit subtalar motion should be used. If two periods of casting fail to limit pain, then surgery is indicated. The symptoms may disappear after the coalition fuses, especially if the heel is in a neutral position.[13] Most authors agree that casting is the preferred technique of nonsurgical therapy for the more severely affected patient.[9-13,16,21,26,27,30,36,40,58] Casting treatment is considered to have failed if there is pain after two cast applications.[37]

*Surgery.* Surgical options are resection of the coalition, arthrodesis, and calcaneal osteotomy.

If two 6-week periods of casting fail, triple arthrodesis is recommended. Resection of the coalition seldom produces satisfactory results because the foot has usually developed secondary degenerative changes.[10] Cowell has reported that resection of the middle facet disturbs the weightbearing mechanics of

the foot and places undue stress on the remainder of the talocalcaneal joint.[11,27] A double arthrodesis, consisting of a subtalar fusion and talonavicular fusion, has been recommended.[20-22,26]

Other authors have recommended talocalcaneal coalition resection if there are no associated degenerative changes.[16,30,36,40,46,48,57,58] In adolescent athletes, coalition resection produced 100% good and excellent results with return of all patients to sports.[16,36] Other authors have reported from 80% to 100% good and excellent results, 0 to 10% fair results, and 0 to 10% poor results.[30,40,48,58]

If significant degenerative changes are present, or if resection fails, then an arthrodesis will give satisfactory results.[16,30,36,40,46,48,57,58] Most authors do not consider talar beaking a degenerative sign, but 50% or greater narrowing of the talonavicular joint is considered significant degenerative disease.[5,48,57] Significant malalignment of the talocalcaneal joint is an indication for arthrodesis.[57] Coalition of greater than 50% of the talocalcaneal joint has been reported to preclude a successful resection.[48]

*Technique.* The technique for excision of a medial talocalcaneal facet has been well described.[5,15,40,48] A headlight and loupe magnification are useful for this procedure. For posterior facet coalition excision, Scranton[48] described a lateral approach either anterior or posterior to the fibula, to avoid disturbance of the fibular collateral ligaments.

Authors vary on whether to interpose material after resection of the medial facet coalition, and what material is best.[30,40,48,58]

Following surgery, a short leg nonweightbearing cast is worn for 3 weeks. Range of motion exercises and partial weightbearing or walking in a short leg cast are then prescribed.[15,40,48] Some surgeons prescribe nonweightbearing for 3 to 6 weeks followed by an orthosis and early active/passive range of motion exercises.[30,46]

## SUMMARY AND PREFERRED TREATMENT

The following conclusions are consistent with the current understanding of tarsal coalition.

1. Tarsal coalition is the most common cause of peroneal spastic flatfoot, or rigid flatfoot. Talocalcaneal and calcaneonavicular coalitions are the most common forms. The etiology is failure of segmentation of primitive mesenchyme. It is classified genetically as a unifactorial disorder of autosomal inheritance with nearly full penetrance.

2. The incidence in the general population is 1 % or less, and it is still unclear how many patients are asymptomatic. Bilaterality is more than 50%, male incidence is equal to if not greater than incidence in the female population, and race predilection has not been proven. The incidence of talocalcaneal and calcaneonavicular coalitions is about equal. The middle facet is the most common site of talocalcaneal coalition.

3. Talar beaking is not a sign of degenerative arthritis, but is more likely a compensatory change with an elevation of the talonavicular ligament and periosteum on the talar head. This is caused by the overriding of the talus on the navicular due to the lack of normal subtalar motion. Narrowing of the talonavicular joint is a more reliable indicator of degenerative arthritis.

4. Pain is the most common complaint. It occurs either over the coalition or deep in the subtalar joint and is related to the age of the patient at the time of ossification of the coalition. Peroneal spasm may or may not be present and symptomatic.

5. The classic presentation of tarsal coalition is a rigid flatfoot with heel valgus, flattening of the arch, and decreased subtalar motion. The foot may present without obvious deformity or present with a varus heel. Varying degrees of subtalar motion may be present.

6. Imaging should proceed in a systematic manner from plain radiographs to more complex imaging studies as needed. CT is the gold standard for imaging tarsal coalition. MRI may become increasingly useful for detecting early coalitions composed of cartilage or fibrous tissue.

8. The initial treatment of calcaneonavicular coalitions should be nonsurgical with 6 weeks of casting. Those who fail this treatment should have resection of the coalition if there are no other degenerative changes in the remainder of the foot. If resection fails, or if their are significant degenerative changes in a symptomatic patient, a triple arthrodesis is appropriate.

9. Treatment of talocalcaneal coalition should begin with 6 weeks of casting. If this fails, and if the patient has no significant degenerative changes, resection is reasonable. If resection fails, and there are no or mild degenerative changes present, a subtalar fusion is indicated. If the associated degenerative changes are severe, or if subtalar arthrodesis fails, a triple arthrodesis is appropriate.

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