Section A -Research paper

Evaluation and Management of Symptomatic Tarsal Coalition

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Abstract:

Tarsal coalition is a common abnormality of the hindfoot skeleton that rarely leads to symptoms. These symptoms occur most commonly in adolescence but also can be found in adults. Although most coalitions are congenital, as a consequence of autosomal dominant inheritance, coalitions also can be acquired by degenerative joint disease, inflammatory arthritis, trauma and infection. Fifty percent of all coalitions are bilateral. Talocalcaneal and calcaneonavicular coalitions are the most commonly found, patients also can have more than one coalition in the same foot. Clinical symptoms of the tarsal coalition frequently follow a sequence of sprains or other minor injuries to the involved foot. This leads to a rigid, painful foot. The pain is worsened by continued activities. The diagnosis of calcaneonavicular coalition is based on the oblique radiograph of the foot, while talocalcaneal coalition is best seen in lateral view, Computed tomography (CT) and magnetic resonance imaging scans show the presence and extent of other coalitions. Secondary signs for the presence of a coalition are talar beaking, anteater nose sign, and C sign. These secondary signs can be demonstrated best on a lateral view of the involved foot. Local anesthetic blocks under image intensifier or CT guidance can identify areas of joint degeneration, which are caused by the altered biomechanics of the foot. Initial treatment should consist of conservative therapy in the form of support or immobilization of the involved foot, change in the activities of the patient, and nonsteroidal anti-inflammatory medication. Surgical treatment in the form of a resection of the coalition should be reserved for those patients for whom conservative therapy has failed. Subtalar or triple arthrodesis should be reserved for those patients for whom all other therapy has failed.

Keywords: Tarsal Coalition, hind foot, Subtalar.

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Introduction:

Tarsal coalition is a disease with failure of segmentation between the tarsal bones. It affects mainly adolescents. Surgical intervention is indicated when deformity and foot pain is resistant to conservative measure. (1)

Tarsal coalition is mostly presented by foot pain, recurrent ankle sprain and rigid pes plano valgus with variable degree. Surgical management is controversial and the optimal management has not yet conclusively determined. (2)

The primary operative option was defined as coalition resection and arthrodesis: This is considered as multiple studies revealed that coalition resection alone had resulted to poorer outcome with increasing hind foot valgus. (3)

Multiple factors have been described as important in predicting outcomes and defining of the optimal operative intervention; age of the patient, size of coalition, pathology of coalition, degree of hind foot valgus, presence of talar breaking, the degree of the forefoot abduction and presence of degenerative changes within adjacent joints.(4)

Biomechanics of Subtalar and Mid Tarsal Joint

Subtalar joint mechanics during gait involve rotation and gliding. The axis of Motion of the subtalar joint is defined as a line deviated 42˚ from the horizontal surface and 16˚ internally rotated from a line extending from the central part of the calcaneus, to a point between the first and second metatarsals. The sinus tarsi is a space on the lateral aspect of the foot that lies anterior to the posterior facet between the talus and the calcaneus. It is in continuity with the tarsal canal (5). The tarsal canal is a cone-shaped opening within the subtalar joint and is situated in a posteromedial-to-anterolateral direction figure 1. Soft tissues within the sinus tarsi include the artery of the tarsal canal, bursae, nerve endings responsible for proprioception, and multiple ligaments (6).

In the stance phase of gait, the subtalar joint rotates from 4˚ valgus to 6˚ of hind foot Varus. When internal rotation is restricted by the coalition, the tarsal joints compensate, flattening the foot and dropping the medial arch, giving the foot its planus appearance in the sagittal plane.(6)

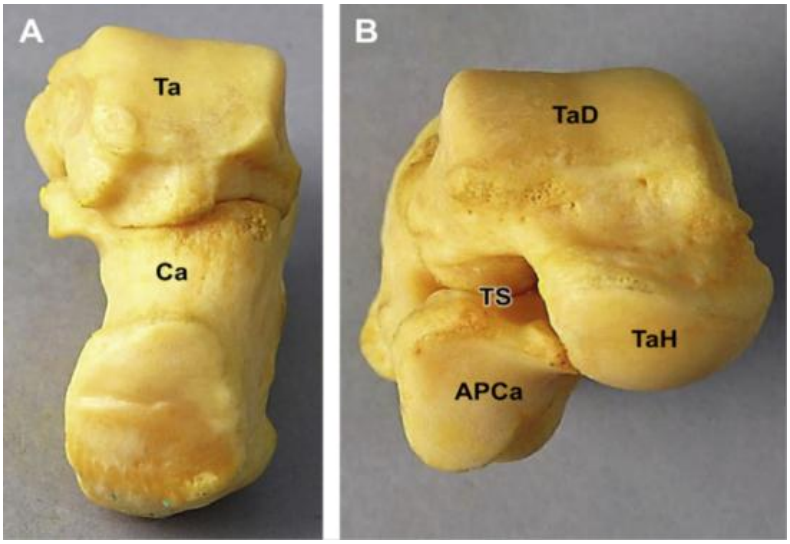

Figure (1**):** Spatial relationship of the talus and calcaneus from (A) posterior and (B) anterior. APCa, anterior process of the calcaneus; Ca, calcaneus; Ta, talus; TaD, talar dome; TaH, talar head; TS, sinus tarsi.(5)

Shortening of the peroneal tendons and reactive peroneal spasm follow, this is defined by some investigators as the "peroneal spastic flatfoot (7).

Prolonged restriction of motion may finally lead to abnormal (eccentric) loading of the subtalar joint and, subsequently, to degenerative changes. The normal gliding motion of the subtalar joint during dorsiflexion is also lost in feet. The subtalar joint is a plane synovial joint

allowing rotation (inversion and eversion) and gliding. Arc of motion varies from 25 to 30 ˚in inversion to 5 to 10 ˚in eversion. The high variability of the range of movement found in the literature can be explained when considering the different techniques used for its determination [(8)]. Furthermore, the position of the ankle joint also affects subtalar movement, for example, dorsiflexion of the ankle joint decreases subtalar movement. Several tendons cross the subtalar joint to balance the ankle in the stance phase and during gait. Their function is dependent on the relation of the tendons to the subtalar joint axis. The extensor halluces longus, extensor digitorum longus and peroneus longus/brevis belong to the evertors. The tibialis posterior, flexor digitorum longus, flexor hallucis longus and tibialis anterior are considered to be invertors. The moment arm of the tendons and thus the amount of force translated by the tendons is dependent on the subtalar joint position .The tibialis posterior and the peroneus longus are the strongest invertors and evertors, respectively. Interestingly, the triceps surae has a slight inversion function, while the ankle joint is in flexion/ inversion and may change to an evertor when the subtalar joint is in eversion. [(9)]

Studies have demonstrated that tarsal coalition lead to a "hinge joint" instead. The midfoot joints widen plantarly and become tight dorsally. Thus, the navicula "override" the talar head at maximum dorsiflexion, and this generates a traction effect on the ligaments and capsule of the talonavicular joint and is thought to produce the "talar beaking" seen in many radiographs of feet with tarsal coalition.[(9)]

The pain may therefore be attributed to recurrent ligament sprain due to rigid subtalar joint, peroneal muscle spasm, sinus tarsi, subtalar joint posterior facet irritation, trabecular fracture of bar, and arthritic changes. The variability of the symptoms in different patients may be due to the variability of subtalar joint motion restriction. Middle facet talocalcaneal coalitions, for example, are associated with greater restriction of subtalar motion and are the most likely to generate valgus[(7)].

The axis of rotation of subtalar joint limits the motion of the talonavicular joint and leads to the triplanar motion of the subtalar/peritalar joint. the subtalar is most often considered a uniaxial joint with a single oblique axis of rotation that extends superiorly and medially from the talus [(10)].

Talocalcaneal joint complex motion is triplanar: inversion, adduction, and plantar flexion occur together whereas eversion, abduction, and dorsiflexion occur together , Talonavicular joint motion is also triplanar due to its close relationship to the talocalcaneal joint. Despite its shared synovial sheath with the anterior part of the talocalcaneal joint, the talonavicular joint is often considered part of the midtarsal joint in conjunction with the calcaneocuboid joint[(11)].

Pathophysiology:

Tarsal coalition is typically asymptomatic in early childhood, it becomes symptomatic as cartilaginous anlage undergoes ossification and flexibility between the conjoined bones is lost, but it can occur as a result of trauma, infection, joint disease or iatrogenically due to surgery . [(12)]

Rigid pes planus and peroneal muscle spasm frequently discussed as essential components of peroneal spastic pes planus, The relaxed position of subtalar joint is valgus, causing the least strain on the talocalcaneal interosseous ligament according to lapidu's. There are a lot of theories related to the etiology of tarsal coalitions can be described as being either congenital or acquired , Congenital as autosomal dominant inheritance due to a specific gene mutation causing failure of differentiation of embryonic mesenchymal tissue to produce normal peritalar joint complex . Talocalcaneal coalitions also can be acquired by degenerative joint disease, inflammatory arthritis, infection, fibular hemimelia, and clubfoot deformities. [(13, 14)]

Clinical examination and evaluation:

- **History and symptoms:**

Patients with TCC tend to present slightly later than those with a calcaneonavicular coalition.

The main presentation of patients suffering from tarsal coalition is vague dorsolateral foot pain centering around the sinus tarsi, difficulty walking on uneven surfaces, foot fatigue usually relieved by rest and aggravated by activity or training, frequent foot and ankle injuries.

Unfortunately Tarsal coalition is often overlooked and misdiagnosed therefore many cases are diagnosed late after occurrence of complications like chronic pain, stiffness even flatfoot and valgus deformity. [15, 16]

Differential diagnosis of hind foot pain in skeletally immature patients:

1-Congenital anomalies

2-Lower extremity alignment

3-Posttraumatic

4-Sinus tarsi syndrome

5-Child abuse

6-Fibrous or cartilaginous talocalcaneal coalition

7-Subtalar loose body

- **Physical examination:**

- Inspection :

In early cases the foot can look completely normal no abnormalities can be inspected until late when deformity occur Hind foot valgus, loss of the medial longitudinal arch, fore foot abduction in severe cases and too many toes sign, callosity on medial foot with severe deformity.

Figure (2): Signs 1.hindfoot valgus 2. Forefoot abduction 3. loss of medial longitudinal arch.

- Palpation :

Tenderness over sinus tarsi and medial above sustanteculum tali, tight peroneal tendons which can be tender as well.

- Range of motion:

Limitation or absence of subtalar motion if performed with the ankle in near neutral position active and passive compared with the other foot, occasional tight fibularis (peroneal) muscles, limited ankle dorsiflexion with tight achilles gastrocnemius complex.

- Special tests:

1- **Heel rise test:** standing on toes normally drives the foot in varus with rigid subtalar heel remains in valgus.

Figure (3): Heel rise test to assess flexibility of hind foot with heel rise heel still in valgus that indicate rigid deformity.

2– **Jack test:** dorsiflexion of the big toe lead to exaggeration of medial arch with flexible flat foot due to windlass effect however, in rigid flat foot no changes occur.

Figure (4): Jack test Arch improvement in flexible flat foot.[17] .

3- **Heel rocking test:** with heel rocking in flexible flat foot hind foot valgus corrects while in rigid deformity no changes occur with heel rocking.

- **Radiological evaluation:**

- Plain X-ray :

Very important in detection and determination of type of coalition , the most common views used ;

1. 45˚ internal oblique lateral X-ray to detect calcaneonavicular coalitions, (anteater nose) sign can be present which resembles anterior tubular elongation of the superior calcaneus which approaches or overlaps the navicular on a lateral radiograph of the foot. [18]

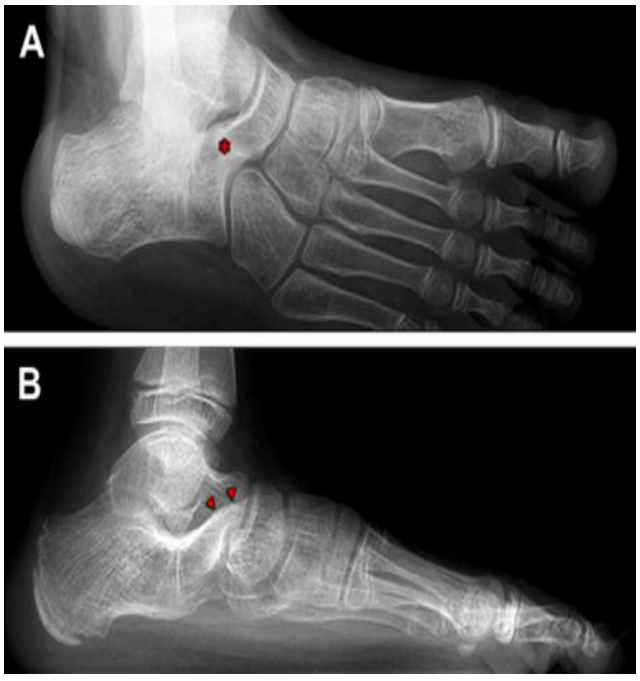

Figure (5): Anteater sign in calcaneonavicular coalition.[19]

2. Harris heel view to detect talocalcaneal coalition a specialized weightbearing foot x-ray to demonstrate the calcaneal body, middle facet of the subtalar joint, and the sustenaculum tali with the x-ray source posterior to the heel and tilted caudally ~45° with respect to the long axis of the foot. [20]

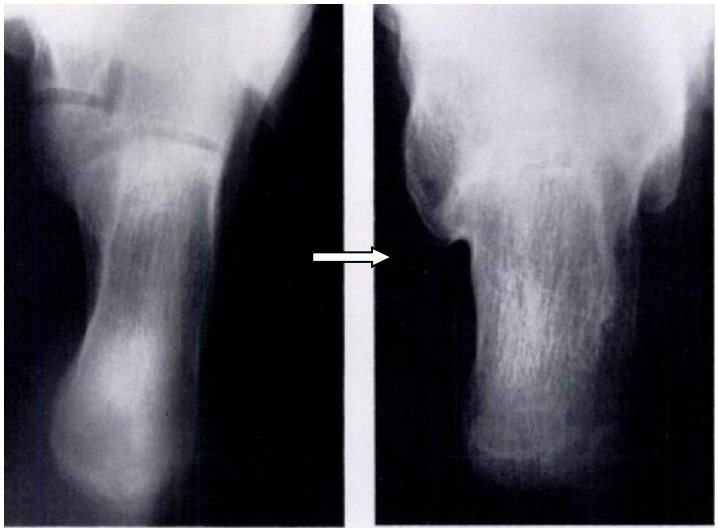

Figure (6): Harris heel view of normal foot (left) & foot with TCC (right) [20]

3. Lateral view of foot and ankle:

C sign: continuous C-shaped arc on a lateral ankle radiograph is formed by the medial outline of the talar dome and posteroinferior aspect of the sustentaculum tali due to their bridging [21]

Talar peak sign: a superior projection of the distal aspect of the talus, It is thought to result from abnormal biomechanic stresses at the talonavicular joint Also standing lateral view can show flatfoot deformity & loss of foot arch.[21, 22]

Figure (71): Talocalcaneal coalition (lateral view). C-sign (white arrows) and talar beaking withshort talar neck (black arrow) [23]

In addition to diagnosis of coalition, X-ray provides very important important radiologic parameters to be assessed in cases of pes-planovalgus for pre and intraoperative assesment of the correction also for follow up, they include:

1- Calcnaeal pitch angle (lateral) normal range (13-23)˚ is the angle between inferior surface of the calcaneus and the supporting surface. Lower angle indicates loss of foot arch and its increase postoperatively indicates improvement of the medial longitudinal arch. [24] Figure 13

2- Talus first metatarsal angle (lateral) (Meary's angle) normal range (2-10)˚ is the angle measured between the longitudinal axis of the talus and the axis of the first metatarsal shaft .the greater the angle the more planus the midfoot is and a decrease in its value indicates an improvement of the planus and the alignment of the talonavicular joint. [25] Figure 8.

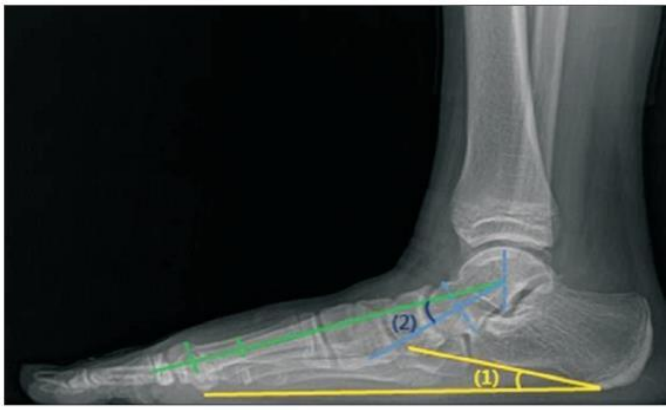

Figure (8): Radiographic parameters (1)Calcaneal pitch angle. (2) Meary's angle.[26]

3- Talonavicular coverage angle (anteroposterior view) normal range (0-7)˚. It is measured between two lines the first one is line perpendicular to medial and lateral margin of articular surface of talus. The second one is line perpendicular to medial and lateral margin of articular surface of navicular .the greater the angle the more abducted the mid foot [24]. Figure 9

4- Talus first metatarsal angle (anteroposteror view) Normal range (3-11)˚.is measured as the intersection of the line that bisects the talar neck and the mid diaphyseal line of the first metatarsal on the AP radiograph. The greater the angle the more abducted the forefoot is .the reduction of its value reflects forefoot correction [27]

Figure (92): Radiographic parameters (3) Talonavicular coverage angle. (4) Talus first metatarsal angle.[26]

- CT scan:

Very important due to its ability to demonstrate osseous anatomy better than other modalities and its usefulness in surgical planning CT coronal cut can detect type and location of tarsal coalitions also 3D can be used to evaluate the morphological characteristics of the coalition.[28, 29]

CT based classification has been proposed by Rozansky et al based on three-dimensional reconstructed computed tomography images and includes five types of talocalcaneal coalitions:

Type I: linear coalitions

Type II: linear coalitions with posterior hook

Type III: shingled coalitions

Type IV: complete osseous coalitions

Type V: posterior coalitions . [30]

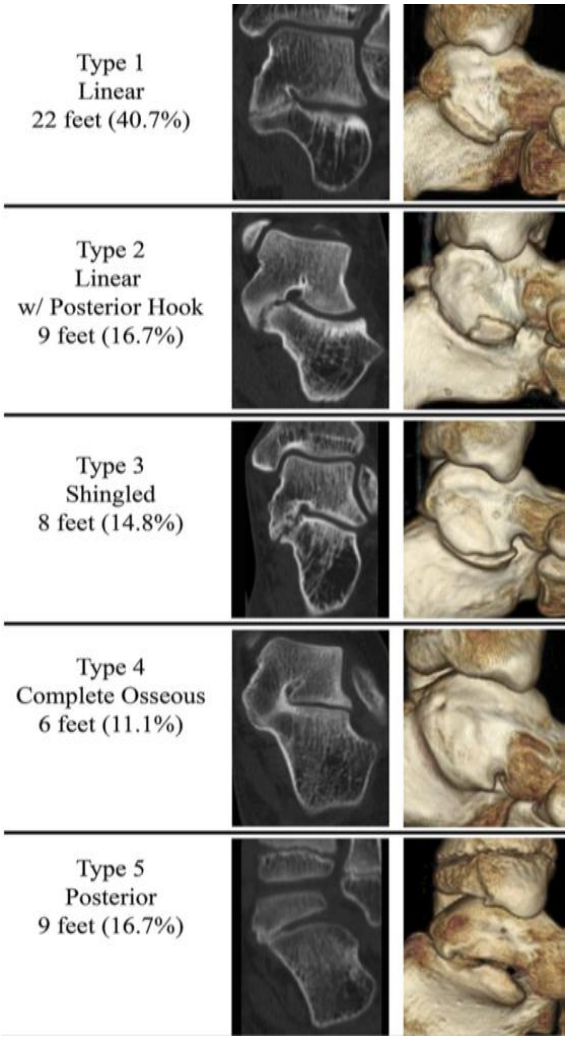

Figure (10): Talocalcaneal classification. Radiologic classification of talocalcaneal coalitions based on 3D reconstruction.[30]

- MRI:

MRI is superior in differentiating osseous from fibrous coalitions because of the superior ability to image cartilage and soft tissue. MRI has proven to be a useful, and increasingly preferred,cross-sectional imaging modality for coalitions. [31, 32]

Classification of coalitions has been proposed based on their anatomic location, as anterior, middle and posterior facet coalitions. Coalitions can be further classified based into type of tissue making coalitions as: fibrous (syndesmosis), cartilaginous (synchondrosis), and osseous (synotosis).[33, 34]

Downey considered joint involvement and arthritis extension in a classification of tarsal coalition to help in recommending surgical therapy. The classification includes four subtypes:

(1) Type IA: extra-articular coalition without secondary arthritis
(2) Type IB: intra-articular coalition with secondary arthritis
(3) Type IIA: extra-articular coalition without secondary arthritis
(4) Type IIB: intra-articular coalition with secondary arthritis.[35]

Also the prementioned CT based classification proposed by Rozansky for determination of different types of TCC.

Management of Tarsal coalition:

1- Non-surgical management:

The goals are decreasing symptoms and improving patient's condition without surgical interventions. Patients can wear supportive shoes or arch support or shoes with a wide toe box, even loss of weight. All these are effective methods. Anti-inflammatory medications are useful in reducing pain and inflammation[19]

Although physical therapy may perform as ultrasound wave and others techniques, Stretching of a contracted Achilles tendon may offer symptomatic relief as well.

Protective pads are effective methods for preventing physical irritation with shoes. Orthotics are diffusely prescribed to alleviate symptoms, there is no evidence supporting the use of orthotics to correct the deformity .Some of orthotics are harmful to soles leading to dependency and long-term negative psychological effects [36]

Orthotic supports and bracing may be appropriate for pediatric patients who are symptomatic, although shoe wear modifications and other inexpensive modalities are quite appropriate for initial management[37, 38]

If symptoms are severe, most authors recommend short leg walking cast immobilization with the foot in neutral or slight varus. 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 the symptoms recur after cast removal, 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, Most authors agree that casting is the preferred technique of nonsurgical therapy for the more severely affected patient.[39]

2- Surgical management:

After adequate trial of nonoperative management, surgical management is recommended, Indications of surgical treatment include:

1. No improvement in symptoms after two 6-week periods of casting is considered failure of conservative treatment.
2. Joint damage and presence of degenerative changes.
3. Presence of deformity "flatfoot or hindfoot valgus ".[39]

The clinical and radiographic measurements can help in stage of deformity and may alter the surgical treatment plan. Some patients may present with mild pain but severe deformity, while other may show mild deformity with severe pain, so it is case dependent.

There are various options of surgical management according to the case progress from dealing with the coalition itself by excision to dealing with complications like joint damage and deformity by corrective osteotomies and even joint fusion, They all aim for symptomatic relief and deformity correction to reproduce the normal biomechanics of the hindfoot.[40]

A. Resection of Calcaneonavicular Coalition:

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. [39]

The investigators prefer Ollier approach over the sinus tarsi. Once the inferior extensor retinaculum is divided the surgeon advances to the coalition reflecting the muscle belly of the short toe extensor from its insertion on the calcaneus. Preventing to open the talonavicular joint capsule protects its cartilage and later subluxation. A bone block of at least 1 cm thickness is resected verifying sufficient removal medially, highlighting the importance of exact preoperative planning of the coalitions' spatial orientation on CT (or MRI) slices. [23]

Swensen describes 2 lines helping to establish the margins of adequate resection: on the navicular side it is the extension of the lateral border of the talar neck and on the calcaneal side the medial border of the cuboid. [41]

In order to prevent any recurrence of ossification tissue interposition (eg, extensor digitorum brevis, fat or use of bone wax, hemostatic agents, and silicon sheets were proposed) can be considered.[23]

B. Resection of Calcaneonavicular Coalition with Concomitant Flatfoot Reconstruction :

Flatfoot deformity is a common finding in patients with coalitions. Although for talocalcaneal coalitions the number of studies on bar resection in combination with deformity correction is growing, the evidence for calcaneonavicular coalitions is sparse. Quinn and colleagues demonstrated successful restoration of radiological angles with calcaneonavicular bar resection and flatfoot correction; however clinical data of the outcome are not yet available [42]. The authors agree with Gougoulias and colleagues that resection of a coalition should be accompanied by deformity correction using a tailored approach of soft-tissue and osseous procedures in order to balance loads.[3]

C. Resection of Talocalcaneal Coalition

Resection of the coalition seldom produces satisfactory results because the foot has usually developed secondary degenerative chances Other authors have recommended talocalcaneal coalition resection if there are no associated degenerative changes, If significant degenerative changes are present, or if resection fails, then an arthrodesis will give satisfactory results.[39]

The authors use a medial approach to the tarsus, which is located over the sustentaculum tali.. The coalition is resected with a 1 cm osteotome to free the joint completely. A bone block of at least 1 cm thickness is resected. Bone wax is placed on the bony surfaces. In order to confirm the accuracy of the resection, the range of motion at the hindfoot is tested and the posterior facet is visualized. If the mobility is not satisfying any possible capsular adhesions have to be resected. Autologous fat graft is placed into the resected area and secured in place. The deep tendon sheath is then closed completely.[23]

In a retrospective review by Gantsoudes a series of 49 feet has been treated by means of open resection of the coalition and fat pad interposition. The average follow-up was 42.6 months. Of all patients 85%showed an excellent result with an average AOFAS score of 90/100. Notably 34% of patients underwent subsequent surgery to correct the alignment of the foot.[43]

D. Resection of a Talocalcaneal Coalition with Concomitant Flatfoot Reconstruction:

As discussed earlier isolated resection of a talocalcaneal coalition tends to fail in case of associated flatfoot deformity due to the related functional deficit. Masquijno and colleagues[44] reported on successful results after flatfoot correction using a calcaneal lengthening osteotomy in patients with resected talocalcaneal coalitions (<50%) and those in which coalitions of less than 50% were left unresected. Combining resection of coalitions less than 50% with medial displacement osteotomies, El-Shazly and colleagues[45] reported of significant improvements of pain VAS and AOFAS scores in a larger series of 30 resected feet. Even though most investigators respect the 50% limit of osseous coalition when indicating resection,[46] it has to be noted that Khosbin demonstrated good results with resection in patients with talocalcaneal bars of more than 50% and more than 16% in those with hindfoot valgus.[1] The authors, therefore, favor according to Zhou the combination with a flatfoot reconstruction in a single-stage operation.[47]

JOINT FUSION IN TARSAL COALITION:

Edwin W. Ryerson first described triple arthrodesis in 1923 as a fusion of the talocalcaneal, talonavicular, and calcaneal cuboid joints. The goal was to create a well aligned, plantigrade, and stable foot for patients with deformity [48]

In case of multiple coalitions, failed primary resection and/or joint degeneration fusion is considered, Fuson and colleagues [49] found that the level of pain was the determining factor to decide for joint fusion. Therefore, resection of coalitions should not be confined to adolescent patients. Good results have been shown not to depend on age as long as no joint degeneration has occurred [50]

The available studies on the outcomes of surgical treatment of tarsal coalitions are not sufficient to draw proper conclusions. Most studies are retrospective series without control groups, small study populations, and variable types of coalitions. In addition, measurements are of variable technique and often assessed using nonvalidated instruments. Subtalar joint fusion is a valuable solution for failed and symptomatic tarsal coalition surgeries. According to the underlying condition, the fusion has to be corrective to reduce mainly hindfoot valgus. Subtalar fusion can be achieved by an open or arthroscopically assisted procedure.[23]

Complications:

1. Superficial or deep infection
2. Wound dehiscence
3. Nonunion
4. Inadequate resection and Recurrence of the coalition
5. Nerve damage eg. superficial peroneal nerve damage (more with calcaneonavicular coalition resection surgery).
6. Loss of inversion/eversion movements at the level of subtalar joint (after subtalar arthrodesis).
7. Malalignment:
   - Varus malalignment leading to increased lateral column forefoot pressures.
   - Valgus malalignment leading to subfibular impingement.

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