Kinematics of The Subtalar and Tarsal Joints
How the manipulation method of Ponseti works

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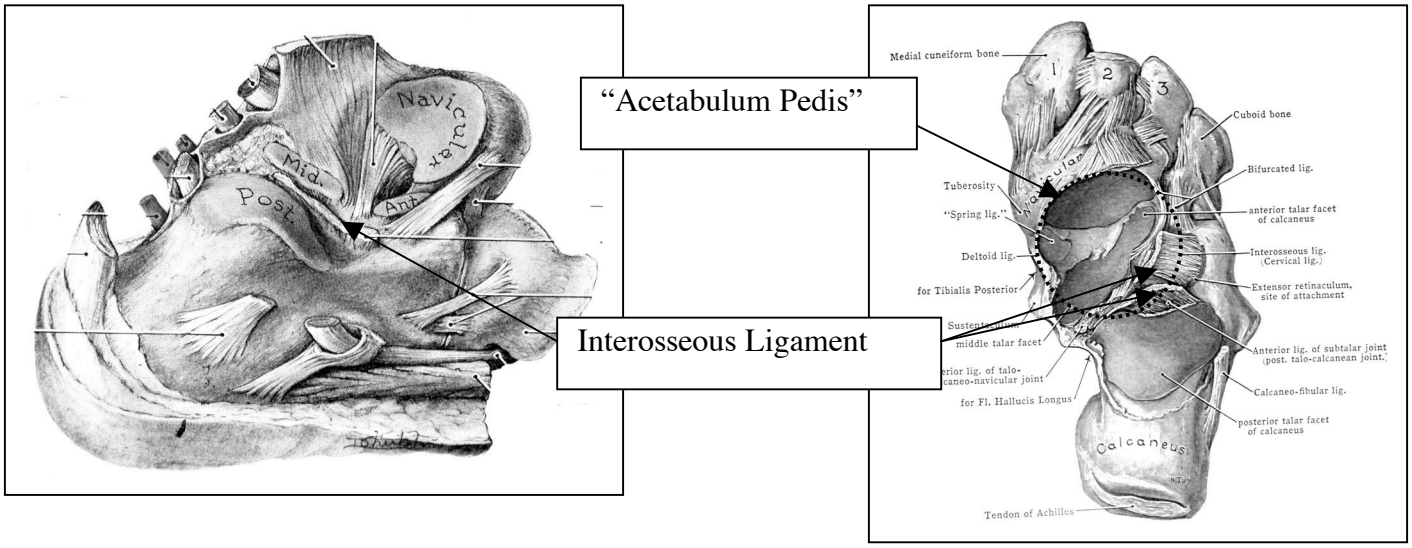
<u>Principle:</u> The Ponseti Method utilizes the normal kinematics of the joints surrounding the talus to effect reduction of the clubfoot deformity.

Anatomy

The subtalar joint complex is one of the most complex and least understood joints in the body. It plays a vital role in adapting ground reaction force during gait to rotation of the lower limb, and adapting a mobile foot to inclined ground surfaces.

- 3 articular facets: posterior, medial, anterior
- 2 functional components:
    - Talo-calcaneal joint – posterior articular facet
    - Talo-calcaneo-navicular joint – the "acetabulum pedis"
        - The anterior and medial facet function with the talo-navicular joint
- Talo-calcaneal interosseous ligament
    - Center of rotation for the subtalar joint
    - Consists of 2 bands



The Posterior articular facet is oblique in the coronal plane and saddle shaped in the saggital plane.

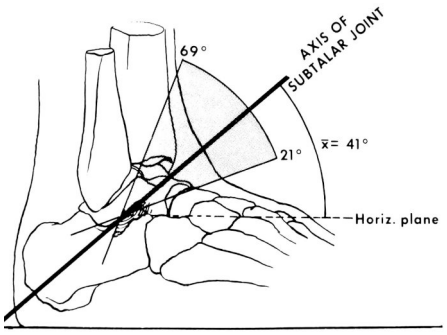
Kinematics

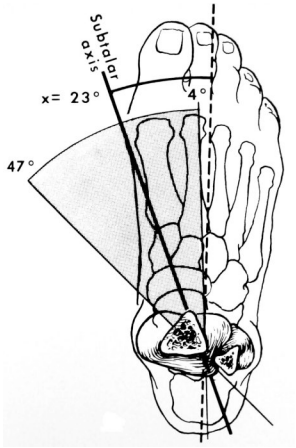
Functionally, all the bones of the foot move as a unit around the talus. There is very little intertarsal motion . (Inman 1976)

The foot moves around the two functional entities of the subtalar joint – the talo-calcaneal articulation and the talo-calcaneo-navicular "acetabulum pedis", with the interosseous ligament as the center of rotation.

Clinical relevance: Abduction of the forefoot during Ponseti manipulation causes abduction of the calcaneus. The entire foot, including the calcaneus, moves around the talus.

The subtalar axis is not a fixed point, but a mobile axis allowing shift and glide around the constraint mechanism of the interosseous ligaments. (Husen, Van Langelann)
Inman resolved this mobile axis axis to **the oblique plane**





The motion of the subtalar joint in this oblique plane is **supination** and **pronation**.
Supination consists of the kinematically coupled motions of adduction, inversion and flexion.
Pronation consists of the kinematically coupled motions of abduction, eversion and extension (dorsiflexion)

Normal subtalar motion:

Subtalar Supination
- Adduction
- Inversion
- Flexion
- Heel Varus

Subtalar Pronation
- Abduction
- Eversion
- Extension (dorsiflexion)
- Heel Valgus

Kinematic coupling

It is usual for orthopaedic surgeons to analyze joint motions in reference to the standard planes of the body: coronal, saggital, etc. Thus we have adduction/abduction, inversion/eversion and flexion/extension of the foot. But when a joint is in the oblique plane, as with the subtalar joint, all these motions are inextricably linked to one another, or "kinematically coupled". Thus abduction of the calcaneus cannot happen without concurrent eversion and extension. Ponseti's technique allows correction by simultaneously correcting the movements in the oblique plain, utilizing abduction as the motor.

The Ponseti technique is at once simple and profound. The forefoot is abducted around the talus, with counterpressure against the head of the talus, simultaneously obtaining abduction, eversion and extension of the foot, and valgus of the heel.

Manter likened kinematically coupled subtalar motion to the helicoid motion of a screw. Farabeuf likened it to the simultaneous pitch, yaw and roll of a ship on the sea.

The mistake of Kite's technique, and other similar methods, is in attempting to correct the foot sequentially, breaking down combined movements into their component parts. Grasping the calcaneus blocks it's normal kinematically coupled motion. Correction can then only occur by deformation of the tarsal bones.

Maximum Abduction:

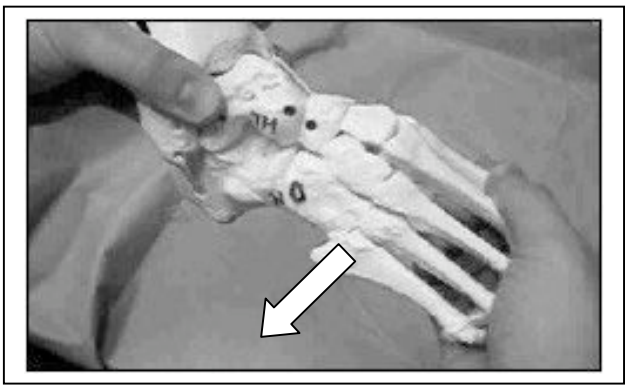
An infant's foot normally abducts 70^0-80^0. A clubfoot is not adequately corrected until **full abduction** is obtained. Calcaneal extension (dorsiflexion) occurs mainly during extreme abduction.
Correcting the foot to neutral, or functional, position is not adequate to accomplish all the kinematically coupled motions and relapse is inevitable.

Normal abduction in a baby

Maximum Abduction:
Obtains full range of motion of the subtalar joint
Reduces the navicular on the head of the talus
Obtains full eversion and pronation
Obtains dorsiflexion of the calcaneus
Results in heel valgus

Practice drills with elasticized foot models

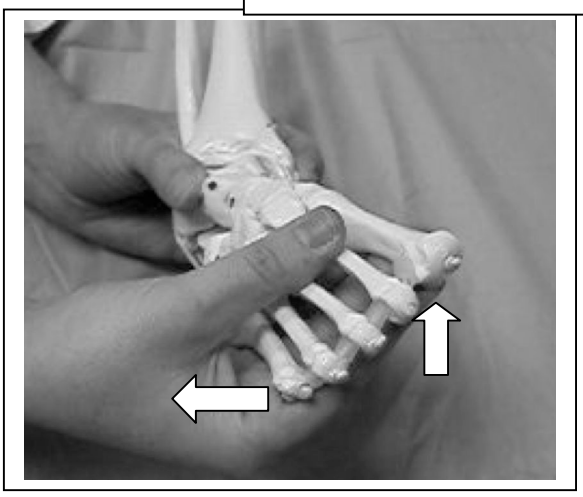
#1 The "Calcaneo-Pedis Block"



Principle: The entire forefoot moves with the calcaneus around talus
Apply the Double Hand Hold. Do not block the calcaneus.
Abduct the forefoot and observe

Practical application:
Correction of the rearfoot & midfoot can be accomplished by abduction of the forefoot
Abduction pressure on the first metatarsal lever can "motor" movement of the calcaneus

#2 Kinematic coupling

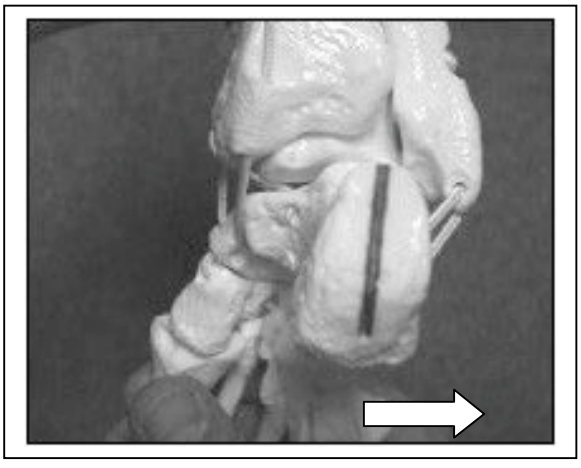


Principle: Abduction and Eversion are "Kinematically Coupled"

- Elevate the first ray
- Abduct the forefoot
- Observe relationship of forefoot to long axis of the tibia
- Observe the oblique plane of talo-navicular motion

Practical Application:
As the foot is abducted, the inversion (apparent supination) spontaneously corrects to neutral
The forefoot is *never* pronated

#3 Heel varus

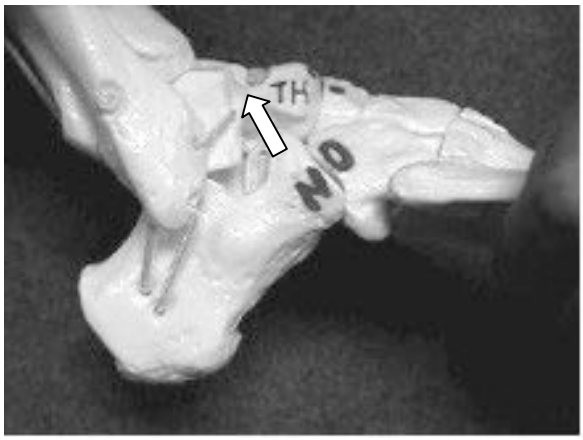


Principle: Abduction of the forefoot spontaneously corrects the heel varus

- Look at the foot model from behind
- Abduct the forefoot
- Note the calcaneus moving from varus to valgus
- Note calcaneus moving away from fibula and stretching of the calcaneo-fibular ligament

Practical Application:
Without touching the calcaneus, the heel spontaneously comes out of varus as the foot is abducted.

4. Subtalar dorsiflexion

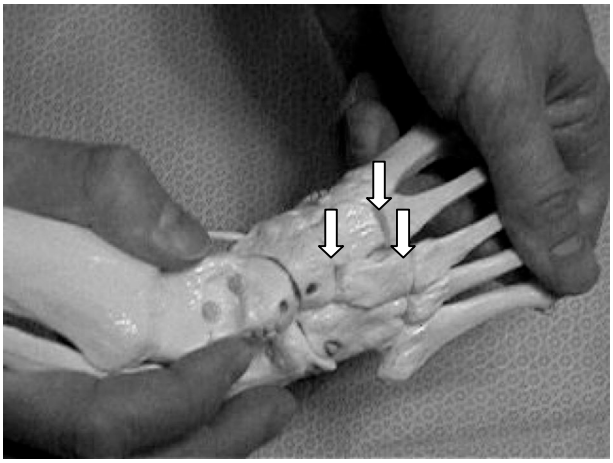


Principle: Abduction and Extension (dorsiflexion) of the subtalar joint are "kinematically coupled"

- Abduct the forefoot
- Observe the anterior process of the calcaneus;
- from the front
- from the side

Practical Application:
As the foot is *maximally* abducted, the subtalar joint spontaneously extends and dorsiflexion improves without rocker bottom risk
Reserve tenotomy for *ankle* dorsiflexion *after* subtalar dorsiflexion is maximized

5. "Kites Mistake"



"Kite's mistake"
Grasp the calcaneus so as to block it from abducting
Abduct the forefoot
How is the forefoot adductus correction obtained?

Blocking the calcaneus from abducting causes iatrogenic deformation of the midtarsal bones and joints! This creates the "bean shaped foot".

References

1. Close, JR., Inman, VT., Poor, PM., Todd, FN. (1967) The Function of the Subtalar Joint. Clin. Orthop. 50: 159. Jan-Feb.

2. Huson A (1991). Functional anatomy of the foot. In: Jahs JH (ed) Disorders of the foot and ankle, 2nd Ed, vol. 1. Saunders, Philadelphia.

3. Inman, VT. (1976) The Joints of the Ankle. Williams & Wilkins Co.

4. Kapandji, IA The Physiology of the Joints. 2nd. Ed. Churchill Livingstone

5. Kite JH (1964) The clubfoot. Grune & Stratton, New York London.

6. Kite, JH. (1972) Nonoperative Treatment of Congenital Clubfoot. Clin. Orthop. 84: 29. May 1972

7. Manter, JT. (1941) Movements of the Subtalar and transverse Tarsal Joints. The Anatomical record, Vol.80, No.4.

8. Ponseti IV (1996) Congenital clubfoot. Fundamentals of treatment. Oxford University Press, Oxford, New York.

9. Ponseti IV(1997). Common errors in the treatment of congenital clubfoot. International orthopaedics 21:137-41

10. Sarrafian, SK (1993) Biomechanics of the subtalar joint complex. Clin. Orthop. 290: 17, May 1993

11. Sarrafian, SK Functional Anatomy of the Foot and Ankle. 2nd. Ed. J.B.Lippincott Company

12. Van Langelann, EJ. (1983) A Kinematical Analysis of the Tarsal Joints. Acta Orthop. Scand., 54 (Supp. 204)