Introduction

Club foot is a congenital foot deformity where the foot points downward with toes turned inward and the foot bottom twisted inward. The bones, joints and muscles of the foot are abnormal. In addition to the foot; the muscles in the lower leg are not as large as usual and will not develop correctly. Finally, the joints in the ankle do not move as much as normal ***(Herzenberg et al., 2002)***.

Uncertain etiology with a broad spectrum of clinical severity and much remains controversial and unsolved about this disorder. It is agreed, however, that early management should be conservative and that operative management should comprehensively address the deformities to avoid, if possible, subsequent operations ***(Dravaric, 1989)***.

Idiopathic clubfoot, one of the most common problems in pediatric orthopaedics, is characterized by a complex three-dimensional deformity of the foot. The treatment of clubfoot is controversial and continues to be so ***(Lourenço and Morcuende, 2007)***.

Assessment of clubfoot is very important in management. Assessment is made by clinical and radiological data ***(Tachdjian, 1985)***.

The Ponseti technique is a well-proven way of managing paediatric clubfoot deformity ***(Docker et al., 2007)***.

The Ponseti method for treatment of idiopathic clubfeet involves the use of serial casts, percutaneous Achilles tenotomy in most cases and bracing with an abduction orthosis to prevent relapse ***(Radler et al., 2007)***.

The Ponseti method of correcting clubfoot is especially important in developing countries, where operative facilities are not available in the remote areas and well-trained physicians and personnel can manage the cases effectively with cast treatment only ***(Gupta et al., 2008)***.

Early recognition and appropriate treatment of recurrent deformity (relapse) is an important component of the Ponseti technique of clubfoot correction ***(Dietz, 2006)***.

Surgery in clubfoot is indicated for deformities that do not respond to the conservative treatment. Often in children with significant rigid clubfoot deformity, surgery must be tailored to the age of the child and to the deformity to be corrected ***(Ponseti, 2000)***.

Aim of the Work

The aim of this essay is to study the Ponseti technique role in management of talipes equinovarus, to spotlight the technique developed by Dr. Ponseti together with the updates of application and follow-up regimens developed under his supervision and finally to evaluate this technique with other methods used for the same purpose.

Epidemiology and Aetiology

Fig. (1): Bilateral talipes equinovarus *(Meidzybrodzka, 2003)*.

Heritability varies between populations. In Caucasian populations, 24-30% of cases report a family history ***(Cartlidge, 1984; Lochmiller et al., 1988; Barker and MacNicol, 2001),*** in comparison to up to 54% of Polynesians ***(Chapman et al., 2000)***. The birth prevalence of ICTEV varies worldwide (Fig. 1), suggesting that genetic background is important.

More cases of ICTEV are delivered by the breech compared to controls; nevertheless, the vast majority of cases have a cephalic presentation (are born head first) ***(Boo and Ong, 1990)***.

Aetiological Theories:

1. Intrauterine Mechanical Factors:

The mechanical theory, the oldest, was advocated by Hippocrates. He proposed that the fetal foot was forced into the equinovarus position by external mechanical forces, that consequent to rapid skeletal growth, the ligaments and muscles developed adaptive shortening, and that the tarsal bone especially the talus, responded by changes in their contour with subsequent malalignment, (Fig. 2) ***(Tachdjian, 1985)***.

Fig. (2):
The feet of a newborn baby with mild equinovarus detormities of the feet, sores on the outer sides of both feet suggest some interuterine pressure *(Porter, 1997)*.

2. The Bone/Joint Hypothesis:

The bone/joint hypothesis postulates that positional bony abnormalities underlie the anomaly. Hippocrates wrote: "The deformity involves the entire combination of bones which make up the skeleton of the foot. All the changes seen in the soft part are secondary …" ***(Miedzybroadzka, 2003)***.

3. The Connective Tissue Hypothesis:

The connective tissue hypothesis suggests that a primary abnormality of the connective tissue is responsible for ICTEV. This is supported by the association of ICTEV with joint laxity ***(Wynne-Davis, 1964)***. ***Ippolito and Ponseti (1980)*** documented the presence of increased fibrous tissue in muscles, fascia, ligaments and tendon sheaths. From this study of five clubfeet and three normal feet, the authors concluded that a retracting fibrosis might be a primary aetiological factor.

4. The Developmental Arrest Hypothesis:

Victoria Diaz (1984) concluded that during embryonic development of the foot passes consecutively into three different positions:

1. When the embryo is in the 15millimeters, stage the foot is in straight line with the leg (initial position).
2. By 30 millimeters, the foot passes to a marked equino varus adductus position (embryonic position).
3. Finally, by 50 millimeters, the foot changes to a slightly equino varus adductus position (Fetal position).

The morphologic and structural changes of the foot from the initial to the embryonic position result from the growth of the distal ends of the fibula and of the skeletal elements of the lateral foot (fibular phase).

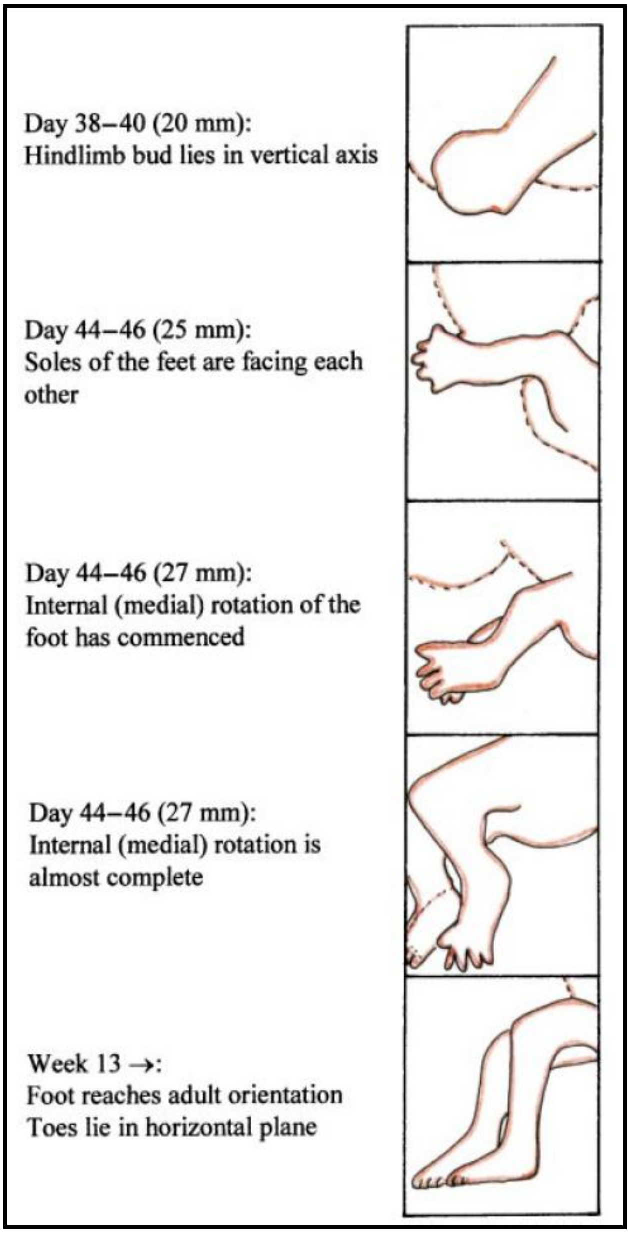


Fig. (3): Development of the human foot *(Miedzybroadzka, 2003)*.

The changes from the embryonic position to the fetal position are due to the growth of the distal ends of the tibia and of the skeletal rays of the medial foot (tibial phase) (Fig. 3).

Böhm (1929) made wax models of the skeleton of the fetal foot at different gestational ages. His observations led him to conclude that "a severe club-foot resembles an embryonic foot at the beginning of the second month … and the deformity is accompanied by underdevelopment of the bones and muscles" (Fig. 4).

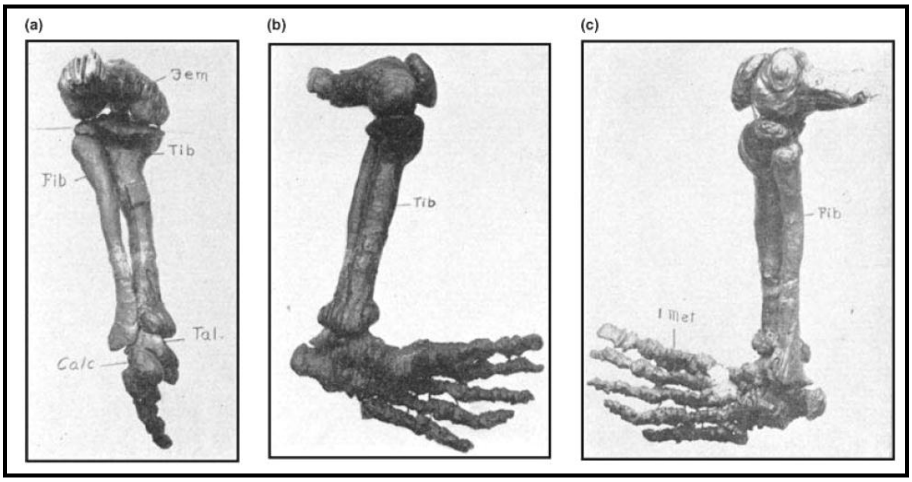


Fig. (4): Bohm's wax models of the skeleton of the human foot during development. Bones Lie in the position seen in untreated clubfoot (Middle third month human embryo wax plate model of left lower leg and foot – back view. (b) as (a), but tibial side. (c) as (a), but fibular side *(Miedzybroadzka, 2003)*.

5. Neuromuscular Hypothesis

Irani (1963) have reported studies of the histology of muscles in clubfeet and recorded no abnormality.

Ionasecu et al. (1993) on the contrary did biochemical and electron microscopy studies on gastrocnemius muscle biopsies from patients with clubfoot and normal controls. They concluded that:

"Fibrosis in severe idiopathic clubfeet may be a major factor in maintaining deformity by limiting the amount of stretch the calf muscles can undergo during growth".

There are many factors that make a neurogenic cause unlikely. The association of clubfoot with spina bifida is well known, however, it is unlikely that a neurogenic disorder is primarily responsible for all idiopathic deformities ***(Turco, 1981).***

6. The Vascular Hypothesis:

Atlas et al. (1980) also studied vasculature in clubfoot. They documented vascular abnormalities in "all deformed feet of 12 foetuses". At the level of the sinus tarsi there was blocking of one or more branches of the vascular tree of the foot. This was "most conspiscious in the early period of foetal life, and reduced to a simple knot of fatty infiltration and fibrous tissue in older specimens and the stillborn". Individuals with idiopathic congenital talipes equinovarus have muscle wasting of the ipsilateral calf, which may be related to reduced perfusion through the anterior tibial artery in development. It is possible that the association of idiopathic CTEV with both early amniocentesis ***(Farrell et al., 1999)*** and smoking ***(Honein et al., 2000)*** may be mediated, at least in part, by vascular insufficiency.

7. Anomalous Tendon Insertions Hypothesis:

Inclan (1958) proposed that in clubfeet. However, other studies have not supported this. It is more likely that the distorted clubfoot anatomy can make it appear that tendon insertions are anomalous.

Pathoanatomy

The four main anatomical abnormalities can easily be remembered by the mnemonic "CAVE"- Cavus, Adduction, varus and Equinus. Cavus is an increased height of the vault of the foot and in clubfoot is due to pronation of the forefoot in relation to the hindfoot, with plantar flexion of the first ray. The midfoot is adducted, primarily at the talo-navicular joint ***(Cooke et al., 2008)***.

The Talus:

Talus is in severe flexion. The body of the talus is small and altered in shape, the trochlear height is decreased and anterior part of the trochlea is in some cases broader while in other cases of the same width as the posterior part (Fig. 5). Only the posterior part of the trochlea articulated with the ankle mortice. The anterior part is covered by the stretched and thin anterior capsule of the ankle joint. In severe cases, the posterior surfaces of the lower end of both the tibia and the fibula are in contact with the superior aspect of the posterior tuberosity of the calcaneus. The posterior part of the body of the talus which is not covered by joint cartilage is intra-articular ***(Ponseti, 1996)***.

The talus does not move and hence fails to maintain articular cartilage that normally results from contact and motion with articular cartilage of the adjoining bones. If the talus stays entrapped in this tight container of a clubfoot, enchondral growth is restricted due not only to lack of motion but also to the actual encasement ***(Epeldegui and Delgado, 1995)***.

The bony mortise stabilizes the body of the talus. In equinus position, only the posterior half of the trochlea articulates with the tibia, the forward portion of the trochlea is out of the mortise anteriorly. In a clubfoot the anterior wider part of body probably never entered the ankle joint; therefore this portion of the trochlea never had the opportunity to respond to physiologic stress. So the anterior trochlea is prone to develop the adaptive morphologic changes ***(Joseph et al.2007).***

The neck of the talus is medially and plantarly deflected. The head is wedge-shaped. There were two surfaces on the talar head: the anterolateral surface, left uncovered by the displaced navicular, was covered only by the stretched joint capsule and the skin; the anteromedial surface extended over the inner surface of the neck and articulated with the navicular ***(Ponseti, 1996)***.

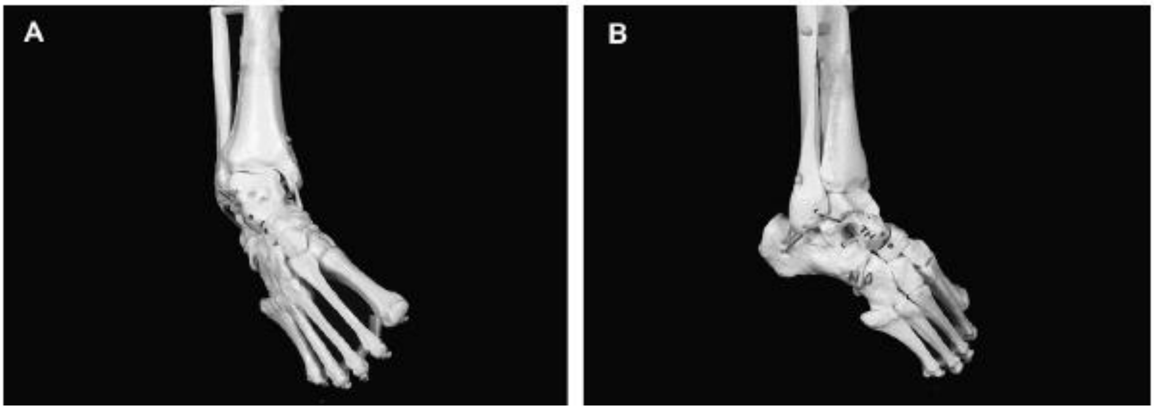


Fig. (5):
A clubfoot model (MD Orthopaedics, lowa, USA) showing the deformities from the front (A), lateral (B) and medial (C) sides. TH – talar head. NO– calcaneocuboid joint *(Cooke, 2008)*.

The deformed talus in clubfoot is small in size and its ossification center may be delayed in appearing and eccentrically situated in a more anterior and lateral location, the vascular channels are arranged in disorganized fashion ***(Howard and Benson, 1993)***.

The Calcaneus:

It is important to note that the calcaneus involved in all three components of the deformity, i.e., equines, varus and adduction ***(Herzenberg et al., 1988)***.

The calcaneus is severely plantarflexed, medially displaced and inverted below the talus such that it lies below and almost in line with the talus. This accounts for the equinus and varus deformities and for the reduced AP and lateral talo-calcaneal angles seen on X-ray ***(Cooke et al., 2008)***.

The body of the calcaneus is consistently in severe flexion and slightly medially bowed. In some cases it is of the same length and in others it was longer than the calcaneus of the normal controls. The calcaneus is adducted and inverted underneath the talus, and most of the anterior tuberosity of the calcaneus was under the head of the talus and not lateral to it as it is in normal feet. The longitudinal axes of the talus and the calcaneus were parallel. The cuboid was medially displaced and inverted in front of the calcaneus. Only the medial part of the anterior tuberosity of the calcaneus articulated with the cuboid ***(Ponseti, 1996)***

The Navicular:

The navicular is uniformly flattened or laterally wedge-shaped and severely medially displaced, adducted, and inverted. The medial tuberosity is large and very close to the medial malleolus; it presents a wide area for the insertion of the enlarged tibialis posterior tendon. This tendon also has a wide insertion in the plantar surface of the first cuneiform ***(Ponseti, 1996)***.

The proximal articular surface of the navicular faces laterally to articulate with the medically deviated head and neck of the talus. In very severe deformities the navicular may even articulate with the medial malleolus. The normal concavity of the proximal articular surface of the navicular is absent, as this surface conforms to the flattened deformed talar head ***(Ippolito and Ponseti, 1980)***.

The navicular tuberosity and the sustentaculum tali are in close proximity to the medial malleolus as a result of the medial displacement of the navicular and varus adduction of the calcaneus ***(Ippoilto, 1995)***.

The Cuboid:

Opinions differ regarding the degree of cuboid involvement, some investigators emphasize significant medial displacement of cuboid bone; these are minimal when compared to the displacement of the calcaneus and the navicular ***(Simons, 1983)***.

The lateral convexity of the foot is predominantly the result of the cuboid moving with the anterior end of the calcaneus, rather than the result of a significant medial displacement of the cuboid relative to the calcaneus.

The proximal end of the cuboid participates in the midtarsal joint (Chopart), and the distal end of the tarsometatarsal joint (Lisfranc). Thus the cuboid bridges the midtarsal and tarsometatarsal areas. Because of this anatomic relationship, significant displacement of the cuboid is obstructed by the navicular and the cuneiforms ***(Simons, 1983)***.

The Cuneiforms and Metatarsals:

The cuneiforms and metatarsals were always adducted but were normal in shape (Fig. 6). The extent to which the relationships of the skeletal components were altered ranged from mild to severe and was better seen in some planes of section than in others ***(Ponseti, 1996)***.

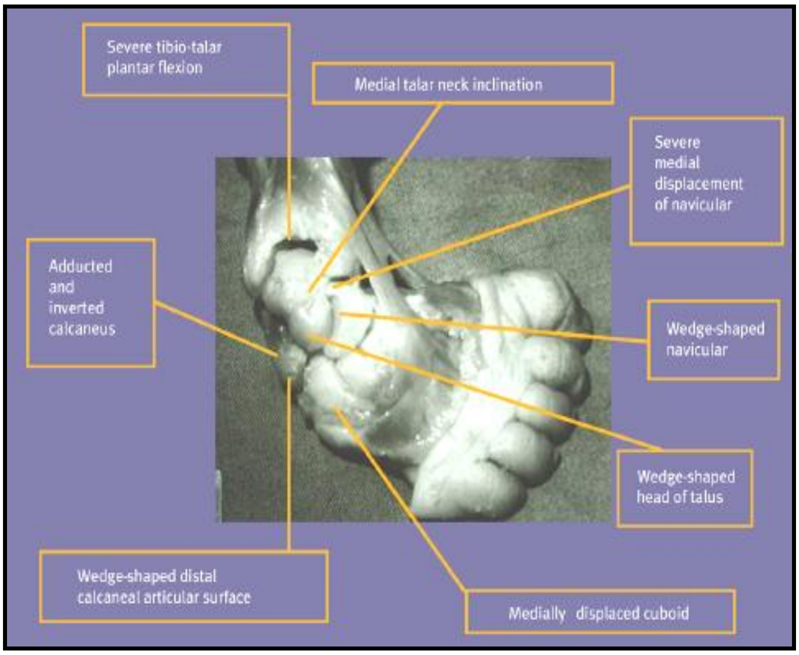


Fig. (6): Anatomy of clubfoot deformity *(Foster and Davis, 2007)*.

The cuneiforms show minimal changes and the metatarsals even less. The medial migration and inversion of all five metatarsal cause the forefoot adduction that contributes to the convexity of the lateral border of the foot and the composite varus adduction deformity. Plantarflexion of the forefoot on the hindfoot contributes to the composite equines deformity and cavus ***(Ippolito, 1995).***

Posterior Contractures:

The posterior and medial structures are short and thick. The calcaneo-navicular (spring), deltoid and talo-navicular ligaments along with the tibialis posterior tendon hold the foot in an adducted position. The posterior talo-fibular, posterior calcaneo-fibular, posterior and medial talo-calcaneal and posterior tibio-talar ligaments along with tightness of the gastro-soleus complex contribute to the equines and varus. Since the insertion of the tendons has medialised, there is medial displacement of tibialis anterior and the long toe extensors. These can now act as deforming forces, pulling the midfoot and forefoot into further adduction and inversion ***(Cooke et al.,2008)***.

Medial Plantar Contractures:

Medial plantar contractures are the most important and resistant in clubfoot. They include the tibialis posterior, the deltoid ligament, the spring ligament and the talonavicular capsule.

The medial talocalcaneal ligament is markedly thickened. The anterior part of the deltoid ligament and the plantar calcaneonavicular ligament are short and thick in all the clubfeet we examined. In many cases they were distorted and matted together with the adjoining tendon sheaths. The posterior tibiotalar, the fibulotalar, and the fibulocalcaneal ligaments were also thick and short and often matted together with abundant fibrous tissue. In the very severe cases, the ligaments of the posterior aspect of the ankle joint were pulled into the joint and their insertions on the talus were covered by the articular surface of the tibia ***(Ponseti, 1996)***.

Both the flexor digitorum longus and flexor hallucis longus are shortened. This shortening does not contribute to the basic clubfoot deformity. The flexor tendon sheaths cross the midtarsal and subtalar joints and if sufficiently contracted and thickened, they can add to the resistance. The contracted Henry's knot (the annular ligament for the two flexor tendons) is an important plantar collagen contracture that restrict the mobility of the navicular by virtue of its attachment of the under surface of the navicular ***(Turco, 1981)***.

The plantar calcaneonavicular ligament (spring ligament) is contracted shortened and inelastic because in the equinovarus position, the navicular is closer to the sustentaculum tali and the spring ligament is relaxed.

The medial part of the talonavicular capsule becomes a shortened contracture secondary to its lax state in the varus position. In cases where there is slight dorsal subluxation of the navicular, the dorsal part of this capsule may be also contracted ***(Howard and Benson, 1993)***.

Subtalar Contractures:

The interosseous talocalcaneal ligaments in the sinus tarsi are underdeveloped and often consist of a few connective tissue strands. This is observed even in the older specimens ***(Ponseti, 1996)***.

The bifurcate ligament is stretched and thin ***(Ponseti, 1996)***. Contracture of the bifurcated (Y) ligament, although less common, can prevent complete correction of the varus and adduction components in some severe deformities ***(Catterall, 1991)***.

Plantar Contractures (Cavus):

The soft tissue contractures associated with flexion deformity of the forefoot include the plantar aponeurosis, abductor hallucis, the intrinsic toes flexors, the quadratus and the deep plantar ligament.

The plantar aponeurosis is invariably contracted and is palpable as a tight, subcutaneous fibrous band along the foot in the older child.

The calf is atrophied and diminished in bulk, with shortening of the triceps, posterior tibial, and both long toe flexors. The discrepancy in the size of the calf musculature becomes more obvious as the child grows ***(Catterall, 1991)***.

Articular Abnormalities:

The Talocalcaneonavicular Complex:

Because of their strong ligamentous connections, the calcaneus and the navicular move as a unit around the talus. The axis of rotation is the interosseous talocalcaneal ligament and posterior subtalar joint, where minimal motion occurs.

Horizontal movements take place at the talonavicular and the anterior and middle subtalar joints. In eversion, the navicular and anterior end of the oscalcis moves laterally, whereas in inversion, they move medially.

On plantarflexion and dorsiflexion of the ankle, both the tibiotalar and the talocalcaneonavicular joints move. During plantarflexion the calcaneus supinates under the talus, with the anterior end moving plantarward and medially, while its posterior tuberosity moves dorsally and laterally. Simultaneously, the navicular moves medially on the head of the talus ***(Ponseti, 1996)***.

The morphological changes observed in the six clubfeet studied at birth were similar to the changes observed in the fetuses. In clubfeet the talus, although in severe equinus was firmly fitted in the ankle mortise. The greatest distortion was seen in the navicular, which was severely medially displaced, inverted, and articulated with the medial aspect of the head of the talus which was wedge-shaped. The navicular tuberosity was nearly in contact with the tip of the medial malleolus. The inversion of the navicular appeared to be caused by the retraction of the deltoid and spring ligaments and by the traction of the shortened tibialis posterior tendon which inserts in the lower part of the navicular tuberosity and first cuneiform and gives off fibrous expansion to the other cuneiforms and to the cuboid. The inversion varied from 40 degrees in the milder cases to 80 degrees in severe ones. Thus, the position of the navicular changes from horizontal in the normal foot to nearly vertical in the severe clubfoot. All the medial tarsal ligaments and the posterior tibial tendon and tendon sheath were greatly thickened and enlarged ***(Ponseti, 1996)***.

The calcaneus was adducted underneath the talus. There was a gap filled with fibrous tissue in the lateral aspect of the subtalar joint with a large opening of the sinus tarsi. Just as is found in fetuses, the posterior talocalcaneal joint was small in size and although nearly horizontal in the back it was inclined laterally in front. The medial talocalcaneal joint was small and the anterior joint was absent. In clubfeet of neonates, ***Howard and Benson (1993)*** have observed the medial facet of the calcaneus to lie vertically, so that with the inverted calcaneus, the subtalar joint is sagittally rather than coronally oriented. In the infants we studied to cuboid was adducted and inverted in front of the wedge-shaped anterior joint surface of the calcaneus. The cuneiforms and the metatarsals were adducted but of normal shape. In some cases, however, the anterior joint surface of the first cuneiform was slanted medially. As in the fetuses, the tendons of the anterior tibial, extensor hallucis longus, and extensor digitorum longus were medially displaced over and just in front of the medial malleolus.

The inversion and adduction of the calcaneus accounted for the varus deformity of the heel. The heel varus, and the adduction and inversion of the navicular and cuboid, accounted for the supination of the clubfoot. The skeletal components of the anterior part of the foot were adducted in front of the severely medially displaced navicular and cuboid ***(Ponseti, 1996)***.

The Calcaneocuboid Joint:

This is abnormal in that cuboid is displaced medially under the navicular and cuneiform bones and the calcaneus does not articulate fully with it. The plantar calcaneocuboid ligament, the bifurcate ligament and the long plantar ligament become tight as a result of this displacement ***(Sharrard, 1993)***.

The Ankle:

In resistant feet, this lateral orientation of the tibiofibular unit increases with age. Some of the increased lateral rotation may be acquired as a result of not stretch. The ankle may yield to this external rotating force by rotating laterally. Another factor is the child's attempts to compensate for the varus adduction deformity of the foot by rotating the leg externally on weight bearing and walking. The lateral malleolus is palpable posteriorly, which is to be expected with the increased external rotation of the mortise, or it may be caused by inward rotation of the talus in the ankle joint ***(Ippolito, 1995)***.

The medial malleolus is usually under developed and appears to be slightly anterior to its normal position. Also, the relationship of the diaphyses of the tibia and fibula is abnormal ***(Ippolito, 1995)***.

Diagnosis

History and Clinical Assessment

The family history should include a detailed inquiry into congenital defects of the locomotor system ***(Ponseti, 1996)***.

The baby should be fully undressed when inspected, first in the supine and then in the prone positions in order to detect possible anomalies in the head, neck, chest, trunk, and spine. A neurological examination should follow and the mobility of trunk and extremities should be evaluated ***(Ponseti, 1996)***.

The degree of the following anomalies should be recorded:

1. Heel equinus,
2. Heel cord tightness,
3. Calf circumference,
4. Proximal retraction of the gastrosoleus muscle,
5. Adduction,
6. Inversion of the calcaneus, and
7. The extent to which the talar head is subcutaneous in front of the lateral malleolus ***(Ponseti, 1996)***.

The angle of forefoot adduction can best be measured from the sole of the foot ***(Alexander, 1990)***. A severe metatarsus adductus must not be confused with clubfoot and treated as such. The result is a disastrous iatrogenic foot valgus deformity. The metatarsus adductus is easily differentiated from clubfoot because it has no equinus ***(Ponseti, 1996)***.

Other joints should be examined for stiffness and deformity, including the hips, which should also be assessed by ultrasound for dysplasia, directing treatment and prognosis ***(Foster and Davis, 2007)***.

To determine the position and range of motion of the navicular in the clubfoot, the orthopedist should keep a steady grasp of the toes and metatarsals with one hand while he feels the malleoli from the front with the thumb and index finger of the other. The thumb should be on the fibular malleolus which is much more prominent than the tibial malleolus on which the index finger rests. The tibial malleolus feels less prominent because the navicular abuts against its tip. As the index finger and thumb slide down the malleoli, the thumb will come up on the prominent head of the talus while the index finger will reach the top of the navicular. With the hand holding the toes and metatarsals the foot is abducted while the index finger of the other hand pushes the navicular downwards and laterally ***(Ponseti, 1996)***.

The distance between the medial malleolus and the navicular indicates the degree of displacement of the navicular. The degree of lateral displacement of the navicular when abducting the foot is the orthopedist's main clue ***(Ponseti, 1996)***. ***Goldner and Fitch (1991, 1994)*** classify the severity of the clubfeet according to the distance between the navicular and the medial malleolus into severe (0-6 mm), moderate (7-12 mm) and mild (13-18 mm). In the normal foot their measured distance is from 19 to 24 mm. Since Goldner and Fitch make no reference to the age of the patient, and the distance changes with age whether in a clubfoot or a normal foot, their figures should be taken with reservation. The lateral aspect of the talar head can be palpated under the head of the talus. The degree of subtalar motion can be estimated when the foot is abducted ***(Ponseti, 1996)***.

It is easy to find by palpation the calcaneocuboid joint to determine the position of the cuboid and the degree of its displacement. Due to the looseness of the ligaments between the navicular and the cuboid, in most clubfeet the medial displacement of the cuboid will easily yield when the forefoot is abducted against counter pressure applied with the thumb on the lateral aspect of the head of the talus. The cuboid, however, may remain medially displaced when the orthopedists apply counter pressure over the calcaneocuboid joint.

The cuneiforms can be palpated in front of the navicular. The first metatarsal is identified in plantar flexion. In most cases, it can be easily displaced in extension since the plantar fascia is usually not very tight if the infant has not been wrongly treated by immobilizing the forefoot in pronation.

The most important factors to be considered in determining the degree of severity of the clubfoot are:

1. The reduction in size,
2. Degree of proximal retraction of the calf muscles;
3. The severity of the equinus and varus of the heel;
4. The rigidity of the adduction of the forefoot,
5. The degree of medial displacement of the navicular, and

6. Depth of the skin creases in the posterior aspect of the ankle and medial aspect of the foot (Fig.7) ***(Ponseti,1996)***.

Fig. (7): Deep posterior and medial skin creases *(Foster and Davis, 2007)*.

Degree of Severity:

There is a definite relationship between the severity of clubfoot and the number and severity of associated abnormalities. Severe or complex clubfeet are more likely to require extensive surgery are more prone to recurrence following treatment and have a somewhat poorer outcome. For these reasons it is important to have a method of assessing and documenting clubfoot severity ***(Cooke et al., 2008)***.

It is also desirable to monitor the effect of interventions. Several scoring systems are in use, for example, the Dimeglio score (table 1), the Harold and Walker severity scale (table 2) and the Pirani score (tables 3 & 4 and Fig. 8). All of these system have been independently validated. Inter- and intra-observer reliability is very good and they correlate well with patient-based assessments of outcome ***(Cooke et al., 2008)***.

Table (1): Dimeglio: classification of clubfoot ***(Uglow et al., 2007)***.

Grade 1	These feet are postural and fully correctable. They respond to physical therapy and do not require surgery. Postoperatively, they are fully corrected or have slight residual deformity and more than 90% flexibility.
Grade 2	These feet remain fairly mobile with more than 50% reducibility. They varus, equinus and supination deformities are less than 20°.
Grade 3	The reducibility of the foot is less than 50%, with between 20° and 45° of varus, equinus and supination.
Grade 4	This is the severe or teratologic foot. The reducibility of the foot is less than 20°, and the varus, equinus and supination deformities are more than 45°.

Table (2): Harrold and Walker classification of clubfoot severity ***(Harrold and Walker, 1983)***.

Definition	**Grade**
Foot correctable beyond neutral.	I
Pushed to neutral, but with fixed equinus or varus heel less than 20°.	II
Fixed varus or equinus greater than 20°.	III

Table (3): Pirani score, (hindfoot) ***(Cooke et al., 2008))***.

"LOOK"	0	No heel crease
Posterior	0.5	Mild heel crease
Crease	1	Deep heel crease
"Feel"	0	Hard heel (calcaneum in normal position)
Empty	0.5	Mild softness
Heel sign	1	Very soft heel (calcaneum not palpable)
"Move"	0	Normal dorsiflexion
Rigidity of equinus	0.5	Foot reaches plantigrade with knee extended
	1	Fixed equines.

Table (4): Pirani score, (midfoot) ***(Cooke et al., 2008)***.

"LOOK"	0	No deviation from straight line
Lateral border of foot	0.5	Medial deviation distally
	1	Severe deviation proximally
"FEEL"	0	Reduced talo-navicular joint
Talar head	0.5	Subluxed but reducible talonavicular joint
	1	Irreducible talo-navicular joint
"MOVE"	0	No medial crease
Medial crease	0.5	Mild medial crease
	1	Deep crease Altering contour of foot

[a] **The foot should be moved to the position of maximum correction when assessing the medial crease.**

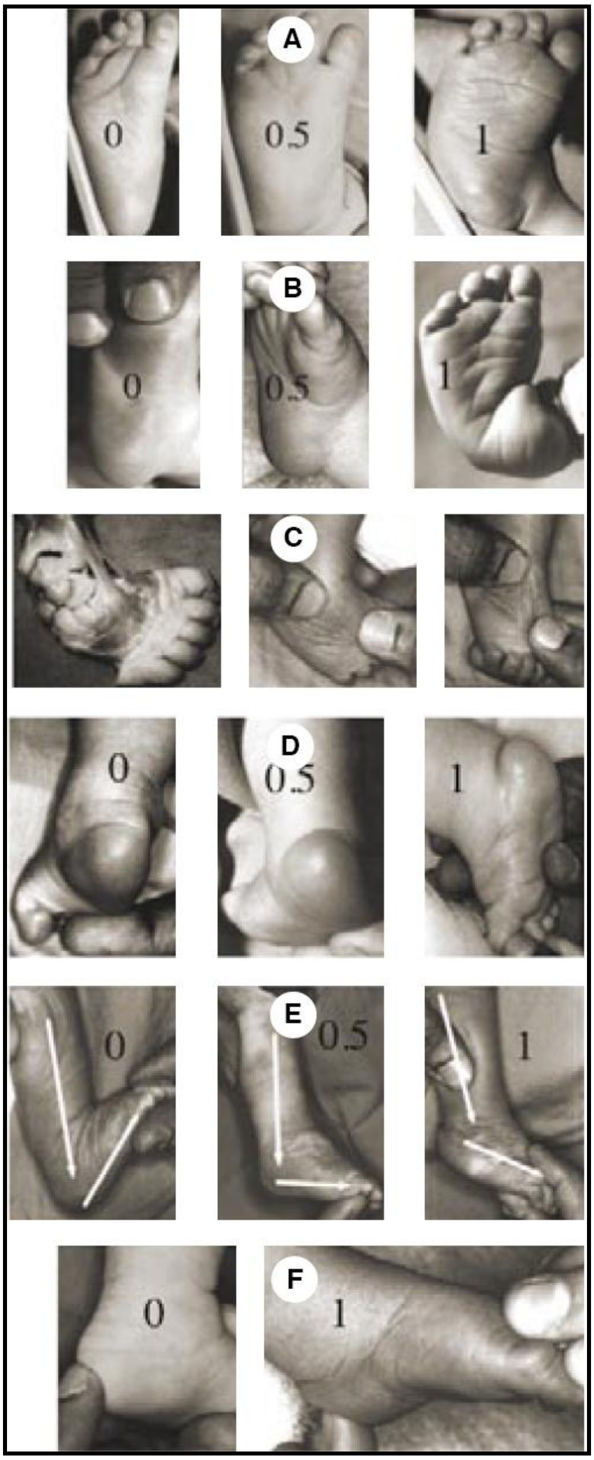


Fig. (8): Pirani score

Midfoot score

Three signs comprise the Midfoot Score (MS), grading the amount of midfoot deformity between 0 and 3.
Curved lateral border [A]
Medial crease [B]
Talar head coverage [C]

Hindfoot score

Three signs comprise the Hindfoot Score (HS), grading the amount of hindfood deformity between between 0 and 3.
Posterior crease [D]
Rigid equinus [E]
Empty heel [F]

(Ponesti et al., 2004)

The correlation of the Pirani and Dimeglio scores before treatment with the lateral tibiocalcaneal angle before the tenotomy may be a sign that the position of the calcaneus before the tenotomy accurately reflects the severity of the hindfoot deformity. The Pirani and Dimeglio classifications help to objectify the severity of clubfeet and make it possible to compare results from different series; therefore, all clubfeet should be assessed with these classifications prior to treatment ***(Radler et al., 2007).***

Roentegnographic Evaluation:

Radiographs (Figs. 9, 10, 11, 12 & 13) may not be useful for assessing the exact amount of correction, and the surgeon should be aware of this limitation when evaluating the radiographs of clubfeet of infants. Ponseti does not recommend the standard use of multiple radiographs during treatment of clubfeet with the Ponseti method. Nevertheless, radiographs are helpful in certain cases to determine the need for an Achilles tenotomy and to detect pseudocorrection so that it can be treated with a tenotomy to ensure sufficient correction before the bracing period. If pseudocorrection is detected, a cast should be reapplied with the foot in some amount of equinus and should be worn for a week or two to allow the plantar ligaments to tighten, after which the percutaneous Achilles tenotomy should be done***(Ponseti, 1996)***.

At birth the talus and calcaneus show well formed centers of ossification and cuboid is also visible in the normal foot. In talipes equinovarus, the centers of ossification are usually late in appearance and the navicular may not be seen until after the third year. The metatarsal shafts are well ossified at birth ***(Simons, 1987)***. The absence of bone in the navicular makes the position of this most important structure in clubfoot very difficult to assess radiologically until the child is 3 years old or more ***(Ponseti, 1996)***.

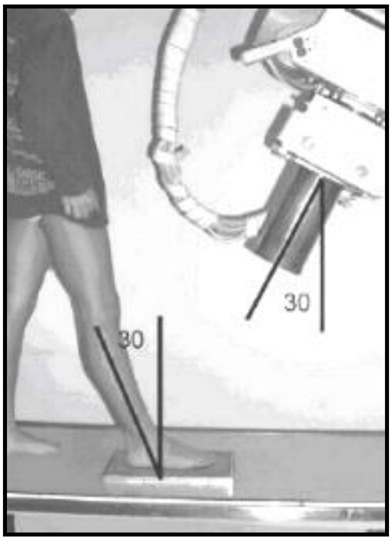


Fig. (9): AP projection (Fridman and Sodré, 2007).

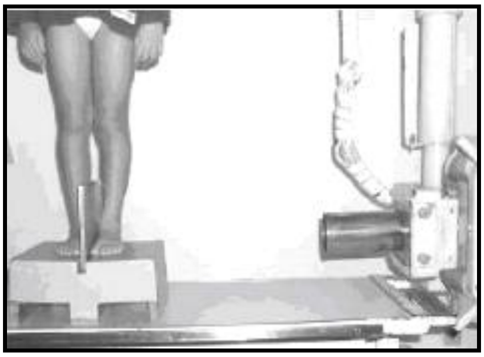


Fig. (10): Lateral projection(Fridman and Sodré, 2007).

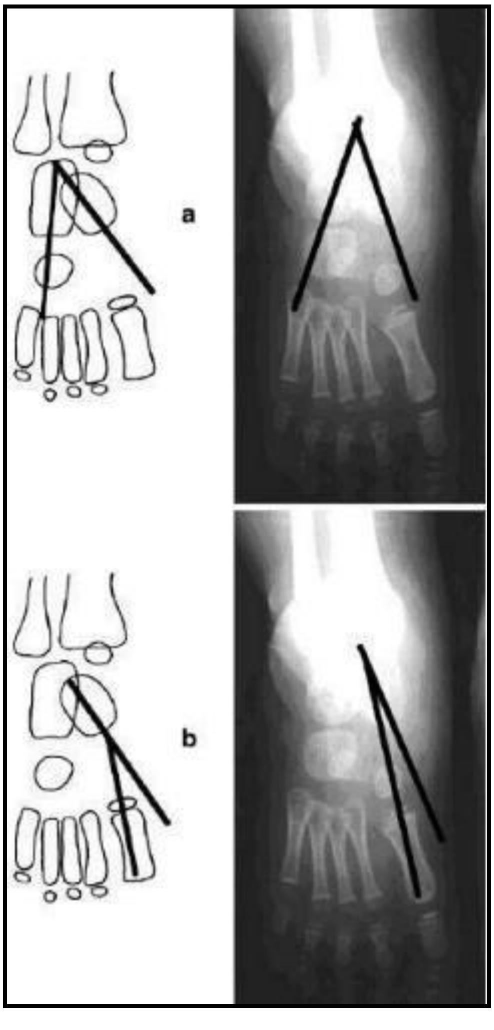


Fig. (11): Talocalcaneal (a) and talo-first metatarsal (b) angles in AP projection *(Fridman and Sodré, 2007)*.

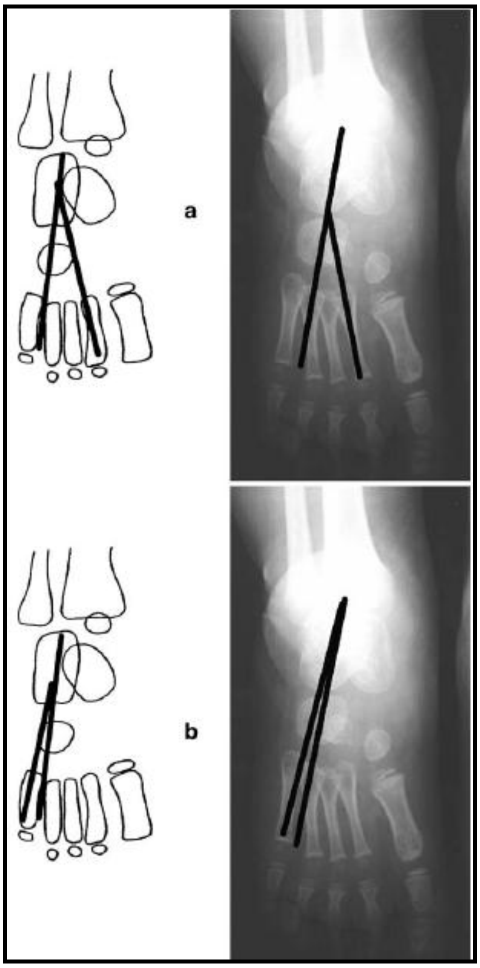


Fig. (12):

Calcaneal-second metatarsal (a) and calcaneal-fifth metatarsal (b) angles in AP projection *(Fridman and Sodré, 2007).*

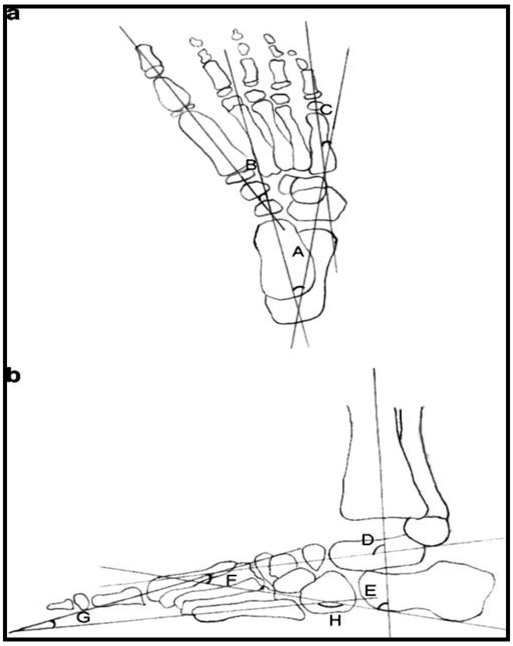


Fig. (13):

Antero-posterior view of the foot showing the following angles: (A) talo-calcaneal angle, (B) talo-first metatarsal angle, (C) calcaneo-fifth metatarsal angle. B Lateral view of the foot showing the following angles: (D) tibio-talar angle, (E) tibio-calcaneal angle, (F) talo-calcaneal angle, (G) first-fifth metatarsal angle, (H) calcaneo-fifth metatarsal angle *(Prasad et al., 2007)*.

In club foot, the previously described relations are altered due to fore foot adduction. The talar axis does not cut the first metatarsal. Middle metatarsal axes are parallel and the calcaneal axis does not strike the fourth metatarsal ***(Simons, 1987)***.

Kite (1972) described parallelism of the talar and calcaneal ossification centres in CTEV as is seen in the AP and lateral radiograph (Fig. 14). In the normal foot, the angle between these bones on the AP and lateral X-ray is20-40°, while in CTEV this angle is reduced to <20°.

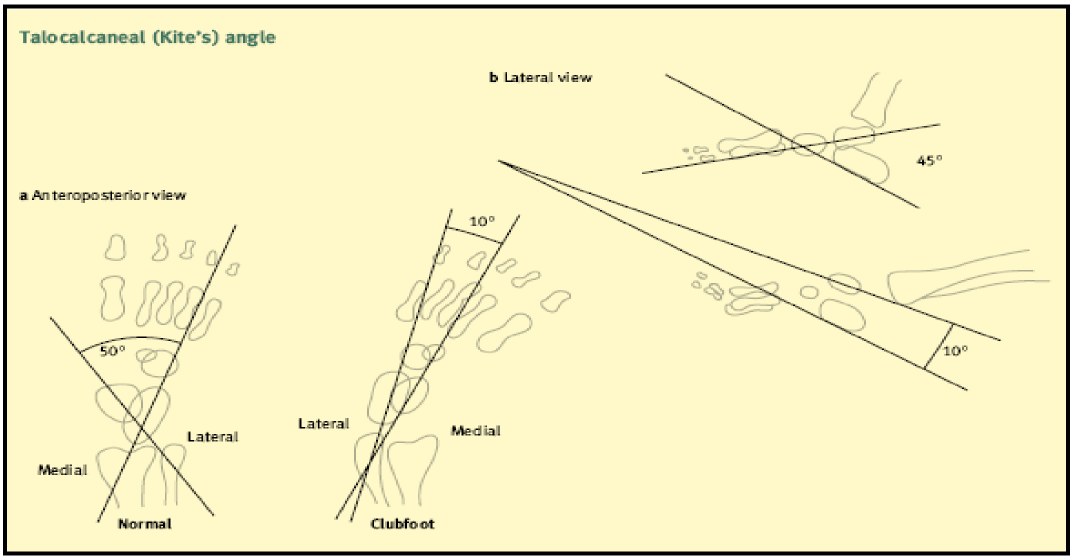


Fig. (14): Talocalcaneal (Kite's) angle *(Foster and Davis, 2007)*.

Simons (1987) quantified the deformity on the basis of alterations in the talocalcaneal angle on AP and lateral views of the foot. The long axis is marked on each bone in each view and talocalcaneal angles are calculated. Summation of these figures defines the talocalcaneal index and provides a method of quantifying the hindfoot alignment. In normal feet, the talocalcaneal index ranges from 51° to 77°. Satisfactory correction was determined as having a talocalcaneal index of >50°.

Thometz et al. (1993) described a grading system to determine the malalignament of the calcaneocuboid joint based on the AP radiograph (Fig. 15). They reported that 29% of the patients had no malalignment and proposed that malalignment of this joint was an indication for surgical reduction of the calcaneocuboid joint and that incomplete reduction was associated with residual deformity.

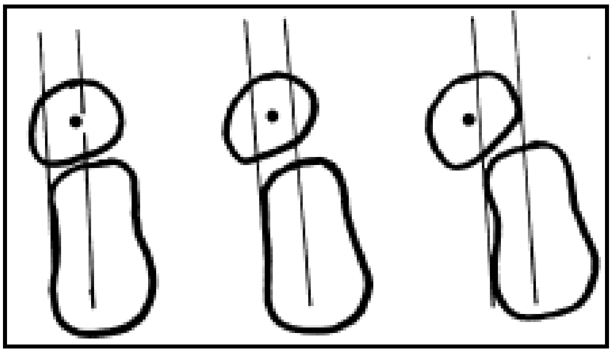


Fig. (15): Thometz grading of calcaneocuboid aligment left–Grade 0–normal aligment, where the midpoint of the ossification centre of the cuboid lies on the long axis of the calcaneus centre – Grade II – the ossification centre lies between a line along the long medial border of the calcaneous. Right – Grade III – the cuboid lies medial to the medial border of the calcaneus *(Ballantyne and Macnicol, 2002)*.

Another measurement which may be useful in determining the recovery of dorsiflexion is that between the tibial axes and the longitudinal axis of the talus or the calcaneus in the lateral view, which normally measures 60 to 40 degree as a result of treatment ***(Simons, 1987)***.

Unfortunately, radiographic measurements in the infant foot are not fully reliable. Simons stated that "considerable controversy exists concerning the use of radiographic techniques in the evaluation of clubfeet" in 1978 and discussed the absence or small size of ossification centers in young children ***(Simons, 1987)***.

The relationship of the ossific nucleus to the overlying cartilage has been described in more detail in a three-dimensional computed tomographic study ***(Herzenberg et al., 1988)***.

It is difficult to estimate the accurate position of the tarsal bones in the roentgenograms of infants, because the centers of ossification of the three visible tarsal bones (calcaneus, talus, and cuboid) are small, oblong, and eccentrically positioned. The navicular, the most displaced component of this deformity, does not ossify until the age of 3 or 4 years ***(Ponseti, 1996)***.

Howard and Benson (1992) showed that the size, position, and alignment of the ossific nuclei in the talus and calcaneus in clubfeet are different from those in normal feet and that radiographs do not reflect the true deformity, especially underestimating equinus in the lateral projection.

Furthermore, in ponseti’s experience with long term results, the values of the talocalcaneal angles do not accurately predict the success or failure of treatment ***(Ponseti, 1996)***.

The position of the infant's foot and X-ray plate is crucial and can be difficult to replicate accurately. This is illustrated by a poor correlation between angles measured by plain radiography and those measured by 3D CT ***(Cooke et al., 2008).***

The correlation between radiological and clinical outcomes is variable and certainly surgery is not indicated to correct radiological abnormality. Decisions on initial treatment are therefore made purely on clinical grounds ***(Cooke et al., 2008)***.

It is important to remember that even in well treated clubfoot some radiological abnormalities persist long term ***(Cooke et al., 2008)***.

Unless the patient has been previously treated or has a very unusual deformity, Dr. Ponseti neither takes roentgenograms of the infant's feet before nor after completion of the plaster cast treatment. Roentgenograms will be helpful if there is a relapse, which usually occurs after 1 or 2 years of age when ossification is more advanced ***(Ponseti, 1996)***.

Treatment

Thometz et al. (1993) recommended treatment of CTEV that ranges from non-operative casting and stretching to complete peritalar surgical release or the "hanging foot" procedure.

This lack of consensus reflects the following factors:

1. The aetiology is incompletely understood, so that predicting the outcomes of intervention is difficult.
2. CTEV represents a spectrum of disease and without a widely accepted classification system comparison between groups and between different treatments is difficult.
3. Failure of studies to define the severity of the deformity in populations under review.
4. A lack of long-term follow-up and randomized, controlled trials to assess the benefits of various treatments.

(Ballantyne and Macnicol, 2002).

The goal of treatment is to reduce or eliminate all the components of the congenital clubfoot deformity so that the patient has a functional, pain-free, normal-looking, plantigrade foot, with good mobility, without calluses, and requiring no modified shoes. A totally normal foot is not attainable and should not be expected ***(Ponseti, 1996)***.

It's not known the etiology of congenital clubfoot and we therefore cannot influence the pathology inherent in the ligaments, tendons, and muscles which seem to determine the degree of resistance to the correction and possibility of relapses ***(Ponseti, 1996)***.

The Objectives of the Treatment of Clubfoot are:

1. To achieve concentric reduction of the dislocation or subluxation of the talocalcaneonavicular joint.
2. To maintain the reduction.
3. To restore normal articular alignment of the tarsus and the ankle.
4. To establish muscle balance between the evertors and invertors, and the dorsiflexors and plantarflexors.
5. To provide a mobile foot with normal function and weight bearing.

(Tachdjian, 1978)

The overall aim of treatment is to correct the deformity early and fully, and maintain correction with growth until skeletal maturity ***(Foster and Davis, 2007)***.

Conservative Treatment

Management Trends:

Historically, treatment was conservative with varying forms of strapping or serial casting applied soon after birth to correct deformity; this usually failed to correct the deformity due to an incomplete understanding of the functional anatomy of the foot. Conservative treatment was the mainstay of treatment for more than 40 years but, with improved anesthetic and surgical techniques, a significant proportion of children then progressed to surgical management, usually with a posteromedial release at the age of one year.

The trend towards surgical management has reversed over the past decade. With increased understanding of the functional anatomy of the clubfoot and deformity parameters, non-surgical techniques have developed to give, in most cases, a result superior to that achieved by surgery ***(Foster and Davis, 2007)***.

Hippocrates described manipulation and bandaging of clubfoot deformities as though moulding a wax model, emphasizing the gentle but steady correction that is required ***(Ballantyne and Macnicol, 2002)***.

Previous generations of surgeons forcibly manipulated deformed feet with the Thomas wrench. Under anesthetic the feel were forcibly wrenched and positioned in plaster. When corrected this was often spurious resulting in a "rocker-bottom" foot with the hindfoot remaining in equinus and the forefoot breaking. It sometimes resulted in a "bean-shaped" foot with the break occurring as a rotatory deformity at the ankle and the forefoot adduction remaining. Sometimes gross deformity remained, the patient requiring surgical footwear and sometimes developing pressure sores requiring amputation. Surgeons skilled in performing hindfoot arthrodesis for poliomyelitis were content to leave a deformed foot until puberty and then arthrodesis the hindfoot in a corrected position. This left a stiff but plantigrade foot ***(Porter, 1997)***.

Even Denis Browne who is famous for the Denis-Browne bar used for positioning of the foot recommended that the surgeon work with his hands up to the limits of his strength. The modern advocate of gentle manipulation with plenty of time, patience and slow stretching was Hiram Kite ***(Kite, 1972)***.

It is no longer permissible to forcibly manipulate the feet of children with talipes. Forced tearing of the tissues results in scar tissue , oedema and an uncontrolled spurious correction. Early management requires gentle positioning of the foot into an improved position without causing any damage to soft tissues. The surgeon has a choice of holding the repositioned foot with strapping, splints or plaster ***(Porter, 1997)***.

Manipulation:

Manipulation is the most important part of nonoperative treatment. The objective is to stretch the soft tissue contractures. Plaster of Paris cast serves to maintain the correction obtained by manipulation. Each successive manipulation gradually corrects more of the deformity until , hopefully, a full correction is obtained. The goals are to relocate the navicular in front of the talus and evert and dorsiflex the calcaneus ***(Turco, 1981)***.

All authors agree that manipulation should be "gentle". However, it must be pointed out that if it is "too gentle" it will be ineffective. Therefore, the manipulation should be gentle but yet strong enough to stretch the soft parts ***(Turco, 1981.)***

Methods of Conservative Treatment:

The principle of conservative management is that the foot is repeatedly manipulated towards a more normal shape. Some form of cast or strapping is usually applied to hold the foot in its maximally corrected position. Progressive improvement deformity occurs as the tight soft tissues are stretched and then held in their elongated position. This process is repeated until the deformity is either completely corrected or remains static with subsequent manipulations.

Conservative management is usually instituted as early treatment for all clubfeet. It is usually started as early as in the first week of life ***(Hulme2005)***.

Ponseti Method:

The Ponseti method has found great favour and demonstrated high rates of correction of deformity in a short period of time. Earlier reports of casting gave results that were not being reproduced by other centres. Attention to detail and good compliance with treatment are essential, particularly in the more difficult feet.

Dr. Ignacio Ponseti studied the functional and pathological anatomy of the foot in great detail. He dissected normal feet and clubfeet from stillborn babies and used cineradiography of normal and clubfeet to study tarsal joint movements. In the late 1940s he developed a method of treatment based on a simple but precise method of applying well moulded above knee casts, following a gentle manipulation of the foot ***(Hulme2005)***.

Kite's Method:

Kite (1939) was one of the main advocates of manipulation. He corrected each component of the deformity separately. He believed that heel varus could be corrected by everting the calcneus. Kite’s method did allow correction of cavus however correction of equines was lengthy. Other advocates recommended pronating forefoot. This fails to correct the cavus and locks the subtalar joint so that the calcaneus does not abduct. ***(Hulme2005)***.

The Kite/Lovell technique starts with stretching of the foot through longitudinal traction of the foot. The manipulation starts with reduction of the talonavicular joint placing a thumb over the head of the talus.

Pushing the navicular onto the head of the talus with the index finger of the same hand, apply a slipper cast after the talonavicular joint is reduced. As this cast dries, the foot is molded on Plexiglas simultaneously pushing the heel out of varus and flattening the foot to prevent cavus.

The forefoot is everted by pressing on the sole of the first metatarsal (correcting any cavus), attempting to push the cuboid and navicular laterally while abducting the foot by gradually increasing amounts ***(Kite, 1972)***.

The medial and plantar ligaments are progressively stretched until the foot is realigned to reduce the talonavicular and calcaneocuboid joints. Abducting the forefoot on the hindfoot as the slipper dries. Actually use the slipper cast to externally rotate the calcaneus and forefoot as a unit from beneath the talus. Then extend the cast to the thigh holding the foot externally rotated ***(Fukuhara et al., 1994)***.

Only at this point should one begin to attempt to correct the posteriorly contracted structures by dorsiflexing the foot. The foot is gradually brought into dorsiflexion by pulling down on the heel and applying pressure throughout the forefoot to avoid breaking the midfoot producing the so called rocker bottom deformity ***(Dimeglio et al., 1996)***.

Making no effort to correct equines until forefoot abduction and heel varus are corrected, Kite/Lovell would first try wedging casts for resistant equinus ***(Bernard and Reginald, 1986)***.

French Technique:

Several centers in France have developed a program for clubfoot treatment consisting of manipulative therapy using a minimum of immobilization. Masse is credited with originating this functional or manipulative correction method, which emphasizes daily corrective manipulation by trained physiotherapists during the first 8 weeks of life ***(Seringe and Atia, 1990)***.

Dimeglio et al. (1996) have reported good results using a method of intensive manipulation and continuous passive motion. This method of treatment remains popular in France but is not widely used in the United Kingdom. Treatment with this method requires long periods as an in-patient and is therefore expensive in terms of use of resources. This method is not said to abolish the need for soft tissue releases, but to reduce the extent of the surgery, predominately to posterior releases in order to correct the deformity. Mostly posterior releases alone are required.

Bensahel et al. (2004) described a method which involves regular gentle manipulations of the foot in a relaxed child and addresses the deformities in a very similar manner to Ponseti. Individual treatments last approximately 30 minutes and are done daily for 2 weeks then twice weekly until correction is achieved. This takes approximately 6 to8 weeks for the cavus, varus and adductus and up to several months to correct the residual equinus. A flexible splint is worn in between sessions. In his hands, Bensahel reports a 93% good or excellent outcome at skeletal maturity with only a 23% operation rate, although surgery tended to be more extensive than simple Achilles tenotomy. More severe cases of clubfoot were associated with longer treatment times, a higher rate of surgical intervention and a poorer outcome.

Seringe and Atia (1990) at St. Vincent de Paul Hospital, in Paris, added active solicitation of peroneal muscle function to the program of Masse and Bensahel, as well as use of the foot-plate with an adhesive bandage and later a custom brace.

Following manipulation, which generally includes maneuvers to disengage the navicular from the medial malleolus, derotation of the calcaneus and foot as a unit (the calcaneopedal bloc), downward traction to lengthen the heel cord and distract the hindfoot joints, and forefoot correction into abduction combined with eversion of the heel, the foot is immobilized with elastic bandages, similar to the original strapping technique described by Robert Jones ***(Tachdjan, 1990)***.

Other Methods of Manipulation:

Turco (1981) proposed the following sequence of correction of the deformity in congenital clubfoot, first, the forefoot adduction and hindfoot varus should be corrected, this should be corrected before any attempts to dorsiflex the foot and ankle, because the equinus of the foot and ankle can not possibly be corrected effectively if the heel varus has not been corrected adequately. Dorsiflexion attempted prior to correction of the hindfoot varus will create either a Rocker bottom deformity of the foot or flattening of the talotibial joint surfaces or both ***(Turco, 1981)***.

Carroll (1990) technique of manipulation is by putting the thumb on lateral side of the foot to stabilize the talus in the ankle mortise. Traction is applied to the first ray to stretch the tight tibialis posterior and to correct the forefoot supination and adduction. As the forefoot correction progresses, one attempts to reduce the talonavicular joint, if the talonavicular joint reduces, this means that one is beginning to correct some of the parallelism between the talus and oscalcis. At that point, one can begin correction of the equinus by pulling the heel away from the lateral malleolus and by pushing laterally and upward on the front of the oscalcis. That is the equinus is corrected by moving the back of oscalcis medially while the front of oscalcis moves laterally. One must avoid attempting to correct equinus by pushing up on the metatarsals, this can result in rocker-bottom deformity ***(Carroll, 1990)***.

It is desirable to remanipulate and change casts as frequently as possible every 3-4 days would be ideal. However, practically it has been impossible to do this more frequently than once a week. The casts are changed at weekly intervals for the first 6 to 8 weeks. During this period, the correction is most dramatic. Thereafter, the casts are changed less frequently. Treatment is continued as long as further correction is achieved with serial manipulation ***(Carroll, 1990)***.

Retention of Manipulation and Reduction:

After manipulation and reduction, the limb is thoroughly washed with soap and water, and cleaned and dried with alcohol. Then one of the following three methods of retention used:

1. Adhesive Strapping:

The strapping provides a dynamic and non rigid splint that prevents disuse atrophy and encourages the peroneal and ankle dorsiflexor muscles to function in the first few weeks of life. Other advantages of adhesive strapping are that it is inexpensive and can be applied easily, changed readily, and reapplied at frequent intervals and it's relatively soft, being least likely to cause pressure sores ***(Fukuhara, 1994)***.

2. Plaster of Paris Casting:

Plaster of Pairs cast immobilization is a static retentive apparatus. The correct application of plaster cast to an infant's foot requires considerable a skill, it should be applied accurately and with great attention to detail.

Three persons working in a harmonious team are necessary, a parent to hold the baby still, a trained assistant who will roll the sheet of wadding and plaster of pairs casting, and the surgeon, whose responsibility is to hold and mold the cast.

Proper and careful molding of the cast is very important. It should be remembered that the plaster of Paris cast is a retentive, not a corrective apparatus. Its purpose is to maintain the concentric reduction of the talocalcaneonavicular joint achieved by manipulation ***(Fukuhara, 1994)***.

3. Denis-Browne (D-B) Splint:

The Denis-Browne Splint (Fig. 16) consists of two foot pieces connected by a cross bar. Each foot is strapped into a foot piece. The rationale of this method depends up on the active kicking movement of each leg, exerting a corrective force on its counterpart ***(Fripp and Shaw, 1996)***, reported a high incidence of failure using the (D-B) splint for correction of deformity of clubfoot.

Fig. (16):

"Boots and bars" to maintain corrected feet *(Foster and Davis, 2007)*.

Operative Treatment

Soft Tissue Release

Because CTEV represents a spectrum of deformity, the extent of the surgery required will vary accordingly. The chosen procedure must address the needs of the individual patient, described by ***Bensahel et al. (1987)*** as the "a la carte" approach, as it must be remembered that undercorrection can lead to recurrent deformity, while over release may lead to a valgus heel and a painful, stiff foot.

Surgical Procedures:

I. Staged surgery:

Early posterior correction followed by medial soft tissue correction in the second year ***(Porter, 1997)***.

Posterior correction (first stage):

The first principle of the posterior operation is correction of the talus. The plantar flexed talus is in equinus and varus and when the equinus is corrected the varus also corrects. The forefoot supination is largely related to the varus of the talus and as the talus is corrected to the neutral position, the forefoot supination also corrects. Thus the first principle of posterior correction relies upon a posterior and medial capsulotomy of the talus to correct the plantar flexion, varus and supination deformity.***(Porter, 1997)***.

The second important principle is to rebalance the foot. The posterior and medial capsulotomy of the ankle has largely corrected the foot but it has created a problem. The deformed foot was balanced, but having now corrected the foot, there is an iatrogenic imbalance. The three medial muscles (tibialis posterior, flexor digitorum and flexor hallucis longus) are now under tension as a result of the correction. The peroneus longus on the outer side of the ankle passing under the foot to be inserted into the base of the first metatarsal and the medial cuneiform is now loose as a result of correcting the equinus and varus and forefoot supination.***(Porter, 1997)***.

An imbalance of muscles in a growing limb will inevitably produce a deformity at the joint where the imbalance occurs (Figs. 17 & 18). This is apparent in poliomyelitis and spina bifida. Thus the correction of a talipes foot, having produced an imbalance will inevitably result in a new deformity. The foot will relapse again into the equinovarus position unless the imbalance is treated. If a surgeon merely corrects a talipes deformity and does not operate on the loose peroneus longus, it will take 18 months before that child will be actively everting the foot ***(Porter, 1997)***.

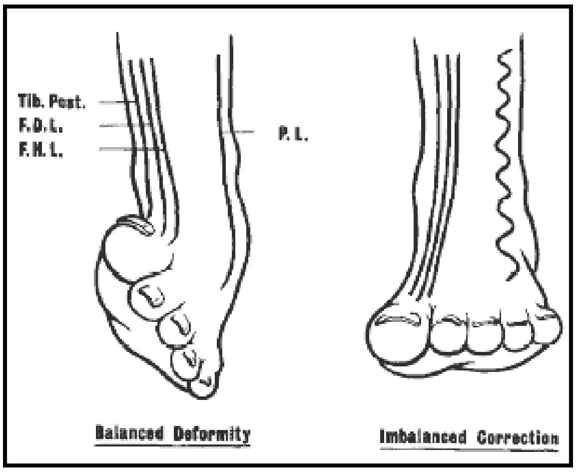


Fig. (17):

A diagram to show how the hindfoot is balanced in the deformed position, but becomes imbalanced when the deformity is corrected *(Porter, 1997)*.

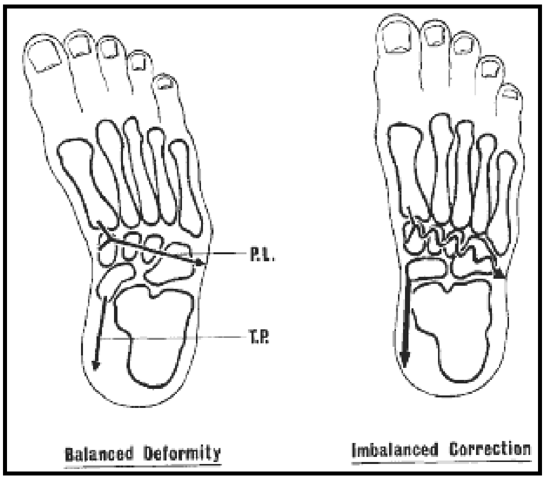


Fig. (18):

The forefoot is similarly balanced in the deformed position, but when corrected, the tubalis posterior is tight, and the peroneus longus is slack *(Porter, 1997)*.

Forefoot correction (second stage):

This operation is probably best carried out between 18 and 24 months of age. The child lies supine on the operating table with a sandbag under the opposite buttock and the table slightly tilted to the affected side so that the medial aspect of the foot faces upwards. A curved incision convex upwards is placed on the medial side of the foot towards the dorsal aspect, extending from the head of the talus to the base of the first metatarsal. The incision is deepened and the insertion of tibialis anterior to the medial cuneiform and base of first metatarsal identified. The three medial joints are then exposed with small, blunt, curved dissecting scissors. This avoids damage to the delicate cartilage of the tarsal bones. The medial aspect of the medial cuneiform-first metatarsal joint is exposed and then the navicular-cuneoform and finally the talo-navicular joint. This last joint is the most difficult. The capsule of the talo-navicular joint can be retracted to expose the head of the talus. With blunt scissors the capsule of these joints is divided on the medial aspect and then on the dorsal and volar aspects. When the forefoot is then abducted these joints will open several degrees to produce an excellent passive forefoot correction ***(Porter, 1997)***.

Towards the volar aspect of the incision the fascia is divided over the abductor hallucis and the tendinous component of this muscle is incised to correct a deforming force.

The curved skin incision is then sutured by "z-plasty". The postoperative dressings are applied and incorporated in plaster with considerable passive abduction force to maintain the correction. The plaster is changed at 2 weeks under general anesthetic when the sutures are removed and a below-knee walking plaster applied. This is then changed again at 4 weeks, 8 weeks and finally removed at 12 weeks ***(Porter, 1997)***.

Further posterior release surgery:

When there is a premature heel lift-off it is always worth carrying out a further posterior release operation. This will usually provide up to 20° more dorsiflexion. Every operation produces some increase in stiffness of the foot, but it is worth maintaining a plantigrade foot in childhood rather than having to carry out bony surgery at a later date ***(Porter, 1997)***.

Further medial corrective surgery:

When a forefoot adduction deformity recurs, it is best corrected early by excising again the medial scar and performing further capsulotomies of the three medial joints. It is sometimes worth extending the capsulotomy across the forefoot, through the mid tarsal joint and there are times when a lateral exposure and capsulotomy of the calcaneo-cuboid joint is worthwhile. The foot is supported in a below-knee plaster, with the foot abducted for a 12-week period ***(Porter, 1997)***.

II. Pantalar correction:

These surgeons who favour a radical correction at one sitting generally will expose the hindfoot through a Cincinnati incision transversely across the back of the foot (Fig. 19). The tendoachilles is exposed and lengthened, the medial three tendons and the neurovascular bundle are exposed and isolated.

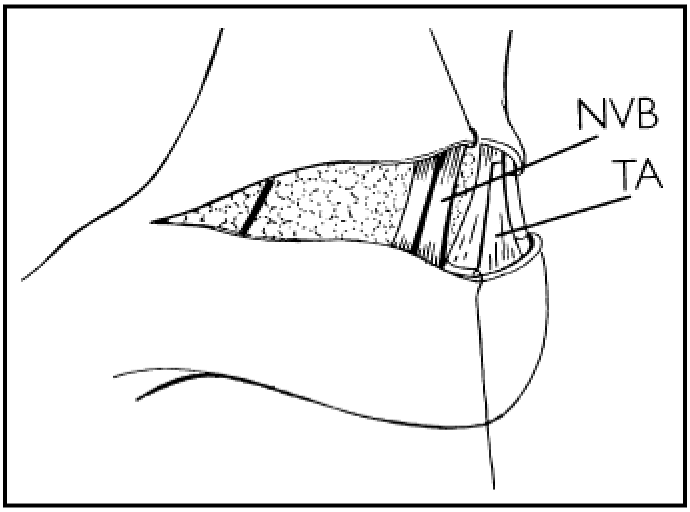


Fig. (19):
The Cincinnati incision allows full exposure of the posteromedial structures and can be easily extended to the talonavicular and calcaneocuboid joints. The neurovascular bundle (NVB) is identified and carefully exposed and the Achilles tendon (TA) z-lengthened over 1-1.5 cm *(Foster and Davis, 2007)*.

A capsulotomy is performed of the posterior and medial ankle joint, the posterior and medial subtalar joint and the talonavicular and navicular cuneiform joint with tenotomy of the abductor hallucis. The talocalcaneo-navicular ligament is divided and the foot can then be fully corrected (Fig. 20). The foot is supported in plaster for 6-8 weeks and night splints are frequently recommended for several months ***(Porter, 1997)***.

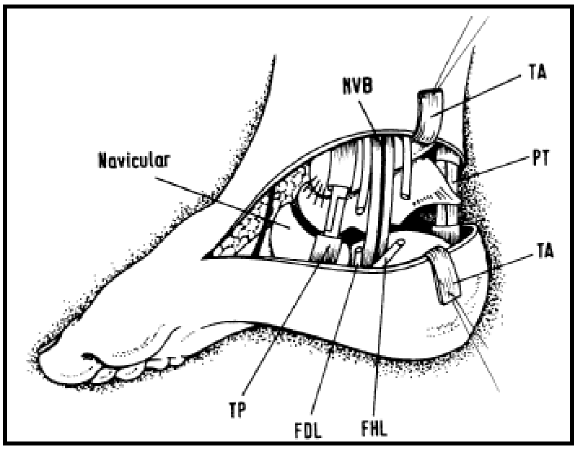


Fig. (20):
A full release of the ankle and subtalar joints is ensured. The deep part of the tibialis posterior (TP) tendon sheath and the anterior tibiotalar fibres in front of the tendons heath are preserved. TP tendon is step lengthened as is the Achilles tendon (TA). Flexor hallucis longus (FHL) and flexor digitorum longus (FDL) are sectioned in the tight foot. The peroneus longus and brevis tendons (PT) are preserved, but their sheaths are sectioned fully *(Foster and Davis, 2007)*.

Complete Subtalar Release (CSTR):

The posteromedial release was the standard procedure for the treatment of clubfeet. With the introduction of the Cincinnati approach, simultaneous access to the lateral as well as the posterior and medial sides of the foot has become possible. Thus, the complete subtalar release is considered procedure of choice in many pediatric orthopeadic centers ***(Crawfard, 1982)***.

One Stage Posteromedial Release:

Posteromedial release with internal fixation was observed by ***George, 1982)***. The results of surgery for resistant congenital talipes equinovarus deformity in 164 children (244 feet):

No patient was followed for less than two years. They were divided into three groups for analysis, based on their treatment. Group 1 consisted of seventy five children (112 feet) who had incomplete releases only, group 2 consisted of twenty three children (thirty-nine feet) who had a failed incomplete release followed by one stage complete posteromedial plantar release, without internal fixation, and serial application of casts, and group 3 consisted of sixty-six children (ninety-three feet) who had the complete posteromedial plantar release as the initial surgical procedure.

- Group 1 had 42%.
- Group 2 had 79%.
- Group 3 had 86%.

Excellent or good long-term results were obtained by complete poster medial plantar release ***(George, 1982)***.

Bony Surgery

Calcaneal Osteotomy

Dwyer operation:

This operation aims to correct varus of the heel, increasing its height and placing it directly under the line of weight bearing, so enabling the force of the calf muscle to be transmitted into the foot or even slightly towards its outer border, as in the normal foot ***(Dwyer, 1963)***.

Osteotomy of the First Cuneiform as Treatment of Residual Adduction of the Fore Part of the Foot:

In children who are beyond the age of infancy, a common residual deformity after treatment of clubfoot is persistent adduction of the fore-part of the foot.

If untreated, the deformity may make the fitting and wearing of shoes difficult, on intoeing gait may by evident, and some degree of metatarsalgia may supervene in later life. The Fowler opening wedge osteotomy of the first cuneiform, accompanied by radical plantar release is used for treatment of this deformity ***(Aaron, 1984)***.

Triple Arthrodesis: Details chapter (surgeries recommended by Ponseti).

Talectomy: Details chapter (surgeries recommended by Ponseti).

Tendon Transfer Surgery

Tibialis anterior tendon transfer:

Details chapter (surgeries recommended by Ponseti)

Dillwyn-Evans Procedure

Dillwyn-Evans recommended a very long course of conservative management, using plaster in the early stages, sometimes with closed tenotomy of the tendo Achilles. Surgery is delayed until about 6 years of age and then the foot is corrected in a single operation. The posterior aspect of the plantar fascia is divided and the tibialis posterior lengthened. Capsulotomies are performed on the talo navicular joint and the anterior part of the subtalar joint. The tendo-Achilles is lengthened and the posterior capsule of the ankle divided. The deformity is then manually corrected by forcible manipulation. A wedge-shaped osteotomy is performed at the calcaneocuboid joint to correct the varus deformity, and is held with two staples. The foot is in plaster for 4 months ***(Taylor and Thompson, 1979)***.

External Fixation

Ilizarov Techniques:

Ilizarov techniques are ideally suited to treatment of a variety of paediatric deformities ***(Grant et al., 1992; Rajacich et al., 1992)***. Although Ilizarov methods are best known for osteogensis by distraction, the technique also allows soft tissue histiogenesis ***(Grant***

et al., 1992). There is gradual lengthening of vessels, nerves and connective tissues. This is applicable to CTEV, where conventional surgery, particularly in the revision situation, may put the tenuous vascular supply of the affected foot at risk. In fact, the principles of this technique are already used in CTEV treatment; corrective casting as described by Ponseti relies on similar soft tissue distraction. However, the Ilizarov method allows a more controlled application of corrective forces and offers an alternative to the use of osteotomies in the correction of recurrent or resistant CTEV deformity, although osteotomies may be used to augment Ilizarov techniques in the correction of complex deformities ***(Tarrif and Carrol, 1992; Grant et al., 1992)***. The Ilizarov frame permits correction of deformity in multiple planes by gradual distraction allowing joint realignment.

Complications of Operative Treatment

Serious complications are uncommon and depend very much on the type of surgery performed including Avascular necrosis (AVN), infection, overcorrection, pain, stiffness , recurrence, loss of sensation to the foot, scar hypersensitivity, wound sloughing and gangrene ***(Ballantyne and Macnicol, 2002) (Cooke et al., 2008)***.

Postoperative Complications:

Early Complications:

1. Wound infection:

At review of pantalar reduction it was found that some patient suffered superficial wound infection, all required revision of the soft tissue release and later osseous correction. This complication is of great consequence and can only be avoided by scrupulous care in handling the skin edges and by waiting two weeks after operation before manipulating the foot to achieve final correction ***(Ghali, 1983)***.

2. Circulatory disturbance:

Circulatory disturbance were noted after Cincinnati incision, skin closure was initially found to be a problem after one stage correction of a severe club foot deformity. Extreme blanching of the skin with the foot in neutral position is seen after closure and after releasing, the tourniquet prior to closure. In such case Crawford recommended that the cast should applied with the foot in less than maximum correction and in some equinus angulation ***(Crawford, 1982)***.

Late Complications:

1. Skin contracture:

Skin contracture may result from improper planning of skin incision preoperative. The posteromedial skin contracture is a potent deforming force which is responsible for many failures or relapse. Contracture of the posteromedial skin is an impediment to correction of moderate and severe deformities at all ages and its release is always indicated ***(Mittal, 1987)***.

2. Recurrence of deformity:

Club foot recurs after inadequate, initial treatment or poor aftercare, even with good treatment (Fig. 21). The incidence being reported as high as 25%, recurrence may due to:

a) Inadequate release of all tight structure.
b) Improper reduction of talonavicular joint.
c) Skin contracture.
d) Improper correction of muscles imbalance.

(Mittal, 1987).

Fig. (21):
Recurrent Cavovarus deformity following corrective surgery. First ray incompetence is demonstrated suggesting incomplete reduction of the talonavicular joint. If the foot is mobile then further soft tissue surgery may be appropriate, otherwise an osteotomy may be required *(Ballantyne Macnicol, 2002)*.

3. Growth changes:

Skeletal deformities of the foot increase with growth if deformities persists. Improper tendon transfer can lead to reversal of deformity and overcorrection. Excessive release of subtalar joint lead to overhanging of the medial border of the mid part of the foot and excessive valgus position of the hind part of the foot (Fig. 22). Growth arrest of the tarsal bone may happen due to use of staples ***(Mittal, 1987)***.

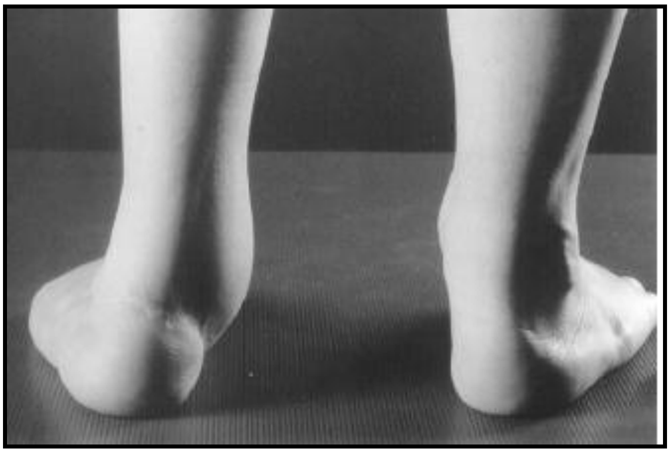


Fig. (22):

The over-corrected foot characterized by the valgus alignment of the heel *(Ballantyne Macnicol, 2002)*.

4. Hidden equinus:

This presents when the heel does not touch the ground while sitting on the feet, even though the foot is fully plantigrade on standing. This deformity usually follows inadequate soft tissue operation ***(Tayton, 1979)***.

5. Stiffness of subtalar joint:

Inversion and eversion of the hind foot were found to be severely limited in 50% of the feet who treated by Dillwyns evans operation ***(Tayton, 1979)***.

Stiffness of the ankle in form of dorsiflexion and plantar flexion were judged to be severely limited in 20% of the patient who treated also by Dillwyn evans operation.

6. Shortening of the foot:

Tayton (1979) noted shortening of the foot with average discrepancy in the length of the two feet in unilateral cases was 1.9 cm after Dillwyn evans operation.

Philosophy

Fig. (23): Dr. Ponseti *(Ponseti et al., 2004)*.

The clubfoot is one of the most common congenital deformities. Many cases are associated with neuromuscular diseases, chromosomal abnormalities, Mendelian and non-Mendelian syndromes, and in rare cases with extrinsic causes. In the present essay, we are limiting ourselves to the study of the idiopathic congenital clubfoot deformity, occurring in otherwise normal infants in Caucasians, the disorder occurs in about one per thousand; among the Japanese, it occurs half as frequently; in South African blacks it occurs three times as frequently; and in Polynesians it occurs six times as frequently. The ratio of male to female is 3 to 1, and 40% of cases are bilateral ***(Chung et al., 1969; Yamamoto, 1979; Cowell and Wein, 1980; Cartlidge, 1984; Yang et al., 1987)***.

The pathology, the functional anatomy of clubfoot, and the structural changes in its ligaments, tendons, and muscles, must be well understood to arrive at a sound approach to early non-surgical treatment of this deformity. The congenital clubfoot is a complex three-dimensional deformity having four components: equinus, varus, adductus, and cavus. Since the definitions of foot movements and of movements of tarsal bones are confusing in the orthopedic literature, yet basic to the understanding of the deformity and its treatment. Ponseti (Fig. (23), described the direction of rotation of a tarsal bone by the appropriately used terms of abduction/adduction, flexion / extension, and inversion / eversion (Fig. 24).

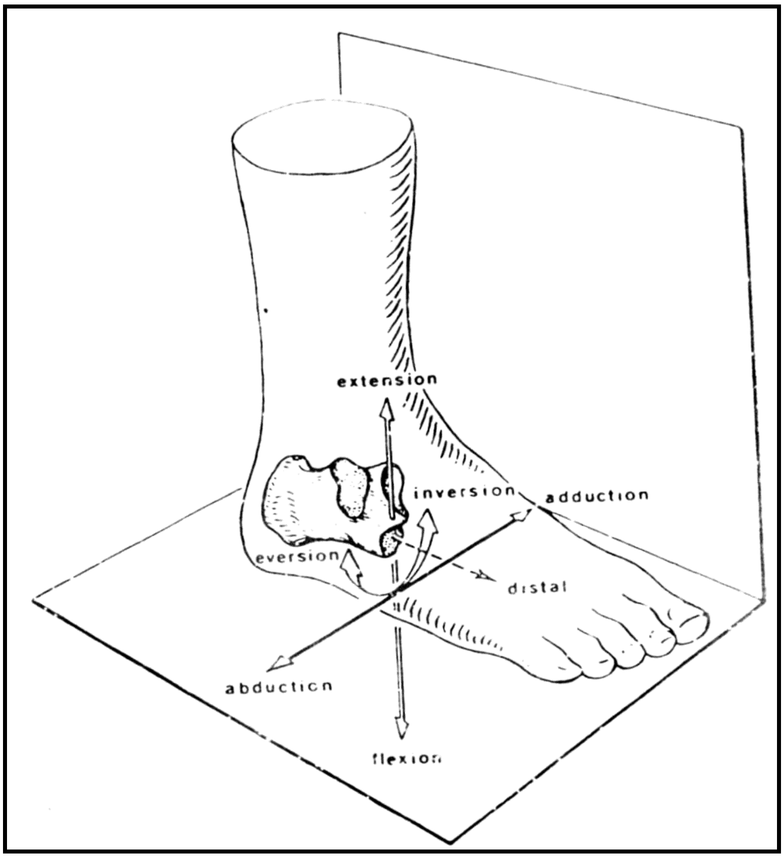


Fig. (24): Definitions of movements for a tarsal (calcaneal) bone with respect to the body planes *(Van Langelaan, 1983)*.

1. Adduction is that movement of a tarsal bone in which the distal part of this bone moves towards the median body plane;
2. Abduction is this movement in the opposite direction;
3. Flexion is that movement of a tarsal bone in which the distal part of that bone moves in the plantar direction;
4. Extension is the movement in the opposite direction;
5. Inversion is the movement of a tarsal bone in which the undersurface of the bone moves towards the median body plane;
6. Eversion is the movement in the opposite direction.

(Ponseti, 1996).

He reserved the term supination for combined movements of adduction, flexion, and inversion, and the term pronation for combined movements of abduction, extension, and eversion.

The term heel varus is used for movements of inversion and adduction of the calcaneus, and the term heel valgus is used for eversion and abduction of the calcaneus.

The term forefoot supination is used for movements of inversion and adduction of the forepart of the foot and the term forefoot pronation is used for eversion and abduction of the forepart of the foot.

Equinus refers to an increased degree of plantar flexion of the foot.

Cavus refers to the increased height of the vault of the foot ***(Ponseti, 1996)***.

The treatment of clubfoot has been controversial throughout the last 150 years. When Ponseti arrived in the University of Iowa Medical School to complete his training in orthopedic surgery in 1941, the clubfoot was treated by different members of the staff, some with manipulations and plaster casts, others by taping the feet in Denis Browne splints, and still others by using the Kite's (1930) method: removing some wedges from a plaster shoe to correct the components of the deformity. The Thomas wrench was occasionally used to correct residual deformities but finally most feet ended up in surgery. The Brockman technique for the medial release of the subtalar and midtarsal joints was one of the most common operations performed in the department ***(Brockman, 1930)***. Ponseti and his colleagues expanded the medial release operation to include a posterior release and often they made a lateral incision to free the tarsal joints so as to align the tarsal bones with the cuneiforms and metatarsals ***(Le Noir, 1966)***. Most often this surgery left deep scarring, joint stiffness and weakness. The techniques of treatment and results in their department before 1948 were reported by Steindler, Le Noir, and others ***(Blumenfeld et al., 1946; Steindler, 1950; Le Noir, 1966)***.

Robert Jones from Liverpool and London wrote in (1923) that he had "nerve met with a case where treatment has been started in the first week where the deformity could not be completely rectified by manipulation and retention in two months" ***(Jones, 1923)***. His experience could not be duplicated in Ponseti's department nor in other clinics Ponseti visited, and the results were far from perfect after a very prolonged treatment. Faced with these disappointing results, he set out to discover how a clubfoot could be corrected through manipulation and retention casts in a two-month period after birth, as Robert Jones had claimed.

Although Kite was the leading advocate of the conservative treatment of clubfoot for many years and should be commended for his lifetime efforts to try to resolve the clubfoot problem without surgery, his treatment was lengthy and short of satisfactory. Ponseti was determined to discover the flaws that prevented him from reaching Robert Jones's claimed results. In 1960, he visited Kite in Atlanta for a few days to observe his method of treatment. In 1965, he gave a course together in Caracas, Venezuela, during which each of them applied plaster casts. Their methods differed greatly.

Kite corrected each component of the deformity separately instead of simultaneously, and although he managed to correct the cavus and to avoid foot pronation and its harmful consequences, the correction of the heel varus took him an inordinate amount of time since he did not realize that the calcaneus must abduct so it can be everted. However, he managed to obtain plantigrade feet ***(Ponseti, 1996)***.

From his observations in the clinic and in the operating room, he realized that the orthopedists' failures in the treatment of clubfoot were related, in part, to a poor understanding of the functional anatomy of the normal foot as well as of the clubfoot. Without this understanding, it is impossible to alter the forces that caused the deformity and apply the proper corrective manipulations and retaining casts. He then studied the pathological anatomy of the clubfoot. He dissected several normal feet and three clubfeet of stillborn babies, and obtained serial sections of the two clubfeet of a 17-week aborted fetus. Under cineradiography, he studied the range of motions of the tarsal joints of normal feet and of clubfeet. He trained his fingers to palpate the joints and bones and feel their motions both in normal feet and in clubfeet ***(Ponseti, 1996)***.

Based on these studies, Ponseti developed and refined a uniform type of treatment in the late forties. By the late fifties, when reviewing Ponseti's patients for a short-term follow-up article ***(Ponseti and Smoley, 1963)***, he knew that he had found the proper approach to the treatment of clubfoot, a treatment that has been followed to the present day in his department with optimum results. Fellows, joining Ponseti's pediatric orthopedic program were impressed to discover the ease with which most clubfeet can be well corrected without surgery in a relatively short time in contrast to the poorer results experienced in other hospitals after extensive manipulations and surgeries. Although relapses were frequent, usually two years after treatment, most could be successfully treated with further manipulations and castings for four to six weeks or with a transfer of the tibialis anterior tendon in severe cases.

Many orthopedic specialists, however, choose surgery over manipulation as the best treatment for clubfeet. This view explains the disappointing results obtained after prolonged faulty manipulations and casting, usually carried out by assistants not thoroughly acquainted with the complexities of the deformity. To correct the severe supination the clubfoot is forcefully pronated instead of abducted. These manipulations cause an increase of the cavus and severe distortions in the tarsal joints and midfoot, making further treatment, whether manipulative or surgical, very difficult or impossible ***(Ponseti, 1996)***.

The biological anomalies in congenital clubfoot have not been studied in great depth. Many orthopedists dealing with clubfoot lack an understanding of the nature of its anatomy and kinematics and of the pathology of the clubfoot's ligaments, tendons and muscles, although such an understanding is crucial for the treatment of this deformity. This lack of understanding has led to major errors in treatment. Most publications on the subject deal with a large variety of surgical interventions under the mistaken assumptions that early alignment of the displaced skeletal elements results in a normal anatomy of bones, joints, ligaments, capsules, and muscles, as well as the mistaken assumptions that roentgenographic appearance in early ages relates to long-term function, and that joint capsules and ligaments can be stripped away and tendons can be lengthened with impunity. These misconceptions have resulted in poor corrections, much suffering, and a number of iatrogenic deformities ***(Ponseti, 1996)***.

In a publication ***(Simons, 1994)*** of the papers presented at a congress on clubfeet, there are scores of reports on surgical procedures, many of them untested, and some exclusively designed for the treatment of iatrogenic deformities. The chapters in that publication on complications of clubfoot surgery attest to the tragic failures of early surgery.

An immediate surgical correction of the clubfoot components is anatomically impossible. After extensive dissections to release joint capsules and ligaments and to lengthen tendons, the tarsal joints do not match. In order to hold the bones roughly in proper alignment, the surgeon is forced to transfix them with wires. Stripping the joint capsules and ligaments, and lengthening tendons cause joint damage, stiffness, over corrections or under corrections, and muscle weakness. Long-term functional results of these operations have not been published. In Ponseti's experience many clubfeet treated surgically become stiff and painful after the second decade of life. The numerous clinical and roentgenographic measurements used to evaluate treatment are subjective in nature and are not always reproducible. In addition, results before completion of skeletal maturity do not foretell long-term functional outcomes ***(Laaveg and Ponseti, 1980; Cummings et al., 1994)***.

A well-conducted orthopedic treatment, based on a sound understanding of the functional anatomy of the foot and on the biological response of young connective tissue and bone to changes in direction of mechanical stimuli, can gradually reduce or almost eliminate these deformities in most clubfeet. Less than 5% of infants with very severe, short, fat feet with stiff ligaments unyielding to stretching will need surgical correction. The parents of all the other infants may be reassured that their baby, when treated by expert hands, will have a functional, plantigrade foot which is normal in appearance, requires no special shoes, and allows fairly good mobility.***(Ponseti, 1996)***.

The guidelines for the clubfoot method of treatment which Ponseti developed in 1948 are as follows:

1. All the components of the clubfoot deformity have to be corrected simultaneously with the exception of the equinus which should be corrected last.
2. The cavus, which results from a pronation o the forefoot in relation to the hindfoot, is corrected as the foot is abducted by supinating the forefoot and thereby placing it in proper alignment with the hindfoot.
3. While the whole foot is held in supination and in flexion, it can be gently and gradually abducted under the talus secured against rotation in the ankle mortice by applying counter-pressure with the thumb against the lateral aspect of the head of the talus.
4. The heel varus and foot supination will correct when the entire foot is fully abducted in maximum external rotation under the talus. The foot should never be everted.
5. Now the equinus can be corrected by dorsiflexing the foot. The tendo-Achilles may need to be subcutaneously sectioned to facilitate this correction.***(Ponseti, 1996)***.

The same guidelines are applied in the initial treatment of the severe, rigid clubfeet in patients with arthrogryposis and myelomeningoceles. In these infants, however, the deformity may be more difficult or even impossible to correct satisfactorily. Any improvement in the alignment obtained is usually lost shortly after the plaster cast is removed. Relapses occur even after extensive tarsal joint releases. In these severe deformities talectomy after one year of age is the best operation to obtain plantigrade feet, albeit with deficient function.***(Ponseti, 1996)***.

Ponseti casting technique was learned from Böhler and applied during the Spanish Civil war in 1936-1939 when treating, more than 2000 war-wound fractures with unpadded plasted casts. Precise, gentle molding of the plaster over the reduced subluxations of the tarsal bones of a clubfoot is just as basic as the molding of a plaster cast in a well-reduced fracture ***(Ponseti, 1992)***.

It was disappointing that his first article on congenital clubfoot, published in the "the journal of Bone and Joint surgery" in March 1963, was disregarded. It was not carefully read and therefore, not understood. His article on congenital metatarsus adductus, published in the same journal in June 1966, was easily understood, perhaps because the deformity occurs in one plane. The approach was immediately accepted, and the illustrations were copied in most textbooks ***(Ponseti, 1998)***.

A few orthopedic surgeons studied his technique and began to apply it only after the publication of his long-term follow-up article in 1995, the publication of his book a year later, and the posting of internet support group web sites by parents of babies whose clubfeet he had treated. He has been reprimanded for not pushing the method more forcefully from the beginning ***(Pirani, 2001)***.

The reason that congenital clubfoot deformity was not understood for so years and was so poorly treated is related, he believes, to the misguided motion that the tarsal joints move on a fixed axis of motion ***(Pirani, 2001)***.

Kinematics

The anatomy and kinesiology of the tarsus of the normal foot and of the clubfoot are lucidly described by ***(Farabeuf, 1893)*** in his book, "Precis de manual operatoire". In the fourth edition, Farabeuf clearly illustrates how in the normal foot the calcaneus moves under the talus by rotating around the inner fibers of the interosseous talocalcaneal ligament. Owing to the inclined contours of the talocalcaneal joint surfaces, as the calcaneus rotates under the talus, it adducts, flexes, and inverts. Farabeuf used the metaphor that it tacks, pitches, and rolols. As the foot goes into varus, the calcaneus adducts and inverts under the talus while the cuboid and the navicular adduct and invert in front of the calcaneus and the talar head, respectively. Farabeuf considered the displacement of the tarsal bones in a child's clubfoot to be the most extreme positions caused by the excessive pull of the tibialis posterior abetted by the gastrosoleus, tibialis anterior, long toe flexors, and plantar muscles.

He states that the deformity of the talar neck is not "a morphological caprice of nature" but results from the "molding" caused by the posteriorly displaced and inverted navicular. Farabeuf illustrates how the ossification center of the talus responds to the abnormal pressures of the displaced navicular. He further states that the skeletal deformities in the infant are usually reversible. If not treated, the subluxations of the navicular and the cuboid present at birth worsen with the progressive displacement of these bones until a nearthrosis develops. Although these deformities may be corrected, he warns, the soft tissues have a "deforming power" causing recurrences. In Farabeuf's time, infants rarely received early treatment and surgery was necessary to correct the deformity in the older child.***(Ponseti, 1996)***.

Huson's Ph.D. thesis in Dutch, "A functional and anatomical study of the tarsus', published in Leiden in 1961, greatly advanced Farabeuf's observations and was a breakthrough in the understanding of the tarsal mechanism of the normal foot.

Joint motions are determined by the curvature of the joint surfaces as well as by the orientation and structure of the binding ligaments. In the proximal part of the normal foot there is a complex combination of motions of the tarsal joints which are integrated in what Huson calls a "closed kinematic chain". The ligaments play an important role as "kinematic constraints of the joints", apart from their share in forced transmission to support the elastic vault structure of the foot ***(Ponseti, 1996)***.

Huson demonstrated that the tarsal joints do not move as single hinges but rotate about moving axes as is the case in the knee. Each joint has its own specific motion pattern. Huson's work is supported by Van Langelaan, who using a roentgenstereophotogrammetric method in post-mortem specimens, has shown that the motions of the tarsal joints can be described by means of a cone or fanshaped bundle of discrete axes, representing the successive positions of a particular moving axis (Fig. 25).

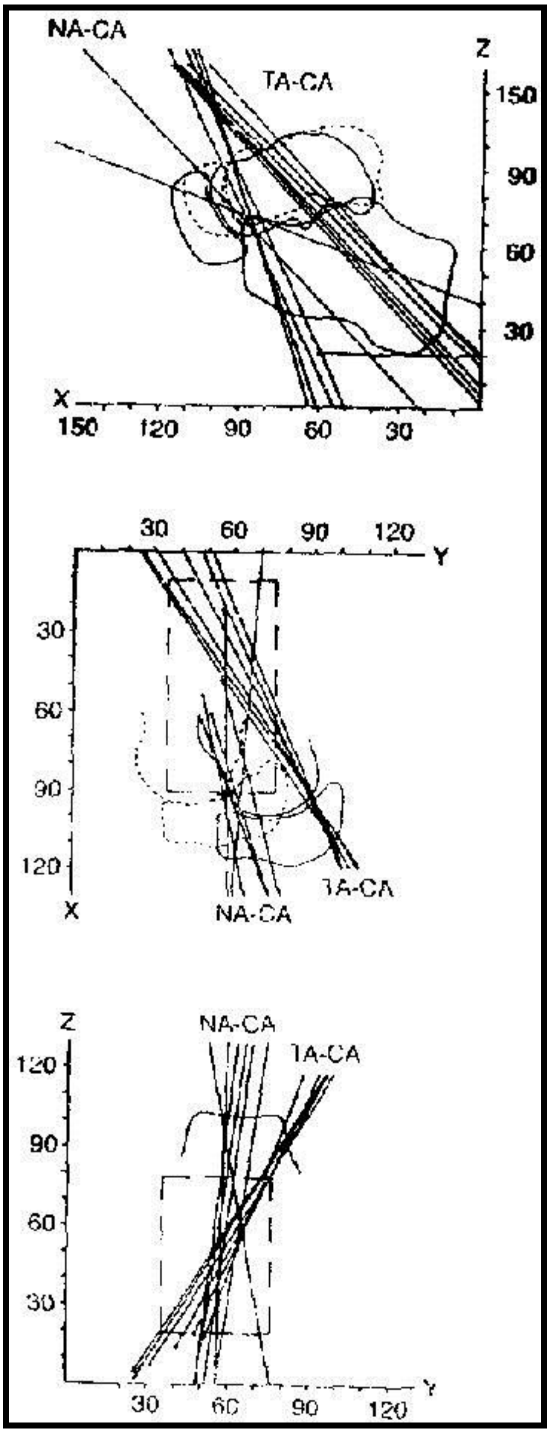


Fig. (25): A kinematical analysis of the tarsal joints: Superpositioned axis bundles of the talocalcaneal (TA-CA) and calcaneonavicular (NA-CA) joints. *Van Langeiaan, 1983)*.

He found that these successive positions followed fixed patterns which were characteristic for the joint concerned and that according to these results axes bundles could be established for all the tarsal joints ***(Van Langelaan, 1983)***. Van Langelaan further observed that the magnitude of the total range of tarsal rotations varies from a mean of 23.6 degrees for the talocalcaneal joint, to a mean of 43.1 degrees for the talonavicular joint, and to only a mean of 15.8 degrees for the calcaneocuboid joint. The last two joints, therefore, have not only different axes bundles but also perform rotations of different magnitude. Huson summarizes, there is no such thing as a single Chopart joint, or midtarsal joint ***(Huson et al., 1986)***. ***Benink (1985)*** showed that continuous motions of the tarsal joints in vivo follow paths similar to the step-like motions recorded in Van Langellaan's experiments. The calcaneocuboid joint has a "close-packed position" when the loaded foot is in the neutral position. During inversion the surfaces of the calcaneocuboid joint are in restricted contact only and enter into a "loose-pack position" regulated by the plantar calcaneocuboid ligament. The longest fibers of this ligament are located laterally and the shortest fibers are located on the medial side of the foot (Fig. 26).

The talocalcaneal joint also has its "close-packed position" in the neutral position of the loaded foot and goes through "loose-pack position" during inversion, regulated by the strong strands of the deep talocalcaneal interosseous ligaments, which play a kinematic role similar to that of the plantar calcaneocuboid ligament (Fig. 27).

The talocalcaneonavicular joint is an arthrodial joint were the connection between the talus, the navicular, and the calcaneus is made

(E.B. Smith, 1896; J.W. Smith, 1958). The plantar calcaneonavicular ligament forms part of the joint and supports the head of the talus while contributing to the maintenance of the arch of the foot (Fig. 26). This ligament contains abundant elastic fibers which contract during inversion ***(Ponseti, 1996)***.

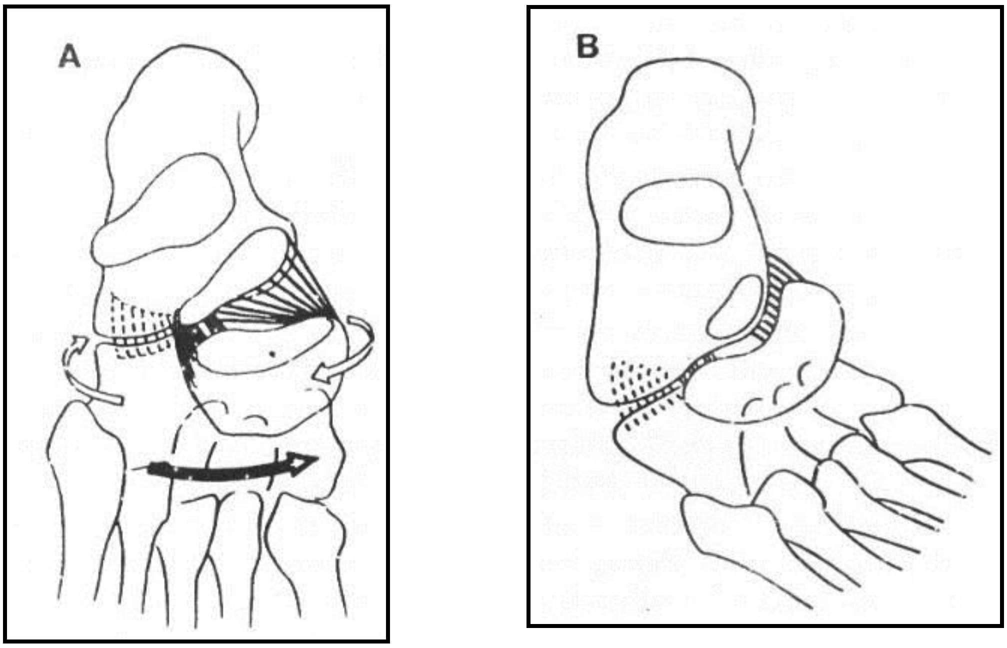


Fig. (26): *(Ponseti, 1996)*.

A) Schematic dorsal view of the subtalar footplate of a normal foot demonstrating the arrangement of the longitudinally running plantar calcaneonavicular and calcaneocuboid ligaments. The shortest fibers are found in the midline of the foot whereas the longest are found at the outer margins of the foot. This arrangement allows inversion and eversion motions of the navicular and cuboid with respect to the talus and the calcaneus (light arrows) combined with an adduction of the navicular and cuboid (heavy arrow) *(Huson, 1961)*.

B) In the clubfoot the shortening of the calcaneonaviucular ligament and medial displacement of the navicular greatly reduces the size of the subtalar foot plate and causes the foot to adduct in front and under the talus.

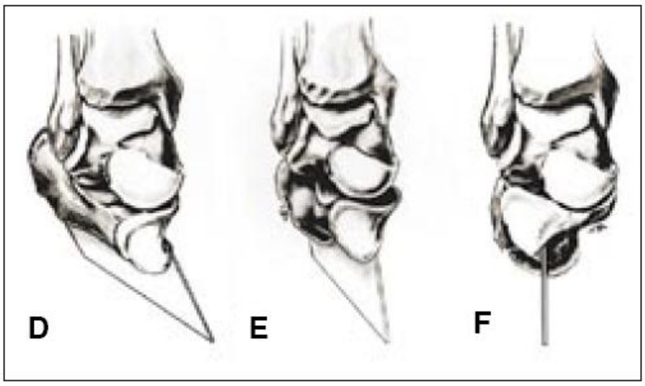


Fig. (27): In the clubfoot (D), the anterior portion of the calcaneus lies beneath the head of the talus. This position causes varus and equines deformity of the heel. Attempts to push the calcaneus into eversion without abducting it, (E) will press the calcaneus against the talus and will not correct the heel varus. Lateral displacement (abduction) of the calcaneus to its normal relationship with the talus, (F) will correct the heel varus deformity of the clubfoot *(Ponseti et al., 2004)*.

Motions of the tarsal joints occur simultaneously. If one of them is blocked the others are functionally blocked, too. This feature indicates that the tarsal joints belong to what Huson calls a "constraint mechanism".***(Ponseti, 1996)***.

In the normal foot, rotations of the leg are converted by the tarsal mechanism into inversion and eversion motions of the foot ***(Lundberg, 1988 & 1989)***. External rotation of the leg is followed by external rotation of the talus, causing the calcaneus to invert and abduct slightly owing to the slope of the posterior talocalcaneal joint. Inversion and slight abduction of the calcaneus cause inversion and adduction of the cuboid and the navicular, thereby raising the arch of the foot and thus inducing the first metatarsal to flex so that it reaches the ground. Inward rotation of the tibia causes the calcaneus to evert and the arch to flatten. In every one of these motions the ligaments are crucial structural elements, especially the horizontally running fibrs of the anterior talofibular ligament ***(Inman, 1976; Huson et al., 1986)***. Benink extended Huson's work to living subjects and found that the input moment to be applied to the tibia to supinate the tarsus by rotation varied greatly from one individual to another ***(Huson et al., 1986)***.

There is no separation between the motion of the ankle and that of the subtalar joint in living subjects. Motion of the foot-shank complex in any direction occurs by the combined motions of both joints (called kinematic coupling by ***Siegler et al., 1988***), and is the result of rotations at both the ankle and the subtalar joints. The contribution of the ankle joint to dorsiflexion/plantarfiexion of the foot is larger than that of the subtalar joint. The contribution of the subtalar joint to inversion/eversion is larger than that of the ankle joint. The ankle and the subtalar joints participate almost equally to internal/external rotation of the foot-shank complex ***(Siegler et al., 1988)***.

In the clubfoot, the kinematics are greatly altered by the severe shortening of the medial and posterior tarsal ligaments and by the tightness of the tibialis posterior and gastrosoleus muscles. The fibrotic and contracted deltoid ligament holds the calcaneus in inversion. The navicular is held severely medially displaced and inverted by the fibrosis of the tibionavicular, the plantar calcaneonavicular ligaments, and the pull of the tight tibialis posterior tendon ***(Attenborough, 1966)***.

In the sections of the fetuses studied, the talocalcaneal interossei, the bifurcate, and the navicular induces medial displacement and inversion of the cuboid and of the calcaneus. Invariably, the navicular and cuboid are severely medially displaced as well as inverted.

The shape of the talar joint surfaces is changed, now adapting to the altered position of the tarsal elements greatly. Only a few degrees of passive abduction can be obtained in the tarsus of rigid feet, while 20 to 30 degrees are reached in less severe cases. Even with forced abduction, the tarsus of an untreated clubfoot cannot be moved to a neutral, normal position.

Although the tarsal bones are displaced and the tarsal joints are misshaped, they are congruent in the clubfoot position. In this position both the talonavicular and the talocalcaneal joints are in a close-packed position. The deformed surfaces of the calcaneocuboid joint are in restricted contact only. The joints become incongruent when correction of the deformity is attempted unless the correction is made gradually for several months allowing for the gradual remodeling of the joint surfaces. A surgical realignment of the skeletal elements requires severing most tarsal ligaments, causing all the tarsal joints to subluxate into a wholly unstable position.***(Ponseti, 1996)***.

The ligaments of the joints between the navicular and the cuneiforms, and those at the Lisfranc line and in the toes, are not involved in the fibrosis that affects mostly the hindfoot. Although adducted, the forefoot is less supinated than the hindfoot. Thus a cavus results with the first metatarsal in greater plantar flexion than the lateral metatarsals. The joints of the anterior part of the foot are nearly normal even though the first cuneiformetatarsal joint may be medially slanted in some clubfeet, as observed in many feet with metatarsus adductus ***(Ponseti, 1996)***.

In the clubfoot, active and passive mobility of the anterior part of the foot and toes is only slightly restricted. In most cases at birth, the forefoot adduction can be corrected to a near normal position at the Lisfranc line, and the metatarsals can be flexed and extended

through a normal range of motion. Even in cases where the first cuneiformetatarsal joint is medially slanted, the first metatarsal can be moved into the proper alignment with the other metatarsals, thereby eliminating the cavus.

The contrast between the stiffness of the severely supinated hindfoot and the suppleness of the forefoot poses a challenge to the orthopedist attempting to correct the deformity. The normal foot can freely supinate and pronate. However, attempts to pronate a clubfoot will only pronate the forefoot but not the hindfoot. Not only are the hindfoot ligaments very stiff, but the axes of motion of the taral joints are severely medially displaced resulting from the extreme medial rotation and displacement of the tarsal bones. Therefore, the hindfoot must be abducted in supination under the talus so that the tight medial ligaments can be stretched. The inversion of the calcaneus, navicular and cuboid will gradually decrease as the foot is further abducted. Forceful pronation of a clubfoot will cause a breach in the midfoot and increase the cavus (***Ponseti, 1996)***.

Technique of Manipulation

Ponseti advised to start manipulation after birth as soon as possible, make the infant and the family comfortable. Allow the infant to feed during the manipulation and casting processes (Fig. 28). Casting should be performed by the surgeon whenever possible. Each step in management is repeated for both right and left feet ***(Ponseti,2000)***.

Fig. (28): Allow the infant to feed during the manipulation *(Ponseti et al., 2004)*.

Cavus

The cavus or high arch is a very common component of the clubfoot deformity. The cavus is often confused with the forefoot equinus, also called plantaris, a rare deformity in which all five metatarsals are in nearly equal degree of plantar flexion. Occasionally, the plantaris is seen in a foot with congenital heel varus and adduction but without equinus. To correct the plantaris all metatarsals must be dorsiflexed simultaneously ***(Ponseti, 1996)***.

In most clubfeet the cavus deformity does not involve flexion of the entire forefoot. Rather, there is excessive plantar flexion primarily of the first metatarsal. Lateral roentgenograms of clubfeet often show the fifth metatarsal to be well aligned with the cuboid and the calcaneus, whereas the first metatarsal is in severe plantar flexion. Consequently, although the entire foot is supinated, the forefoot is pronated with respect to the hindfoot, thereby causing the cavus deformity. This deformity is, therefore, the result of the first metatarsal being in more plantar flexion than the last three metatarsals ***(Ponseti, 1996)***.

In the normal foot as in the clubfoot, the forefoot, the forefoot can be twisted into inversion and eversion around a longitudinal axis formed by the second metatarsal solidly slotted into a socket formed by the cuneiform bones, in ***Huson's (1991)*** words. A pronatory twist of the forefoot with a rise in the plantar arch occurs in stance in the normal foot when the leg externally rotates and the talus abducts forcing the calcaneus into inversion. In the clubfoot the arch can be very high.

Correction of the cavus component of the clubfoot is not addressed in most publications. In the 1940s, Steindler stated that "the cavus deformity was one component which at times defied complete correction under the Kite treatment and more often, under that of Denis Browne" ***(Steindler, 1951)***. Certainly, the cavus can be improved with the Kite technique but not with the Denis Browne method of taping the feet on his L-shaped metal plates ***(Browne, 1934)***. Even now, in many clinics, the cavus appears to be a difficult deformity to correct. Norris C. Carroll has stated that "there is a cavus component to a severe clubfoot deformity" that "can only be corrected by lengthening the plantar fascia and the intrinsic muscles" ***(Carroll,***

1987). Actually, the cavus can be easily corrected in most infants without surgery. Out of 104 clubfeet treated in Ponseti's clinic and followed for over thirty years, only six feet needed plantar fasciotomy to correct completely the cavus ***(Laaveg and Ponseti, 1980)***.

The plantar fascia and the abductor muscle are rarely very tight in the infant, and the Forepart of the foot is usually flexible. Consequently, after gentle manipulation of the forefoot into supination and abduction, the cavus deformity usually corrects with the first plaster cast ***(Ponseti, 1996)***.

Exactly locate the head of the talus, this step is essential. First, palpate the malleoli with the thumb and index finger of the left hand while the toes and metatarsals are held with the right hand for correction of right club foot. Next, slide your thumb and index finger of the left hand forward to palpate the head of the talus in front of the ankle mortis (Fig. 29). Because the navicular is medially displayed and its tuberosity is almost in contact with the medial malleoli you can feel the prominent lateral part of the talar head barely covered by the skin in front of lateral malleolus. The anterior part of the calcaneus will be felt beneath the talar head ***(Ponseti, 2000)***.

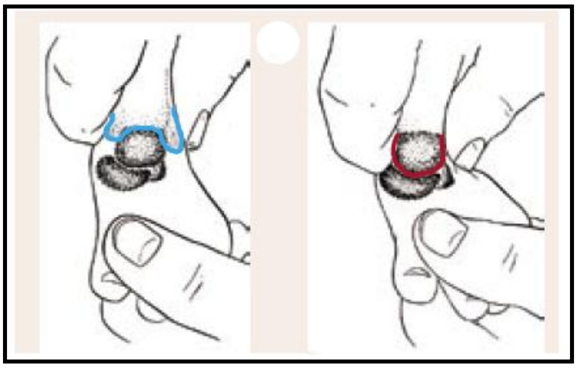


Fig. (29): Exactly locate the head of the talus. This step is essential. First palpate the malleoli (blue outline). Next slide your thumb and index finger forward to palpate the head of the talus in front of the ankle mortis (red outline) *(Ponseti et al., 2004)*.

The first element of management is correction of the cavus deformity by positioning the forefoot in proper alignment with the hindfoot. The cavus, which is the high medial arch, is due to the pronation of the forefoot in relation to the hindfoot. It is always supple in newborns and requires only supinating the forefoot to achieve a normal longitudinal arch of the foot ***(Ponseti, 2000)*** (Fig. 30).

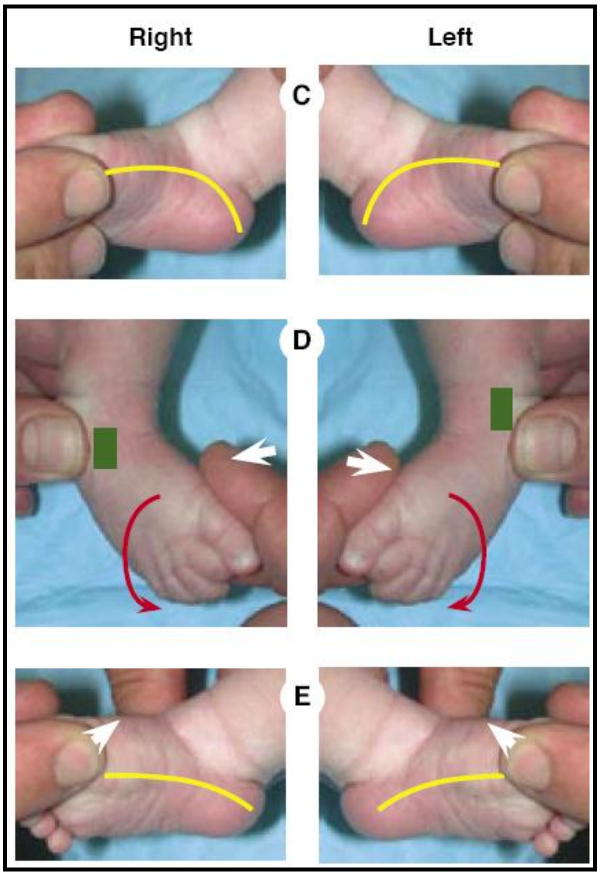


Fig. (30): *(Ponseti et al., 2004)*.

(C) The cavus, is the high medial arch due to the pronation of the forefoot in relation to the hindfoot.

(D & E) The cavus requires only supinating the forefoot to achieve a normal longitudinal arch of the foot.

In other words, the forefoot is supinated to the extent that visual inspection of the plantar surface of the foot reveals a normal appearing arch neither too high nor too flat. Alignment of the forefoot with hindfoot to produce a normal arch is necessary for effective abduction of the foot to correct the adduction deformity and varus ***(Ponseti, 2000)***.

While moving the forefoot laterally in supination with the right hand, you will be able to feel the navicular move ever so slightly in front of the head of the talus as the calcaneus moves laterally under the talar head ***(Ponseti, 2000)***.

Stabilize the talus place the thumb over the head of the talus, as shown by the arrows in the skeletal model. Stabilizing the talus provides a pivot point around which the foot is abducted. The index finger of the same hand that is stabilizing the talar head should be placed behind that lateral malleolus. This further stabilizes the ankle joint while the foot is abducted beneath it and avoids any tendency for the posterior calcaneal-fibular ligament to pull the fibula posteriorly during manipulation ***(Ponseti, 2000)***.

Manipulate the foot next, by abducting the foot in supination, with the foot stabilized by the thumb over the head of the talus, abduct the foot as far as can be done without causing discomfort to the infant. Hold the correction with gentle pressure for about 60 seconds, then release. The lateral motion of the navicular and of the anterior part of the calcaneus increase as the clubfoot deformity corrects. The foot is never pronated ***(Ponseti, 2000)***.

While the cast is applied it is necessary to maintain the forefoot supinated and abducted in proper alignment with the hindfoot. The sole of the foot should be molded so as to maintain the height of a normal arch. By abducting the foot with counter-pressure applied on the head of the talus, not only is the adduction of the forefoot partially corrected by the first cast but, to a lesser degree, also the hindfoot adduction. At this stage, since the whole foot is in supination, the inexperienced orthopedist may believe that the clubfoot deformity has been increased ***(Ponseti, 1996),*** (Fig. 31).

The first portion of the plaster cast should extend to the knee and maintain the whole foot in equinus, in supination, and in as much abduction as possible while mild counter pressure is applied over the lateral aspect of the head of the talus in front of the lateral malleolus. After the plaster sets, the cast must be extended to the upper third of the thigh with the knee flexed 90 degrees for reasons we shall explain later ***(Ponseti, 1996)***.

Fig. (31): Initial Ponseti Cast *(Foster and Davis, 2007)*.

An attempt to correct the supination of the foot by forcibly pronating the forefoot increases the cavus deformity since the first metatarsal is further plantar-flexed. Unfortunately, in most papers and textbooks, photographs show the forefoot held in pronation in the plaster cast. The cavus deformity remains uncorrected in this situation. In fact, it tends to increase and become more rigid when the forefoot is immobilized in pronation with respect to the hindfoot ***(Ponseti, 1996)***.

Adduction and Varus

During the second-third and fourth casts, the adduction and varus are fully corrected. The distance between the medial malleolus and the tuberosity of the navicular tells the degree of correction of the navicular when palpated with the fingers.

When the clubfoot is corrected, that distance measures approximately 1.5 to 2 cm and the navicular covers the anterior surface of the head of the talus ***(Ponseti, 2000)***.

The talocalcaneal, the talonavicular, and the calcaneocuboid joints operate in a strict mechanical interdependence. This is the reason it is necessary to simultaneously correct the tarsal displacements in the clubfoot ***(Ponseti, 1996)***.

The correction of the cavus brings the metatarsals, cuneiforms, navicular, and cuboid onto the same plane of supination. All these structures form the lever arm necessary to laterally and slightly downwardly displace the navicular and the cuboid. The lateral shift of the navicular, the cuboid, and the calcaneus in relation to the talus will be possible when the tight joint capsules, ligaments, and tendons on the inner aspect of the foot gradually yield to manipulation. This manipulation abducts the foot held in flexion and supination so as to accommodate the inversion of the tarsal bones while counter-pressure is applied with the thumb on the lateral aspect of the head of the talus. The heel should not be constrained so as to allow the abduction of the calcaneus under the talus. After two or three minutes of gentle manipulation, a thin, very well molded plaster cast is applied over a thin layer of soft cotton. The tightness of the ligaments decreases with immobilization ***(Ponseti, 1996)***, (Figs. 32, 33 & 34).

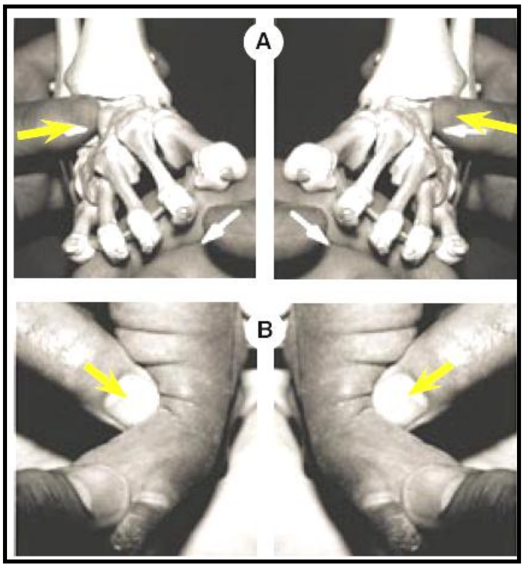


Fig. (32): Manipulate the foot by abducting the foot in supination (A), with the foot stabilized by the thumb over the head of the talus (yellow arrow). Abduct the foot as far as can be done without causing discomfort to the infant. Hold the correction with gentle pressure for about 60 seconds, then release. The lateral motion of the navicular and of the anterior part of the calcaneus increases as the clubfoot deformity corrects (B). Full correction should be possible after the fourth or fifth cast. For very stiff feet, more casts may be required. The foot is never pronated *(Ponseti et al., 2004)*.

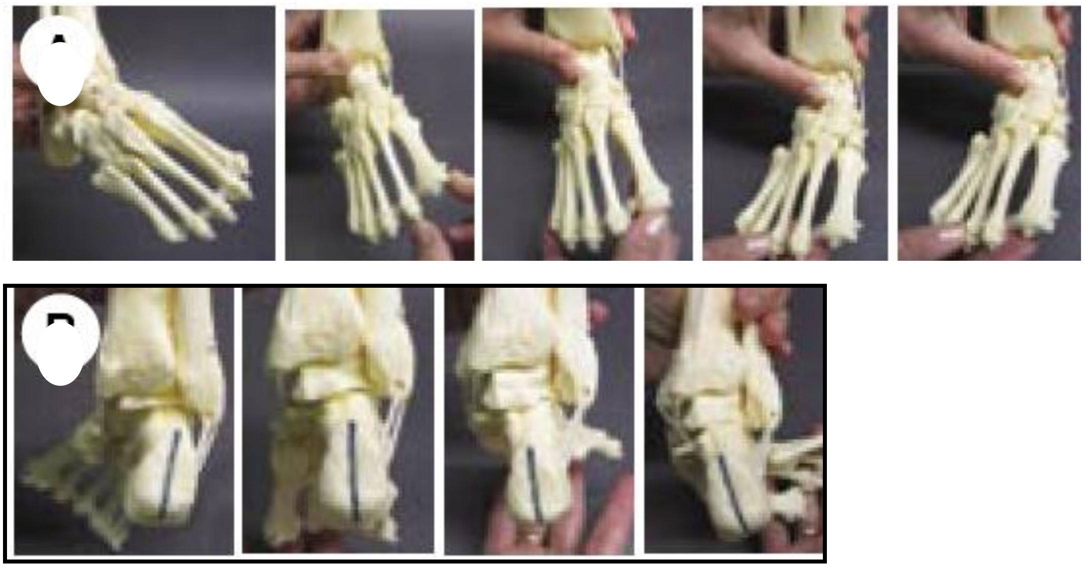


Fig. (33): The heel should not be constrained so as to allow the abduction of the calcaneus under the talus (Ponseti et al., 2004).

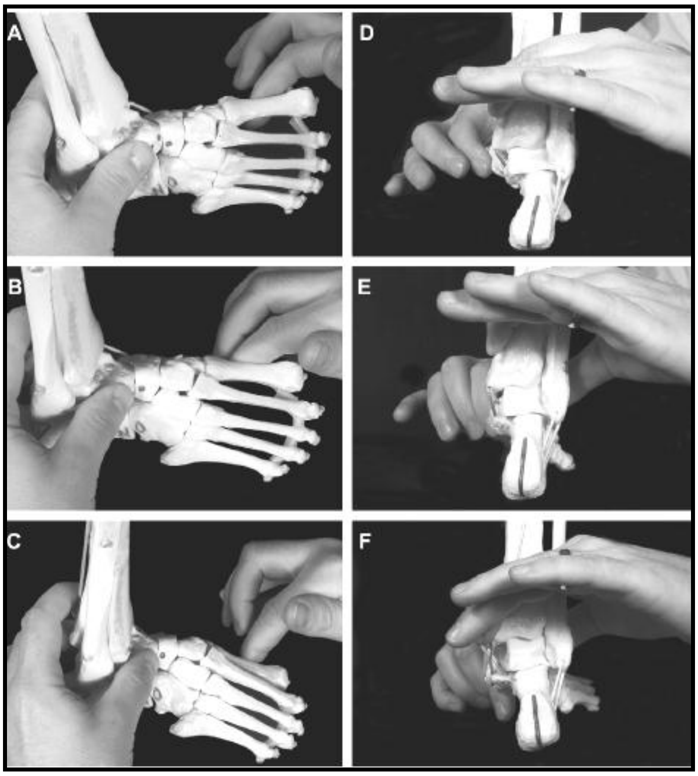


Fig. (34): Sequence of pictures showing the Ponseti method of clubfoot correction. The 1st ray is elevated correcting the alignment of the forefoot (A). In this position, the heel remains in varus (D). The forefoot is then brought in to progressively greater degrees of abduction with counter pressure against the talar head (B, C). the calcaneus corrects to neutral (E) and finally valgus (F) without any direct manipulation of the heel itself *(Cooke et al., 2008)*.

Three, four, or rarely five plaster casts changed weekly following gentle manipulations may be needed to loosen the medial ligamentous structures of the tarsus and partially mold the joints (Fig. 35).

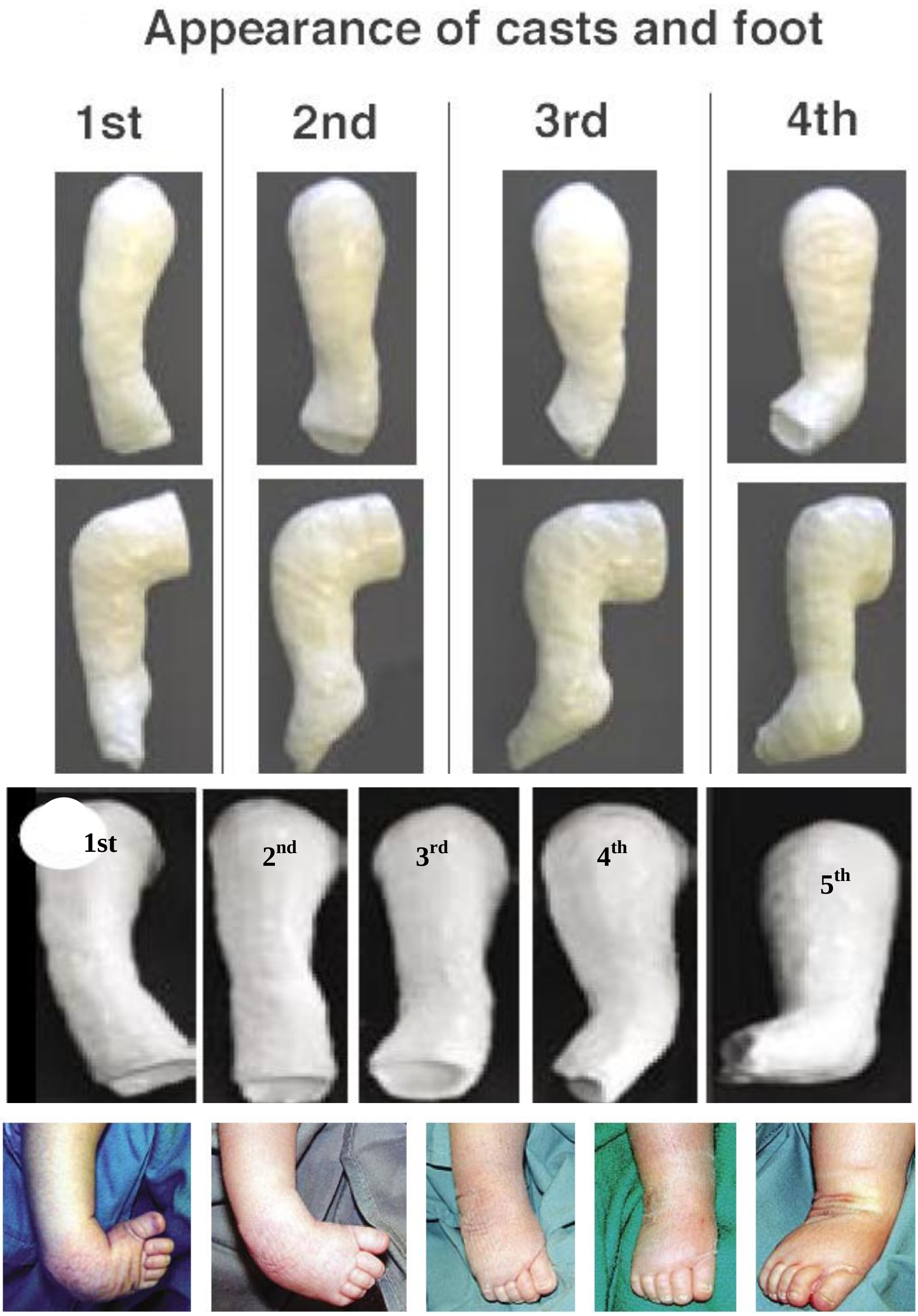


Fig. (35): ***(Ponseti et al., 2004).***

In the first cast, the plantar flexed foot is in supination and in the following two or three casts the supination can be gradually decreased to correct the inversion of the tarsal bones while the foot is further abducted under the talus. Care should be taken not to pronate the foot so as not to lock the calcaneus in varus under the talus. Care should also be taken not to evert the navicular while still in adduction. To ensure that the foot is not pronated, the plane of the sole and that of the metatarsal heads, which are in supination at the onset of treatment, should be gradually turned into a neutral position, so that they are at right angles to the leg in the last plaster cast when the inversion of the tarsal bones is fully corrected. The sole of the foot and the plane of the metatarsal heads should never be turned into pronation, to avoid an increase of the cavus and a breach in the midtarsal area ***(Ponseti, 1996)*** (Fig. 36).

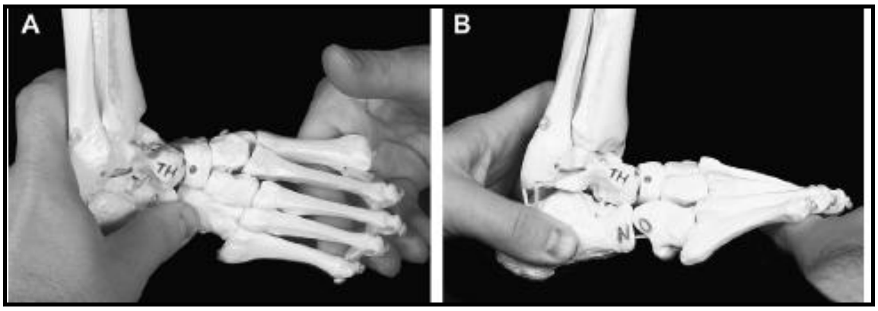


Fig. (36): Pressure on the calcaneocuboid joint rather than the talar head leads to a midfoot break (A). Although the foot may appear corrected, the talo-navicular joint is not reduced and the hindfoot is not corrected. Forced dorsiflexion of the forefoot can lead to a rocker-bottom deformity (B) *(Cooke et al., 2008)*.

Correction of the clubfoot deformity necessitates a prolonged stretching of the medial tarsal ligaments and tendons. This can be achieved only by abducting the whole foot under the talus to a much greater degree than is usually done by orthopedists. We must obtain 70° of abduction of the foot by the last cast after correction of the equinus. This cast must be left on for three weeks. For several months thereafter, the foot must be maintained in 70° of abduction in shoes attached to a bar in order to prevent retraction of the medial tarsal ligaments ***(Ponseti, 1996)***.

In the normal foot the heel is in a straight line with the axis of the leg and "eversion of the tarsal mechanism beyond its neutral position is very limited except for individuals with very relaxed ligaments ***(Huson, 1961)***. ***(Huson (1991)*** also states that "starting from the neutral position the tarsal mechanism can perform only an inversion motion". In the clubfoot, the severe varus of the tarsus is related to the severe adduction and inversion of its skeletal components. As stated earlier, correction of the heel varus entails abduction of the foot distal to the talus. By this maneuver, the calcaneus will evert into its normal, neutral position. In most clubfeet, over-correction of the heel varus is neither possible nor desirable. In very severe cases, the distorted, laterally inclined posterior talocalcaneal joint can make correction of the heel varus difficult. The calcaneus in flexion will abduct only gradually as the subtalar joint partially remodels. In less severe cases, owing to a more horizontal profile of the talocalcaneal joint surfaces and to the orientation of the tarsal ligaments, the inversion of the calcaneus often corrects itself when the foot is abducted under the talus even if the heel is not touched ***(Ponseti, 1996)***.

The foot can be maintained in abduction only if the talus, the ankle, and the leg are stabilized by a toe-to-groin (to upper thigh) plaster cast while the knee is in 90° flexion. In order to maintain a strong abduction of the foot under the talus while the talus is firmly immobilized against rotation in the ankle mortice, a toe-to-groin plaster cast is mandatory. The talar head will continue to stretch the tight plantar calcaneonavicular ligament as well as the tibionavicular part of the deltoid ligament and the posterior tibial tendon just as we stretch them with manipulation. A cast extending to just below the knee cannot immobilize the foot in firm abduction under the talus. The reason is that since the leg of a baby is round and the anterior crest of the tibia is covered with baby fat the cast cannot be well molded and therefore will rotate inwardly with the foot. As a result, the stretch of the tarsal ligaments and posterior tibial tendon obtained by manipulation is lost and the varus and adduction of the tarsus are left uncorrected. To insist on using short-leg casts in the treatment of clubfeet is to ignore the basic role that the leg and talus rotation have on the kinematics of the subtalar joint, the midfoot and the forefoot ***(Inman, 1976; Huson, 1991)***. Furthermore, short-leg casts tend to slip off the foot. To prevent this, the orthopedists often apply the casts too tightly around the calf and the malleoli, causing sores. Below-the-knee casts are not only useless but detrimental ***(Ponseti, 1996)***.

In severe clubfeet, complete reduction of the extreme medial displacement and inversion of the navicular may not be possible with manipulation, because the calcaneonavicular and the tibionavicular ligaments as well as the posterior tibial tendon, cannot be stretched sufficiently to properly position the navicular in front of the head of the talus. But even if the navicular were freed by cutting off the ligaments, the deformed contour of the talar head would be inadequate to accommodate it. This is the rationale for stretching the medial ligaments as much as they will yield rather than cutting them, regardless of whether or not a perfect anatomical reduction is obtained.***(Ponseti, 1996)***.

With a partially reduced navicular, the forefoot can be brought into proper alignment with the hindfoot because the naviculocuneiform ligaments in front of the navicular, and the bifurcated ligaments yield and allow the lateral displacement and lateral angulation of the cuneiforms with respect to the navicular while the cuboid falls into normal position or in slight abduction with respeft to the anterior tuberosity of the calcaneus. The calcaneus can be abducted sufficiently to bring the heel into its normal neutral position. This "spurious" correction will provide good functional and cosmetic results and avoid the many complications of tarsal release surgeries.***(Ponseti, 1996)***.

The term "spurious" is used here in the meliorative sense of "superficially like but morphologically unlike" and not in the pejorative sense of "false or fraudulent" ***(Webster tenth Collegiate Dictionary)***. Orthopedists have accepted "spurious" corrections of many skeletal deformities such as the correction of a coax vara by an intertrochanteric osteotomy and not by an osteotomy of the femoral neck which could destroy the blood supply to the femoral head. For the same reason, the correction of a severe slipped upper femoral epiphysis is not done at the site of the growth plate where the slipping has occurred but by an osteotomy at a lower level. A third example of a "spurious" correction is that of a severe tibia vara with an osteotomy at the upper tibial metaphysic and not through the upper tibial growth plate at the site of the disorder.***(Ponseti, 1996)***.

Relapses are common in severe cases of clubfoot for which a partial correction of the displaced navicular has been obtained. A bar with shoes holding the feet in 70° of external rotation worn at night may delay or prevent a relapse. When a relapse occurs, transfer of the tibialis anterior tendon to the third cuneiform is needed. This treatment results in a nearly perfect clinical and functional foot for at least four decades ***(Ponseti, 1996)***.

Equinus

The equinus deformity gradually improves with correction of adduction and varus. This is part of the correction because the calcaneus dorsiflexes as it abducts under the talus. No direct attempt at equinus correction is made until the heel varus is corrected.

Foot appearance after the fourth cast shows full correction of the cavus, adduction, and varus. Equinus is improved, if this correction is not adequate, it necessitates a heel cord tenotomy. In very flexible feet, equinus may be corrected by additional casting without tenotomy. When in doubt, perform the tenotomy ***(Ponseti, 2000)*** (Fig. 37).

Fig. (37): Clinical photographs of an 8 day with isolated unilateral clubfoot (A, B). The same patient after 3 (C) and 5 (D) weeks of Ponseti treatment *(Cooke et al., 2008)*.

The equinus is corrected by dorsiflexing (extending) the foot with the heel in neutral position after the varus and adduction of the foot have been corrected. The correction of the equinus entails stretching the tight posterior capsules and ligaments of the ankle and subtalar joints and the tendo-Achilles to allow the trochlea of the talus to slide backwards in the mortice. While the foot is extended, with one hand placed flat under the entire sole, the heel is grasped with the thumb and fingers of the other hand and pulled downwards. The index finger bent over the tendoAchilles insertion can also exert considerable pressure downwards ***(Ponseti, 1996)***.

Two or three plaster casts applied after manipulations, carefully molding the heel, are usually needed to correct the equinus deformity. Care should be taken not to cause a rocker-bottom deformity which can occur when the orthopedist attempts to dorsiflex the foot by applying pressure under the metatarsal heads rather than under the entire sole of the foot. When at least 15° of ankle dorsiflexion, or more when possible have been obtained, the last plaster cast is applied and worn for three weeks with the foot in 70° of external rotation. Special care should be taken never to pronate the foot in the slightest degree so as to avoid a relapse of the cavus, a breach in the midfoot, and a backward displacement of the lateral malleolus ***(Ponseti, 1996).***

Correction of Equinus by Tendo-Achilles Tenotomy:

Decision to Perform Tenotomy

A major decision point in management is determining when sufficient correction has been obtained to perform a percutaneous tenotomy to gain dorsiflexion and to complete the treatment. This point is reached when the anterior calcaneus can be abducted from underneath the talus. This abduction allows the foot to be safely dorsiflexed without crushing the talus between the calcaneus and tibia [E]. If the adequacy of abduction is uncertain, apply another cast or two to be certain ***(Ponseti, 2000)*** (Fig. 38).

Fig. (38): Adequate abduction *(Ponseti et al., 2004).*

Characteristics of adequate abduction

Confirm that the foot is sufficiently abducted to safely bring the foot into 15 to 20 degrees of dorsiflexion before performing tenotomy.

- *The best sign* of sufficient abduction is the ability to palpate the anterior process of the calcaneus as it abducts out from beneath the talus.
- *Abduction of approximately 60 degrees* in relationship to the frontal plane of the tibia is possible.
- *Neutral or slight valgus of os calcis* is present. This is determined by palpating the posterior os calcis.

Remember that this is a three-dimensional deformity and that these deformities are corrected together. The correction is accomplished by abducting the foot under the head of the talus.

Correction of equinus can be done by cord tenotomy. Perform the tenotomy approximately 1 cm above the calcaneus. Avoid cutting into the cartilage of the calcaneus. A "pop" is felt as the tendon is released. An additional 10 to 15° of dorsiflexion is typically gained after the tenotomy. Apply the fifth cast with the foot abducted 60 to 70° with respect to the frontal plane of the tibia. Note the extreme abduction o the foot with respect to the leg and the overcorrected position of foot. The foot is never pronated. This cast is left in place for 3 weeks after complete correction. After 3 weeks, the cast is removed. Note the correction, thirty degrees of dorsiflexion is now possible, the foot is well corrected, and the operative scar is minimal. The foot is ready for bracing ***(Ponseti, 2000)*** (Fig. 39).

Fig. (39): (B) Prep the foot medially, posteriorly, and laterally. (C) A small amount of local anesthetic may b infiltrated near the tendon. (D) Perform the tenotomy approximately 1 cm above the calcaneus. (E) An additional 10 to 15° of dorsiflexion is typically gained after the tenotomy. (F) Apply the fifth cast with foot abducted 70° with respect to frontal plane of tibia. (G) After 3 weeks, the cast is removed. Note the correction, thirty degrees of dorsiflexion is now possible *(Ponseti et al., 2004)*.

Dorsifiexion of the ankle to more than 10 to 15° is often impossible because of the talar and calcaneal malformations and tight ligaments. A posterior capsulotomy of the ankle and subtalar joints is rarely performed because the additional degrees of correction obtained by surgery may be completely lost later due to the retraction of the scar tissue. This is corroborated in recent reports from two leading clinics. They indicate that posterior surgical release of the ankle in clubfeet is followed by restriction of dorsiflexion and reduced mobility of the ankle in nearly half of their patients ***(Hutchins et al., 1985; Aronson and Puskarich, 1990)***.

Tibial Torsion:

Medial torsion deformities of the leg have been thought by some to be a component of the clubfoot deformity. However, in many treated clubfeet the lateral malleclus is displaced backwards in spite of the alleged medial tibial torsion ***(Hutchins et al., 1986)***. Several studies have attempted to determine the degree of tibial torsion by measuring with a torsionmeter the angle between the bicondylar axis (or the tibial tubercle) and the bimalleolar axis. None of these methods is accurate.

A new more precise method for measuring tibial torsion using computerized tomography (CT) has been recently reported. It is solely dependent on tibial landmarks and therefore measures true tibial torsion. The same technique is applicable to ultrasound as well as to CT. ***Krishna et al. (1991)*** have measured the angular differences between the proximal and distal posterior tibial planes as defined by ultrasound scans in normal children and in children with clubfeet. Normal children have a mean external tibial torsion of 40° whereas children with clubfeet have a mean external tibial torsion of only 18°. Of interest is the finding that the normal legs of patients with unilateral clubfoot have a mean external torsion of 27°, considerably less than that of normal children ***(Krishna et al., 1991)***.

Children with clubfeet, therefore, have no medial tibial torsion deformity but rather half the amount of external tibial torsion than children with normal feet. The posterior displacement of the distal fibula is caused by faulty treatment. Posterior displacement of the fibular malleolus and excessive lateral torsion of the ankle occurs when the foot is wrongly manipulated into abduction (external rotation) with the heel locked in inversion and adduction under the talus. Attempts to laterally rotate the foot in pronation with the heel inverted will force the talus to rotate laterally at the ankle joint, in turn displacing the fibular malleolus backwards. In addition, when walking with the heel uncorrected in varus and adduction, the child will turn his foot laterally to avoid tripping, causing further displacement of the fibular malleolus. A breach in the midfoot is incurred to make the foot plantigrade, causing a "bean-shaped" deformity ***(Swann et al., 1969)***. This deformity is avoided when the heel varus is corrected by abducting and externally rotating the calcaneus under the talus without pronating the foot. Placement of the thumb on the lateral aspect of the head of the talus helps prevent the talus from rotating laterally in the ankle joint ***(Ponseti, 1996)***.

The relative medial torsion associated with clubfoot will persist if below-the-knee casts are used in the treatment. Tibial torsion, varus deformity of the heel, and adduction of the foot can be gradually corrected if toe-to-groin plaster casts are applied with the knee in 90° of flexion and the foot externally rotated under the talus. Splints with shoes in external rotation worn at night for many months will maintain the correction of the medial tibial torsion ***(Ponseti, 1996)***.

Outline of the Ponseti Method

Week 1	Week 2	Week 3
Moulded cast to correct foot cavus deformity, by supinating the foot and dorsi-flexing the first metatarsal	Correct varus and adduction -obtained by abducting the supinated foot with counter-pressure to lateral aspect of head of talus	Continue abduction, stretching the medial tarsal ligaments
Week 4	**Week 5**	**Week 6**
Abduction continues of the midfoot and forefoot. Foot is not pronated. Medial tarsal ligaments stretched by abducting foot to 70 degrees	Abduction continues. N.B. All casts applied above knee, with knee at 90 degrees flexion and tibia externally rotated	Further manipulation if required

⇩

Minor Surgical Procedure

Achilles tenotomy performed to correct equinus.

Performed under local or general anaesthetic.

Plaster cast for further 3 weeks.

⇩

Boots on a bar for 23 hours a day for 3-4 months.

A unilateral clubfoot deformity is positioned at 70 degrees, with the normal foot at 40 degrees.

Bilateral clubfeet are both positioned at 70 degrees.

Bar bent in 15 degrees of dorsi-flexion

⇩

AFO's (Ankle foot orthosis) and Piedro Boots (daytime)

Boots on bar (night-time) for 2 years

Fig. (40): Outline of the Ponseti Method *(Judd, 2004)*.

Cast Application and Molding:

Success in Ponseti management requires good casting technique. Those with previous clubfoot casting experience may find it more difficult than those learning clubfoot casting for the first time.

Ponseti recommended that plaster material be used because the material is less expensive and plaster can be more precisely molded than fiberglass. Preliminary manipulation before each cast is applied.

Surgeon Apply only a thin layer of cast padding to make possible effective molding of the foot. Maintain the foot in the maximum corrected position by holding the toes while the cast is being applied. First apply the cast below the knee and then extend the cast to the upper thigh. Begin with three to four turns around the toes, and then work proximally up the leg. Apply the plaster smoothly. Add a little tension to the turns of plaster above the heel. The foot should be held by the toes and plaster wrapped over the holder's finger to provide ample space for the toes.

Mold the cast and try not to force correction with the plaster. Use light pressure, do not apply constant pressure with the thumb over the head of the talus; rather, press and release repetitively to avoid pressure sores of the skin. Mold the plaster over the head of the talus, while holding the foot in the corrected position. Note that the thumb of the left hand is molding over the talar head while the index finger of the left hand is molding above the calcaneus.

The arch is well molded to avoid flatfoot or rocker-bottom deformity. The index finger of the right hand is maintaining the correction. There is no pressure over the calcaneus. The calcaneus is never touched during the manipulation or casting (Fig. 41).

At the completion of casting, the foot appears to be overcorrected into abduction with respect to normal foot appearance during walking. This is not in fact an overcorrection. It is actually a full correction of the foot into maximum normal abduction, full abduction prevents recurrence and does not create an over-corrected or pronated foot ***(Ponseti, 2000)*.**

Fig. (41): (A) Preliminary manipulation before each cast is applied. (B) Applying the padding apply only a thin layer of cast pad. (C) Begin with three to four turns around the toes, and then work proximally. (D) Add a little tension to the turns of plaster above the heel. (E) Mold the plaster over the head of the talus while holding the corrected position. (F) Extend cast to thigh use much padding. (H) Trim the cast leave the plantar plaster to support the toes. (G) The plaster may be layered back and forth over the anterior knee for strength *(Ponseti et al., 2004)*.

Cast removal

Remove each cast in clinic just before a new cast is applied. Avoid cast removal before clinic because considerable correction can be lost from the time the cast is removed until the new one is placed. Although a cast saw can be used, use of a plaster cast knife is recommended because it is less frightening to the infant and family and also less likely to cause any accidental injury to the skin. Soak the cast in water for about 20 minutes, and then wrap the cast in wet cloths before removal. Use the plaster knife [A], and cut obliquely [B] to avoid cutting the skin. Remove the above-knee portion of the cast first [C]. Finally, remove the below-knee portion of the cast (D) ***(Ponseti et al., 2004)*** (Fig. 42).

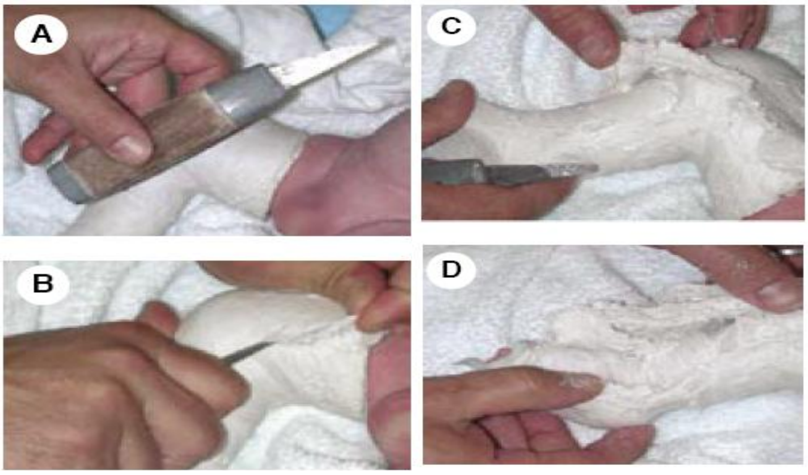


Fig. (42): Removal of the cast *(Ponseti et al., 2004)*.

Post Casting Management:

Bracing:

The brace is applied immediately after the last cast is removed, 3 weeks after tenotomy. The brace consists of open toe high-top straight last shoes attached to a bar (Fig. 43A). For unilateral cases, the brace is set at 75° of external rotation on the clubfoot side and 45 degrees normal side (Fig. 43B). In bilateral cases, it is set at 70° of external rotation on each side. The bar should be of sufficient length so that the heels of the shoes are at shoulder width.

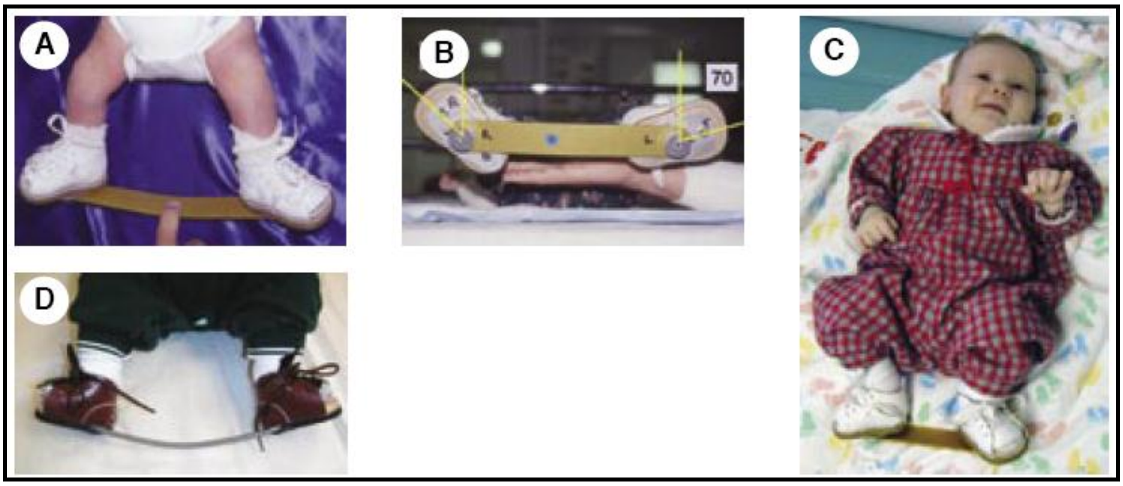


Fig. (43): ***(Ponseti et al., 2004).***

(A) At the end of casting, the foot is abducted to an exaggerated amount.

(B) For unilateral cases, the brace is set at 75° of external rotation on the clubfoot side and 45° normal side. In bilateral cases. It is set at 70° of external rotation on each side.

(C) The bar should be of sufficient length so that the heels of the shoes are at shoulder width. A common error is to prescribe too short bar, which is uncomfortable.

(D) The bar should be bent 5° to 10° with the convexity away from the child, to hold the feet in dorsiflexion.

A common error is to prescribe too short bar, which is uncomfortable (Fig. 43D). A narrow brace is a common reason for a lack of compliance. The bar should be bent 5 to 10° with the convexity away from the child, to hold the feet in dorsiflexion (Fig. 43C).

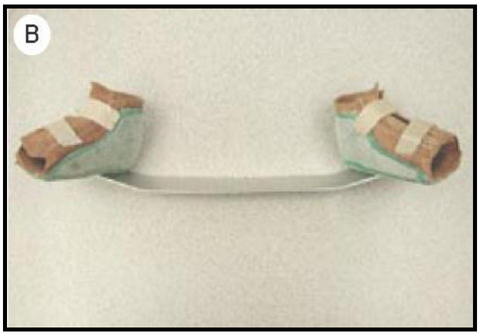
The brace should be worn full time (day and night) for the first 3 months after the tenotomy cast is removed. After that, the child should wear the brace for 12 hours at night and 2 to 4 hours in the middle of the day for a total of 14 to 16 hours during each 24-hours period. This protocol continues until the child is 3 to 4 years of age.

However, there is no scientific answer to how long should the nighttime bracing protocol continue. Severe feet should be braced until age 4 years, and mild feet can be braced until age 2 years. It is not always easy to distinguish which foot is mild and which is severe, especially when observing them at age 2 years.

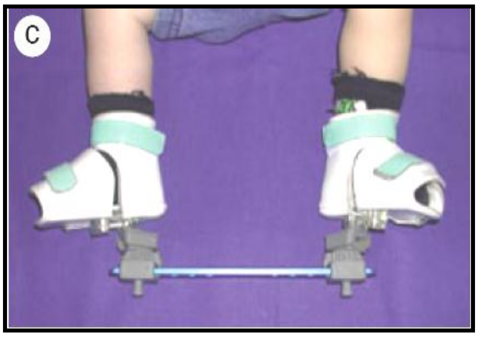
Therefore, it is recommended that even the mild feet should be braced for up to 3 to 4 years, provided the child still tolerates the nighttime bracing. Most children get used to the bracing, and it becomes part of their life style.

Several types of commercially made braces are available (Fig. 44). With some designs, the bar is permanently attached to the bottoms of the shoes, with other designs, it is removable. With some designs, the bar length is adjustable, and with others, it is fixed.

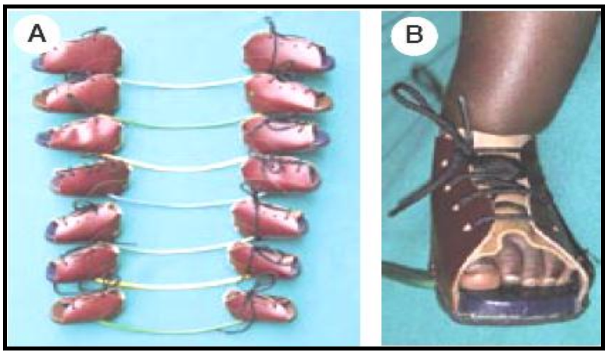
(A) John Mitchel Brace – United States.



(B) Gottenberg Brace – Sweden.



(C) Lyon Brace – France.



(A, B) Steenbeek Foot Abduction Brace.

Fig. (44): Different types of braces *(Ponseti et al., 2004)*.

Ponseti's protocol calls for a brace to maintain the abduction. This degree of foot abduction is required to maintain the abduction of the calcaneus and forefoot and prevent recurrence. The foot will gradually turn back inward, to a point typically of 10° of external rotation. The medial soft tissue stay stretched out only if the brace is used after the casting.

The Ponseti manipulations combined with the percutaneous tenotomy regularly achieve an excellent result. However, without a diligent follow-up bracing program, recurrence and relapse occur in more than 80% of cases. This is in contrast to a relapse rate of only 6% in compliant families ***(Ponseti, 2000)***.

Atter applying the brace for the first time after the tenotomy cast is removed, the child returns according to the following suggested schedule ***(Ponseti, 1994)***.

- Two weeks (to troubleshoot compliance issues).
- Three months (to graduate to the nights – and – naps protocol).
- Every 4 month until age 3 years (to monitor compliance and check for relapses).
- Every 6 months until age 4 years.
- Every 1 to 2 years until skeletal maturity.

Some surgeons have tried to improve Ponseti management by modifying the brace protocol or by using different braces. They think that the child will be more comfortable without the bar and so advise use of straight last shoes alone. This strategy always falls. The straight last shoes by themselves do nothing. They function only as an attachment point for the bar. Some braces are no better than the shoes by themselves and therefore, have no place in the bracing protocol. If well fitted, the knee-ankle-foot braces, such as the Wheaton brace, maintain the foot abducted and externally rotated ***(Ponseti, 1994)***.

However, the knee-ankle-foot braces keep the knee bent in 90° of flexion. This position causes the gastrocnemius muscle and Achilles tendon toe atrophy and shorten, leading to recurrence of the equinus deformity. This is particularly a problem if a knee-ankle-foot brace is used during the initial 3 months of bracing, when the braces are worn full time ***(Ponseti, 2000)***.

In summary, only the brace as described by Ponseti is an acceptable brace for Ponseti management and should be worn at night until the child is 3 to 4 years of age ***(Ponseti, 2000)***.

Common Management Errors:

A) Pronation or eversion of the foot:

This condition worsens the deformity by increasing the cavus. Pronation does nothing to abduct the adducted and inverted calcaneus, which remains locked under the talus. It also creates a new deformity of eversion through the mid and forefoot, leading to a bean-shaped foot (Fig. 45) ***(Ponseti, 1996)***.

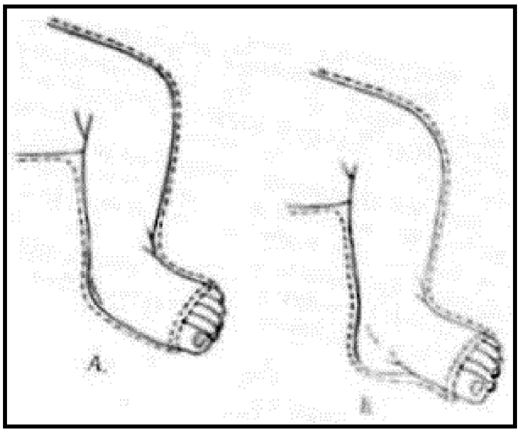


Fig. (45): A and B: The main errors in the correction of the clubfoot are the pronation of the whole foot (A), and the pronation of the forefoot (B) *(Ponseti, 1996)*.

B) External rotation of foot to correct adduction while calcaneus remains in varus:

This causes a posterior displacement of the lateral malleolus by externally rotating the talus in the ankle mortise. This displacement is an iatrogenic deformity. Avoiding this problem by abducting the foot in flexion and slight supination to stretch the medial tarsal ligaments, with counter-pressure applied on the lateral aspect of the head of the talus. This allows the calcaneus to abduct under the talus with correction of the heel varus ***(Ponseti, 1992)***.

C) Kite's error:

Kite's method does not incur foot pronation. However, it is far from flawless. Kite believed that the heel varus would correct simply by everting the calcaneus. He did not realize that the calcaneus can evert only when it is abducted under the talus. Abducting the foot at the midtarsal joints with the thumb pressing on the lateral side of the foot near the calconeo-cuboid joint blocks abduction of the calcaneus and interferes with correction of the heel varus (Figs. 46 & 47) ***(Ponseti, 2000)***.

Fig. (46): Kite's error *(Ponseti et al., 2004)*.

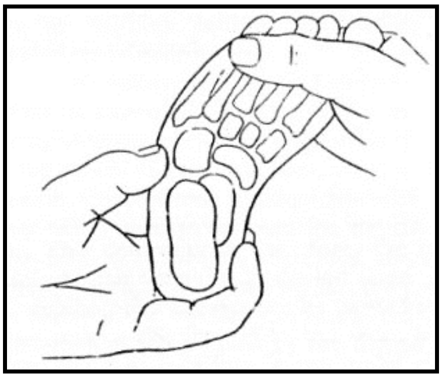


Fig. (47):(Kite's error). By abducting the forefoot against pressure at the calcaneocuboid joint the abduction of the calcaneus is blocked thereby interfering with the correction of the heel varus. Grasping the heel with the hand will prevent the calcaneus from abducting *(Ponseti, 1996)*.

D) Casting errors:

i) The foot should be immobilized with contracted ligaments at maximum stretch obtained after each manipulation. In the cast, the ligaments loosen, allowing more stretching at the next session.

ii) The cast must extend to the groin. Short leg casts do not hold the calcaneus abducted.

iii) Attempts to correct the equinus before the heel varus and foot supination are corrected will result in a rocker-bottom deformity. Equinus through the subtalar joint can be connected by calcaneal abduction.

(Ponseti, 1994).

E) Failure to use night brace:

Failure to use shoes attached to a bar in external rotation full time for 3 months and at night for 2 to 4 years is the most common cause of recurrence ***(Ponseti, 2000)***.

Complications of Ponseti Method

1. Compliance to the Night Bracing:

The families who are the most compliant to the bracing protocol are those who have read about the Ponseti method of clubfoot management on the internet and have chosen that method. They come to the office educated and motivated. The least compliant parents are often from families who did no background research on the Ponseti method and need to be sold on it. The best strategy to ensure compliance is to educate the parents and indoctrinate them into the Ponseti culture. It helps to see the Ponseti method of management as a lifestyle that demands certain behavior ***(Ponseti, 1994)***.

Take advantage of the face-to-face time that occurs during the weekly casting to talk to the parents and emphasize the importance of bracing. Tell them that the Ponseti management method has two phases: the initial casting phase, during which the doctor does all the work, and the bracing phase, during which the parents do all the work. On the day that the last cast comes off after the tenotomy, pass the baton of responsibility to the parents ***(Ponseti, 1994)***.

During the initial instruction, teach the parents how to apply the brace, putting it on and taking it off several times during the first few days (Fig. 48). Leave the brace of for brief periods of time during few days to allow the child's feet to get accustomed to the shoes. Teach the parents to exercise the child's knees together as a unit (flex and extend) in the brace, so that the children get accustomed to moving legs simultaneously.

Fig. (48): During the initial instruction, teach the parents how to apply the brace *(Ponseti et al., 2004)*.

If the child tries to kick one leg at a time, the brace bar interferes, and the child may get frustrated. Worn the parents that there may be a few rough nights until the child gets accustomed to the brace. Suggest the analogy of saddle training a horse, it requires a firm but patient hand. There should be no negotiations with the child. Schedule the first return visit in 10 to 14 days. The main purpose of that visit is to monitor compliance. If all is well, then the next scheduled visit is in 3 months, when the child advances to the nighttime only protocol.

It is useful to approach brace compliance as a public issue, similar to tuberculosis treatment. It is not sufficient to prescribe anti-tuberculosis medications; it is must also to monitor compliance through a public health nurse. Monitoring compliance by frequently calling the families of patients, who are in the brace phase, between office visits.

Occasionally, a child will develop excessive heel valgus and external tibial torsion while using the brace. In such instances, the physician should dial the external rotation of the shoes on the bar from approximately 70° to 40°.

However, if compliance becomes very problematic after age 2 years, it may become necessary to discontinue the bracing to ensure that the child and parents get a good night's sleep. This leniency is not tolerable in the younger age groups. Below age 2 years, the children and their families must be encouraged to comply with the bracing protocol at all costs ***(Ponseti, 2000)***.

2. Clubfoot Relapses:

Relapses that occur after Ponseti management are easier to deal with than relapses that occur after traditional posteromedial release surgery. Early relapses in the infant show loss of foot abduction loss of dorsiflexion correction and/or recurrence of metatarsus adductus.

The most common cause of relapse is noncompliance to the post-tenotomy bracing program. Morcuende found that relapses occur in only 6% of compliant families and more than 80% of noncompliant families. In brace compliant patients, the basic underlying muscle imbalance of the foot is what causes relapses.

Relapses in toddlers can be diagnosed by examining the child walking. As the child walks toward the examiner, look for supination of the forefoot indicating an over-powering tibialis anterior muscle and weak peroneals. As the child walks away from the examiner, look for heel varus. The seated child should be examined for ankle range of motion and loss of passive dorsiflexion.

At the first sign of relapse, reapply one to three casts to stretch the foot out and regain correction. This may appear a first to be a daunting task in wriggly 14-month-old toddler, but it is important. The case management is identical to the original Ponseti casting used in infancy. Once the foot is recorrected with the cast, the bracing program is again begun.

Recurrent equinus is a structural deformity that can complicate management. Equinus can be assessed clinically, but to illustrate the problem, a radiograph is included to show the deformity.

Several plaster casts may be needed to correct the equinus to at least a neutral position of the calcaneus. Sometimes, it may be necessary to repeat the percutaneous tenotomy in children up to 1 or even 2 years of age.

They should undergo casting for 4 weeks postoperatively, with the foot abducted in a long leg bent knee cast, and then go back into the brace at nigh. In rare situations, open Achilles lengthening may be necessary in the older child.

Varus heel relapse are more common than equinus relapses. It can be seen while the child is standing. It should be treated by recasting when the child is between age 12 and 24 months, followed by reinstitution of a strict bracing protocol.

Some children will require anterior tibialis tendon transfer for dynamic supination deformity, typically between ages 2 and 4 years. Anterior tibialis tendon transfer should be considered only when the deformity is dynamic and no structural deformity exists. Transfer should be delayed until radiographs show ossification of the lateral cuneiform that typically occurs at approximately 30 months of age. Normally, bracing is not required after this procedure ***(Ponseti, 2000)***.

Surgeries Recommended By Ponseti

When proper treatment of clubfeet with manipulation and plaster-casts has been started shortly after birth, a good clinical correction can be obtained in the majority of cases. The arbitrary classification of true clubfeet and positional clubfeet according to whether or not surgical correction has been effected is, as Coleman puts it, an "artificial" "preselection concept" ***(Coleman, 1987)***. If such classification were applied to Ponseti's cases in Iowa, the number of true clubfeet vs positional clubfeet would turn out to be 90 to 10 before 1950 ***(Le Noir, 1966)*** and 10 to 90 after 1950, a ludicrous reversal.

An early surgical release operation may be indicated only in the small percentage (under 5 percent) of patients who have short, unusually rigid feet with very severe equinovarus deformity, and who do not respond to proper manipulations. Such patients may be afflicted by peripheral arthrogryposis and should be carefully studied. Recently, neonatal clubfoot surgery and surgery in the first three months of life performed in leading clinics around the world has yielded very disappointing results owing to excessive deep scar formation ***(Dimeglio, 1977; Epeldegui, 1993)***. Most orthopedists have agreed that even in very rigid feet, surgery should be delayed until after the third month of life when post-surgical scarring is less abundant. Results from extensive dissections to release the stiff tarsal joints in infants are usually poor even after three months of age and further surgery at a later date is needed. During the first three months, therefore, attempts should be made to reduce the deformity as much as possible with manipulations and casting. Surprisingly, with a good technique, very difficult feet are often corrected***(Ponseti, 1996)***.

After the removal of the last plaster cast, the orthopedist must clinically appraise the degree of correction obtained by manipulation. A foot with an acceptable correction will have the heel varus and equines well corrected with about 15 degrees or more of ankle dorsiflexion. The navicular will be felt in front of the head of the talus, the cuboid will be well aligned with the calcaneus, and the shape of the foot will be normal. As previously explained, the position of the navicular is easily determined when it is felt moving in front of the head of the talus grasped with the index finger and thumb of one hand while adducting and abducting the foot with the other. In very severe clubfoot when the navicular cannot be fully laterally displaced, the navicular tuberosity is felt closer to the medial malleolus than in a normal foot***(Ponseti, 1996)***.

The degree of correction of the deformity can also be inferred from an analysis of anteroposterior and lateral roentgenograms of the foot. However, as stated before, it is difficult to estimate the accurate position of the tarsal bones because the centers of ossification are small, ovoid, and eccentrically positioned, and the navicular does not ossify until three or four years of age ***(Rose et al., 1985; Cummings et***

al., 1994). It is important to understand that a talocalcaneal angle that is at some variance from the normal range does not signify a poor clinical result. Surgical release of the talar joints solely to obtain a normal talocalcaneal index as viewed in roentgenograms is contraindicated. When the clinical correction of the foot and the motion of the foot and ankle are satisfactory, even though the correction may not be perfect on roentgenograms, the result of treatment should be considered successful***(Ponseti, 1996)***.

In most clubfeet well treated by manipulations from early infancy, the only operations indicated to facilitate the treatment are tenotomy or lengthening of the tendo-Achilles, and lateral transfer of the tendon of the tibialis anterior muscle to the third cuneiform. Joint releases should be avoided if possible since, in Ponseti's experience, they cause stiffness, pain in adult life, and limited function***(Ponseti, 1996)***.

Many techniques have been devised to release the tarsal joints in the treatment of clubfeet. No long-term functional results have been reported. The long-term follow-up on the Heyman-Herdon ***(Stark et al., 1987)*** tarsometatarsal capsulotomy for metatarsus adductus, published in 1987, showed that capsular release surgery on children's feet may cause severe disabilities. There was an overall failure rate of 41 percent, an incidence of pain in 40 percent, degenerative changes in the operated joints. Surgeons should not ignore the consequences of joint damage inflicted by the extensive tarsal joint releases routinely performed in an effort to align the bones of a clubfoot deformity. The assumption that early "correction" of bone positions results in a normal anatomy of the joints and good long-term function, is a mistake***(Ponseti, 1996)***.

A) Tendons:

Tenotomy of the Tendo-Achilles:

The percutaneous tenotomy of the tendo-Achilles is an office procedure. An assistant holds the leg with the foot in dorsiflexion while the baby is relaxed with a bottle of milk under local anesthesia, a Beaver eye blade is introduced through the skin in the medial aspect of the tendo-Achilles about two centimeters above its calcaneal insertion. The tendon is felt with the tip of the knife and care should be taken not to spear it. The knife is introduced in front of the tendon which is severed from front to back. The angle of dorsiflexion of the ankle will suddenly increase some 10 to 15 degrees and the equinus deformity is corrected. The puncture wound is covered with a small sterile pad and a sterilized soft roll is wrapped around the foot, ankle, and leg, then a very well molded plaster cast is applied, maintaining the foot in maximum dorsiflexion and in about 70° of abduction, as described above. When the plaster cast is removed three weeks later, the space between the two ends of the tendon has been bridged. The scar left in the tendon is minimal, as observed in cases needing a tendo-Achilles lengthening to correct a recurrence. During the first year of life a lengthening of the tendo-Achilles through a skin incision is unnecessary***(Ponseti, 1996)***.

Lengthening the Tendo-Achilles:

Open lengthening of the tendo-Achilles is indicated for children over one year of age. With the child under general anesthesia, a 2.5cm long skin incision is made over the medial aspect of the tendo-Achilles about 3 cm above its distal insertion. The medial border of the tendon should be exposed by sharp dissection and the tendon sheath should be open longitudinally. The tendon should not be dissected from its sheath to avoid damage to the connective tissue strands that carry tiny blood vessels and nerve fibers from the sheath to the tendon. The tendon is split longitudinally in the frontal plane the length of 4 to 5 cm and severed posteriorly at the upper end of the incision and anteriorly at the lower end. The foot is dorsiflexed and the two halves of the tendon slide along each other and are sutured together with the ankle in 5 degrees of dorsiflexion. Excessive lengthening of the tendon must be avoided since it may permanently weaken the gastrosoleus. The tendon sheath is carefully closed before suturing the skin. The foot and leg are immobilized for four to five weeks in a long-leg plaster cast with the knee in slight flexion.

It is important not to make long incisions because they leave ugly scars. Long dissection of the sheath from the tendon leave large areas of the tendon devascularized. This may cause necrosis of the tendon with disastrous consequences. A 2.5 cm long skin incision is sufficient to expose a long enough stretch of the tendon above and below the incision when flexing and extending the foot ***(Ponseti, 1996)***.

Transfer of the Tibialis Anterior Tendon:

The tendon is transferred after the first or second relapse in children older than two-and-a-half years of age when the tibialis anterior has a strong supinatory action. This often occurs when the navicular remains partially medially displaced and the varus of the calcaneus is not fully corrected. The relapsed clubfoot deformity must be well corrected with manipulations and two or three plaster casts left on for two weeks each before the transfer of the tendon. The tibialis anterior tendon transfer prevents further relapses and corrects the anteroposterior talocalcaneal angle as shown in the roentgenograms ***(Laaveg and Ponseti, 1980)***. The transfer greatly reduces the need for medial release operations.

A 4 to 5 cm long incision is made along the course of the tibialis anterior tendon from just below the ankle to the first cuneiform. The tendon sheath and the inferior extensor retinaculum are incised longitudinally and the tendon is severed just proximal to its insertion into the first cuneiform and first metatarsal. The distal end of the tendon is secured with a Kocher clamp and the tendon is lifted from its sheath up to its compartment under the superior retinaculum which is left intact. A second 2 cm long incision is made over the dorsum of the foot centered over the third cuneiform. This bone is under the extensor digitorum brevis and is reached by retracting laterally the tendons of the extensor digitorum longus. The third cuneiform is identified by palpating its joint with the third metatarsal which is felt when extending and flexing the third metatarsal. A quarter-inch drill hole is made through the middle of the third cuneiform from the dorsal to the plantar aspects of the foot. The tendon of the tibialis anterior is passed subcutaneously to the second incision. The tip of the tendon is secured with two Keith needles and a Bunnell-type suture with a strong thread. With the needles the tendon is passed through the hole into the plantar aspect of the foot where it is firmly anchored over a piece of foam rubber and a button.

To prevent bow stringing of the tendon under the skin in front of the ankle, the tendon must be left under the superior retinaculum. To obtain a straight line of pull, the lateral septum of the retinacular compartment may be incised for a short distance. A toe-to-groin (to upper thigh) plaster cast is applied with the foot in neutral position and the knee at 90° of flexion for four weeks***(Ponseti, 1996)***.

B) Ligaments and Joints:

With appropriate early manipulations and plaster cast treatment of the clubfoot, surgery of the ligaments and joints should be rarely necessary. A very few patients with severe deformities unyielding to manipulation treatment, in addition to patients with neglected clubfeet or with iatrogenic deformities, will be in need of joint releases. They should not be performed before five or six months of age. Maximum correction should be obtained with manipulative treatment and casting before undertaking any radical foot surgery***(Ponseti, 1996)***.

Only the very tight ligaments should be sectioned to achieve a proper alignment of the bones, since a perfect anatomical reduction is unattainable owing to the incongruency of the joint surfaces and changes in the shape of the bones. As explained before, a complete reduction of the severe medial displacement of the navicular is not necessary for the correction of the heel varus and the medial angulation of the cuboid. If the foot is well aligned it is inadvisable to attempt to reduce completely the medially displaced navicular, since this requires an extensive dissection of the midfoot, sometimes with distressing results such as a navicular subluxation or dislocation and deep scarring. ***Le Noir (1966)*** as well as ***Simons (1994)*** described severe medial subluxation of the cuboid that requires surgical reduction in some patients. Patients initially treated by Ponseti have not needed surgery to reduce and cuboid except in one instance when the clubfoot had a very large branch of the posterior tibial tendon that inserted into the cuboid***(Ponseti, 1996)***.

The ligaments that may need to be released through a posteromedial incision are the superficial fibers o the deltoid ligament, the tibionavicular ligament, the talonavicular ligament, the plantar calcaneonavicular ligament, and the posterior ligaments of the ankle and subtalar joints. Whenever the tibialis posterior tendon needs lengthening, it can be done following the technique described by ***Coleman (1987)*** of suturing the detached tendon to the flap of the tibionavicular ligament left attached to the navicular. Lengthening the tendons of the long toe flexors are rarely necessary since the muscles will stretch with time. The ligaments on the lateral aspect of the foot and the interosseous talocalcaneal ligaments are usually not excessively tight and should not be severed. To avoid over-correction, the tendon of the tibialis anterior should not be transferred to the dorsum of the foot at the time of joint-release surgery***(Ponseti, 1996)***.

Surgery to correct forefoot adduction should not be necessary since the forefoot is not rigid and easily yields to manipulation. A severe deformity may be corrected by metatarsal osteotomies but never by capsulotomies at the Lisfranc line ***(Stark et al., 1987)***. Occasionally, a rigid cavus deformity will necessitate subcutaneous sectioning of the plantar fascia. A cock-up big toe can be corrected by transferring the long toe extensor to the neck of the first metatarsal ***(Ponseti, 1996)***.

C) Bones:

Osteotomies or wedge resections of the bones on the outer aspect of the foot are not necessary in clubfoot treatment if manipulations and plaster cast applications are properly done.

Cavovarus:

A common residual deformity of the poorly treated or of the relapsed clubfoot is the cavovarus, in which the tarsus remains in some degree of varus while the forefoot is pronated. The arch of the foot is high and the plantar fascia and muscles are shortened. This deformity usually originates from a faulty pronatory twist of the forefoot during the initial treatment. The cavus may be very mild at birth but it worsens when the forefoot is immobilized in pronation in a plaster cast. Furthermore, the heel remains in varus since foot pronation cannot evert the calcaneus unless the midfoot and the calcaneus are severely abducted. With the heel in varus, the cavus increases when the child starts walking.

The motions between the hindfoot and forefoot take place mainly at the Lisfranc line. The base of the second metatarsal is wedged between the first and third cuneiforms and therefore tends to move with the mid and hindfoot. The forefoot twists into pronation and supination around the second metatarsal. In the cavovarus foot the hindfoot varus causes the second metatarsal to invert. When standing and walking, the first metatarsal has to plantarflex to reach the ground, while the lateral metatarsals have to dorsiflex. The plantar fascia becomes thicker and shorter as it holds the first metatarsal in plantar flexion. If there is a residual adduction of the foot, the child will walk with the leg in external rotation to avoid tripping, thus forcing the talus to follow in the same direction, in turn increasing the heel varus. The powerful anterior talofibular ligament plays an important role in what Huson calls "this remarkable mechanism of talocrural transmission" ***(Huson, 1991)***. All these interrelated motions create a vicious circle which keeps aggravating the condition***(Ponseti, 1996)***.

The correction of the cavovarus deformity in clubfoot entails severing the plantar fascia and correcting the flexion of the first metatarsal and the supination of the tarsus. Steindler, who in 1920 published his plantar fascia release operation, stated repeatedly that the cavus would recur unless the plantar release was accompanied by some other corrective procedure.

The cavovarus residual deformity in children under six or seven years of age, when the subtalar joint motion is adequate, can be treated by manipulation, application of two or three plaster casts for two weeks each, percutaneous section of the plantar fascia, and transfer of the tendon of the tibialis anterior to the third cuneiform. The tendo-Achilles may have to be lengthened when there is residual equines. In severe cavus deformities, the extensor hallucis longus can be transferred to the shaft of the first metatarsal after attaching the distal end of the tendon to the tendon of the extensor hallucis brevis. A toe-to-groin plaster cast is applied holding the foot in the corrected position for five weeks ***(Ponseti, 1996)***.

In older children the tarsal deformity as well as the cavus tend to become more rigid. It is very important to find out with the ***Coleman's (1987)*** lateral block test whether the heel supination is correctable. Here a block of wood two or three centimeters high is placed under the lateral aspect of the sole of the foot so that the head of the first metatarsal touches the ground accommodating the forefoot pronation. If the hindfoot varus is not rigid, it will correct and the heel will no longer be in varus. When the heel varus corrects to within 5 degrees of the neutral position with the Coleman's test, the cavovarus deformity is best corrected by a series of procedures advocated by Reginald R. cooper, as follows:

1. The tight plantar fascia is severed percutaneously.
2. A small dorsal-lateral wedge of bone is resected from the base of the first metatarsal, with care not to damage the growth plate.

3. The tendon of the extensor hallucis longus is severed at the level of the MP joint, its distal end is sutured to the tendon of the extensor hallucis brevis, and its proximal end is passed through a drill hole in the shaft of the first metatarsal and tied to itself with a strong tension to hold the first metatarsal in proper alignment after it has been dorsiflexed and supinated (inverted) while immobilizing the osteotomy site.
4. Through a small lateral incision, the tendon of the peroneus longus is severed in the plantar aspect of the foot and sutured under tension to the tendon of the peroneus brevis.
5. The tibialis anterior tendon is transferred to the third cuneiform if it has a strong supinatory action.
6. The Achilles tendon is lengthened when necessary to correct any residual equines.
7. A toe-to-groin plaster cast is applied holding the knee in slight flexion and the foot in the corrected position for six weeks. A below-the-knee cast is sufficient if the tendo-Achilles is not lengthened or if the tibialis anterior is not transferred.

In rare cases when calluses form under the head of the second metatarsal, it is advisable to remove a dorsal wedge of bone from the base of the second metatarsal as well as from the first metatarsal. Only in one case in his experience did Dr. Cooper find an indication for a lateral closing-wedge osteotomy of the calcaneus as described by Dwyer. In most cases this operation is not necessary since a few degrees of heel varus are compatible with a normal gait. The long-term results of Cooper's procedures performed over thirty years are very gratifying***(Ponseti, 1996)***.

Triple Arthrodesis:

A triple arthrodesis is a salvage procedure to be done in children over 9 or 10 years of age with a rigid cavovarus deformity. These patients have large calluses on the lateral aspect of the sole of the foot, particularly under the base of the fifth metatarsal, and often under the head of the first metatarsal. The triple arthrodesis is indicated when the ankle joint motion is fairly good but the tarsal joints are very rigid in supination.

The operation is done through a lateral incision from the tip of the lateral malleolus to the base of the fourth metatarsal. The skin, the subcutaneous tissue, and a portion of the inferior extensor retinaculum are incised. The branches of the sural and musculocutaneus nerves are preserved and retracted with the deep fascia to expose the extensor digitorum brevis. This muscle is detached from the calcaneus and reflected forward. The tendons of the peroneus tertius and the extensor digitorum longus are retracted forwards. The inferior peroneal retinaculum with the peroneal tendons are retracted downward. After stripping the joint capsules, the calcaneocuboid and the talonavicular joints are clearly exposed. The cartilage of these joints is removed with a sharp osteotome taking only a minimal amount of subchondral bone. To remove all the cartilage of the talonavicular joint it is helpful to pass a Kocher retractor along the joint margin while lifting the joint capsule. A Kocher retractor is now inserted around the lateral and posterior margins of the posterior talocalcaneal joints stripping the capsular insertions and fully exposing the joint. The cartilage and a minimal amount of subcondral bone is removed with a sharp osteotome. The calcaneus is separated from the talus and the interosseous talocalcaneal ligaments are thoroughly removed. The cartilage of the medial talocalcaneal joint is removed while care is taken not to injure the sustentaculum tali and the neurovascular and tendon structures of the medial aspect of the foot. A medial incision is not necessary.

Only the joint cartilage and a minimal amount of subchondral bone has to be removed from the three joints to facilitate the lateral displacement and abduction of the navicular, cuboid, and calcaneus necessary to correct the heel varus and the tarsal supination. No fixation is required and the foot remains stable in the corrected position. After suturing the extensor digitorum brevis to the inferior peroneal retinaculum the wound is closed in layers. The foot is immobilized in the neutral position in a short-leg plaster cast. The cast is worn without weight-bearing for four weeks. Another very-well-molded walking plaster cast is applied for six more weeks.

Bone-wedge resections are unnecessary to correct varus deformities of the hindfoot. Indeed, a clear understanding of how the heel varus and foot supination of a clubfoot should be corrected at any age is gained when a triple arthrodesis is properly performed. The wrong technique is described and illustrated in most orthopedic textbooks: wedges of bone are removed from the lateral aspect o the midtarsal and subtalar joints, gaps are closed by abducting the foot and everting the heel, and staples are used to maintain the correction. This incorrect technique illustrates the common misunderstanding that heel varus is corrected by everting the calcaneus instead of abducting (externally rotating) it under the talus, and that hindfoot varus is corrected by everting the midfoot at the Chopart's line rather than by displacing the navicular laterally in front of the head of the talus, and the cuboid in front of the abducted calcaneus. This misunderstanding interferes, even to the present day, with the correct technique for a triple arthrodesis as well as with the successful manipulative treatment of the clubfoot.

To correct the cavus after a triple arthrodesis, a dorsal wedge of bone is resected from the base of the first metatarsal, and the extensor hallucis longus tendon is transferred to the first metatarsal, as previously described.

Tibial osteotomies to internally or externally rotate the foot should never be necessary ***(Ponseti, 1996)***.

Talectomy:

Talectomy is indicated for the treatment of very stiff clubfeet with little or no ankle motion that have relapsed after extensive tarsal release operations. The operation gives satisfactory results when performed between one and six years of age. Talectomy can be a primary surgical procedure in patients with severe clubfeet and poor or absent leg muscles suffering from arthrogryposis or myelomeningocele. The operation is performed after improving as much as possible the alignment of the foot with weekly manipulations and casting for a period not co-exceed two or three months***(Ponseti, 1996)***.

Removal of the talus is a safe operation because it decompresses the hindfoot and allows for the correction of the supination and the equines deformities without stretching the nerves or the vessels. The foot is stabilized by pushing the foot backwards so that the heel is forced into its normal, posterior, prominent position. This procedure results in a plantigrade foot that articulates with limited motion between the ankle mortice and the anterior aspect of the subtalar foot plate. The foot is functional and not painful. Relapses of the deformity are rare ***(Menelaus, 1971)***.

The approach for the talectomy is the same as for the triple arthrodesis. The head of the talus appears prominent laterally because the navicular and the calcaneus are in severe adduction. All the ligaments and joint capsules inserting into the talus are severed with tenotomy scissors to avoid damaging the joint cartilage of the adjacent joints. The talus is grasped with a large towel clip and the foot is manipulated into equines and supination so that the posterior and medial ligaments can be clearly seen while they are being divided. To facilitate the posterior displacement of the foot, the deltoid, spring, and posterior ankle ligaments as well as the tip of the lateral malleolus should be resected. The ankle mortice should fit into the anterior upper surface of the calcaneus. The lateral surface of the lateral malleolus below the growth plate should be trimmed to narrow the ankle and facilitate shoeing. A Steinman pin is inserted upwards through the calcaneus into the tibia to maintain the foot posteriorly in the proper position with respect to the tibia.

The foot is immobilized in a few degrees of plantar flexion in a short-leg cast. The cast and the Steinman pin are removed four weeks later and another well-molded walking plaster cast is applied for six more weeks. A well-molded leg brace is worn for 6 more months to prevent relapses of the deformity ***(Ponseti, 1996)***.

Evaluation of Ponseti Technique

CTEV is the commonest congenital deformity of the foot that we encounter in the pediatric age group ***(McKeown and Record, 1960)***. Despite this, its treatment remains confusing. Various manipulation techniques have been described with variable results. Dangelmajer ***(Dangelmajer, 1961)*** gave a response rate of 40%. Kite ***(Kite, 1930)*** reported a response rate of 90% with his technique. These results could not be reproduced and Zimbler ***(Zimbler, 1994)*** reported a response rate of only 10% with Kite's technique. The Ponseti technique is based on sound understanding of the pathoanatomy of clubfoot ***(Ponseti, 1996)***. Various workers have given consistently better results with this technique ***(Lehman et al., 2003)*** reported a response rate of 92%. ***Colburn and Williams (2003)*** reported a response rate of 94.1% ***(Morcuende et al., 2004)*** reported a response rate of 98%. Various studies on surgical treatment have also given variable results. ***Brockman (1930)*** reported a relapse rate of 46%. ***Turco (1971)*** reported a relapse rate of 50%. ***Morcuende et al. (2004)*** reported a relapse rate of 11% with the Ponseti technique. ***Herzenberg et al. (2002)*** reported a relapse rate of 3.7% with the Ponseti technique. There was a strong positive correlation between the initial Pirani score and the number of casts required. The difference between the mean precorrection and mean postcorrection Pirani score was statistically significant . the difference between the mean footprint angle before and after correction was statistically significant. Thus Pirani scoring and podography can be used to monitor the treatment.

The Pirani score can also be used to estimate the duration of treatment***(Abbas et al., 2008)***

The good results obtained by the Ponseti technique show that posteromedial soft tissue release may no longer be required for most cases of idiopathic CTEV ***(Abbas et al., 2008)***.

(Ippolito et al., 2003)The purpose of this study was to review and compare the long-term results in two groups of patients with congenital clubfoot treated with two different techniques. In both groups, treatment was started within the first three weeks of life by manipulation and application of toe-to-groin plaster casts, with a different technique in each group. At the end of the manipulative treatment, a posteromedial release was performed when the patient was between eight and twelve months of age in the first group and a limited posterior release was performed when the patient was between two and four months of age in the second group.

The clubfoot deformity in the first group of patients was manipulated with the technique described by ***Marino-Zuco (1934)***, and then casts were applied starting around the tenth day of life.

In the second group of patients, the foot was manipulated weekly, starting in the first week of life, according to the method described by ***Ponseti and Smoley (1963)***.

In the second group, use of Ponseti's manipulation technique and cast immobilization followed by an open heel-cord lengthening and a limited posterior ankle release gave much better long-term results than those obtained in the first group, treated with our manipulation technique and cast immobilization followed by an extensive posteromedial release of the foot. In our hands, this operation did not prevent relapse, and neither cavovarus nor forefoot adduction was completely corrected ***(Ippolito et al., 2003)***.

Ponseti's method has excellent both short-and long-term outcomes, with the result that its practice is expanding worldwide ***(Laaveg and Ponseti, 1980; Cooper and dietz, 1995; Ippolito et al., 2003; Morcuende et al., 2004)***. Although our study is small with shot follow-up, the early results (success rate of 95%) are encouraging and compare favourably with those achieved by other centres ***(Herzenberg et al., 2002; Dobbs et al., 2004; Morcuende et al., 2004; Goksan et al., 2006; Shack and Eastwood, 2006)***.

The Ponseti method has found great favour and demonstrated high rates of correction of deformity in a short period of time. Earlier reports of casting gave results that were not being reproduced by other centres. Attention to detail and good compliance with treatment are essential, particularly in the more difficult feet ***(Hulme, 2005)***.

In a retrospective review of 24 children (39 feet) with idiopathic congenital talipes equinovarus, managed by a physiotherapist-led service in a district general hospital, early results suggest that a combined on sultant/physiotherapist-delivered Ponseti service can be effectively and successfully administered in a district general hospital, Fig. (49) ***(Kampa et al., 2008)***.

The Ponseti method of correcting clubfoot is especially important in developing countries, where operative facilities are not available in the remote areas and well-trained physicians and personnel can manage the cases effectively with cast treatment only ***(Gubta et al., 2006)***.

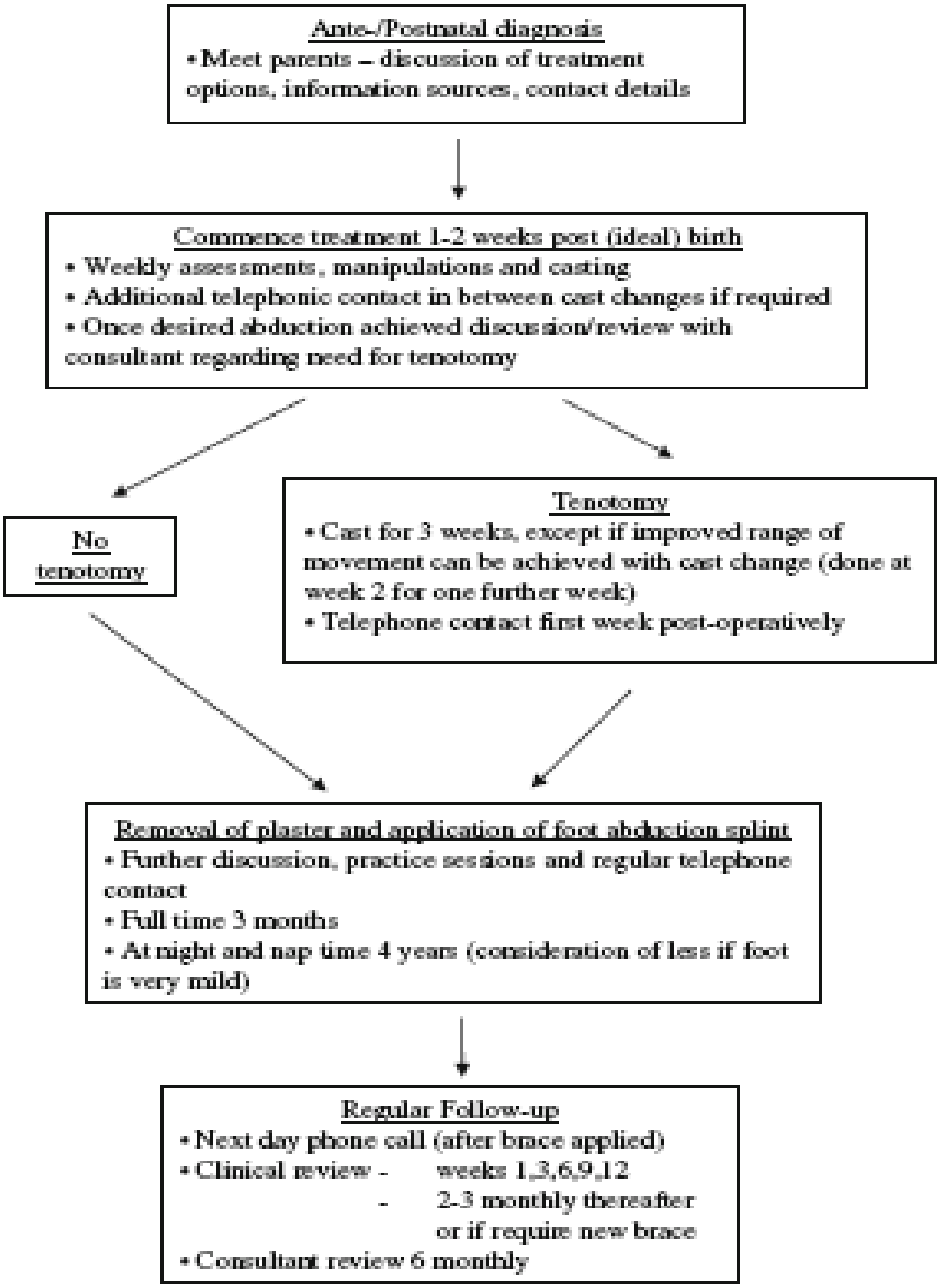


Fig. (49): Physiotherapist-delivered pathway for management of CTEV *(Kampa et al., 2008)*.

After successfully treating many children with club foot by the Ponseti method, and based on previous experience which showed good results up to the age of two years, we have expanded the indications for the use of this method to older children with neglected club feet ***(Morcuende et al., 2004)***.

Early results with a physiotherapist-delivered Ponseti service for the management of idiopathic congenital talipes equinovarus deformity are as good as those from other published series using medical personnel ***(Herzenberg et al., 2002; Ponseti and Smoley, 1963; Morcuende et al., 2004; Morcuende et al., 2005)***. ***Shack and Eastwood (2006)*** would agree with ***Tindall et al. (2005)*** that "the Ponseti method is readily transferable to non-doctor practitioners", but they believe that this philosophy should be followed in developed countries as well as the less developed ones. The most important factor is that these practitioners are appropriately trained and experienced.

It is perhaps unfair to consider the Ponseti method non-operative as an Achilles tenotomy is performed in about 70% of cases, often percutaneously in a manner that may lead to over lengthening and a calcaneus deformity of the heel ***(Ponseti, 1992)***. Overall authors concluded that there was satisfactory outcome in 88.5% of feet ***(Ballantyne and Macnicol, 2002)***.

The Ponseti method is a very safe, efficient treatment for the correction of clubfoot that radically decrease the need for extensive corrective surgery. Furthermore, it can be used successfully in children up to ~2 years of age when no previous surgical treatment has been attempted. The decline in extensive clubfoot surgery should encourage national efforts to make this method the gold standard in the treatment of congenital idiopathic clubfoot. Educational programs should be targeted to primary care physicians to increase awareness of the Ponseti method and its excellent results so that they can advise families accordingly. Physicians who adopt the Ponseti method will feel rewarded by the satisfaction of successfully correcting what traditionally has been a very frustrating deformity to treat ***(Poseti et al., 2002)***.

Conclusion and Summary

Clubfoot is a congenital foot deformity where the bones, joints and muscles of the foot are abnormal. If left untreated, a child will begin to walk on the outer edge of their foot and is likely to develop many related health problems.

Most orthopedic surgeons agree that the initial treatment of congenital clubfoot should be non operative. Beginning in the first days of life so as to take advantage of the favorable fibroblastic properties of the connective tissue which forms the ligaments, joint capsules and tendons. Failures of manipulative treatment usually occur when the surgeon lacks a through knowledge of the kinematics and pathological anatomy of the deformity.

Ponseti method was developed by Ignacio Ponseti. The method includes correction of the cavus firstly by supinating the forefoot and dorsiflexing the first metatarsal, the forefoot must never be pronated, to correct the varus and adduction, the foot in supination is abducted while counter pressure is applied with the thumb against the head of the talus, the index finger of the same hand rests over the posterior surface of the lateral malleolus, the heel must not be touched, then calcaneus abducts by rotating and sliding under the talus, as the calcaneus abducts it simultaneously extends and everts, and thus the heel varus is corrected, the calcaneus cannot evert unless it is abducted.

The improvement obtained by manipulation is maintained by immobilizing, the foot in a plaster cast for five to seven days. With immobilization, the tight medial and posterior tarsal ligaments tend to yield. The deformity can be gradually corrected with further manipulations and five to six changes of cast. The equines is corrected by dorsiflexing the fully abducted foot. Percutaneous tenotomy of the Achillis tendon is often necessary to completely correct the equines. Finally, the foot is putted in Dennis-Browne splitly until reach the age of three to fours years old.

The Ponseti method delivers excellent correction of clubfoot without the associated risks and complications of major foot surgery. Moreover, studies show that patients treated with the Ponseti method has the upper hand in treating clubfoot than those treated by other conservative methods and the method provides more flexible foot and ankle than those treated surgically, Dennis-Brown splint is a must in this method to prevent relapses. Tibialis anterior transfer can be done in case of dynamic deformity or relapse.

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