Part 2 of 2

Summary of the Attached Published Articles on the Ponseti Method

(from the most recent to oldest articles)

Published Articles

Morcuende, J; Ponseti I.V.; **Radical Reduction in the Rate of Extensive Corrective Surgery for Clubfoot Using the Ponseti Method**, Journal of Pediatrics, Volume 113 No 2 Feb 2004 University of Iowa

Lehman, Wallace; **A Method for the Early Evaluation of the Ponseti (Iowa) Technique for the Treatment of Idiopathic Clubfoot**, Journal of Pediatric Orthopedics B 2003, 12:133-140 NYU

Colburn, M; **Evaluation of the Treatment of Idiopathic Clubfoot by Using the Ponseti Method**; Journal of Foot and Ankle Surgery 42(5): 259-267, 2003 Kaiser Permanente Medical Center, Walnut Creek, California

Morcuende, J. Ponseti I.V.; **The Effect of the Internet in the Treatment of Congenital Idiopathic Clubfoot**, Iowa Orthopedic Journal, 2003: 83-86 University of Iowa

Herzenberg, J,; **Ponseti Versus Traditional Methods of Casting for Idiopathic Clubfoot**; Journal of Pediatric Orthopedics 22:517-521; 2002 Maryland Center for Limb Lengthening and Reconstruction, Baltimore, Maryland

Pirani, S.; **Magnetic Resonance Imaging Study of the Congenital Clubfoot Treated with the Ponseti Method,** Journal of Pediatric Orthopedics 21:719-726, 2001 Royal Columbian Hospital, New Westminster, British Columbia, Canada

Ponseti, I.V.; **Relapsing Clubfoot: Causes, Prevention and Treatment**, Iowa Orthopedic Journal, Vol. 22:55-56, 2002. University of Iowa (not a full copy of the article)

Ponseti, I.V.; **Editorial, Clubfoot Management**, Journal of Pediatric Orthopedics, vol. 20: 699-700, 2000, University of Iowa (not a full copy of the article)

Dobbs, M., Ponseti I.V.; **Treatment of Idiopathic Clubfoot: An Historical Review**; Iowa Orthopedic Journal, 2000, volume 20 pages 59 to 64, University of Iowa

Ponseti, I.V., **Current Concepts: Common Errors in the Treatment of Congenital Clubfoot**, International Orthopedics (SICOT) 1997, 21:137-141 University of Iowa

Dietz, F., **Treatment of Idiopathic Clubfoot, A Thirty Year Follow-Up Note**, Journal of Bone and Joint Surgery, Vol 77-A No 10 October 1995, pages 1477 – 1489 University of Iowa

Group 1 copies

Morcuende, J., Ponseti, I.V.; **Plaster Cast Treatment of Clubfoot: The Ponseti Method of Manipulation and Casting**, Journal of Pediatric Orthopedics Part B 3:161-167, 1994, University of Iowa

Ponseti, I.V., **Current Concepts Review: Treatment of Congenital Club Foot**, Journal of Bone and Joint Surgery, 1992 pages 448-454, University of Iowa

Group 2 copies

Ponseti, I.V., **A Radiographic Study of Skeletal Deformities in Treated Clubfoot**, Clinical Orthopedics, October 1981 Volume 160 pages 30 – 42, University of Iowa

Laaveg, S., Ponseti, I.V., **Long-Term Results of Treatment of Congenital Club Foot**, Journal of Bone and Joint Surgery, vol. 62-A No 1 January 1980, pages 23 – 31, University of Iowa

Ponseti, I.V.; **Congenital Club Foot: The Results of Treatment**, Journal of Bone and Joint Surgery, vol. 45-A No 2 page 261-275, March 1963, University of Iowa

Unpublished Articles

UNKNOWN AUTHOR, **The Ponseti Method of Clubfoot Treatment**

Penny, J.N., Kinematics of the Subtalar Joint. **How the Manipulation Method of Ponseti Works.** Approx 2004

Penny, J.N., Pirani, S., Morcuende, J., Schwentker, E. **The Ponseti method of Clubfoot Care: A Vision for the Developing World**. Approx 2003

Pirani, S., **A Method of Clubfoot Evaluation** Clubfoot Clinic of the Royal Columbian Hospital, University of British Columbia, B.C., Canada

Reprinted from CLINICAL ORTHOPAEDICS, October 1981
Volume 160

A Radiographic Study of Skeletal Deformities in Treated Clubfeet

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Roentgenographic reports of anatomical deformities in treated clubfeet after skeletal maturity are scarce.[1,3,6,10] Interpreting these deformities is difficult and often confusing. The severity of the congenital anomaly of the foot and type of treatment performed determine the final appearance of the foot. The purpose of this report is to evaluate the abnormalities in 32 patients with unilateral clubfoot deformity and to correlate the roentgenographic findings with the functional results.

MATERIALS AND METHODS

Thirty-two patients, 21 males and 11 females, with unilateral clubfoot deformity were included in the study. Twenty-eight patients had been previously examined within the recent year in connection with a study of long-term results of treatment,[6] twelve of whom had volunteered to return for more extensive roentgenologic evaluation. In addition to the 28 patients, four more patients returned for clinical and roentgenologic evaluation. At the time of the last follow-up examination, the patients ranged in age from 13 to 30 years (average, 19½ years). The treatment, gentle manipulations of the foot and application of toe to groin plaster cast, was repeated weekly for five to seven weeks in eight patients; the remaining patients had the same treatment followed by subcutaneous Achillis tendon tenotomy and a plaster cast. This cast was worn for three to four weeks, followed by a Denis-Browne bar with shoes attached at the ends of the bar in 70° of external rotation. The splint was worn at all times for approximately three months and then at night only for another two to six years.[6,10] There were ten relapses treated by further manipulation of the foot and transfer of the anterior tibial tendon to the third cuneiform. None of the feet had surgical releases of the soft tissues of the posterior and medial aspects of the ankle or subtalar joints. No bony resections were performed.

Roentgenographic examination of the feet consisted of an anteroposterior standing view of 24° cephalad angulation and lateral standing views.[14] In ten patients, dynamics of both feet were studied employing fluoroscopy, to determine the range and type of motion at the ankle, subtalar and midtarsal (Chopart's) joints. In seven patients bilateral tomography of the subtalar joint was helpful in assessing the exact shape, size and orientation of the articular facets of the joint.[9]

Using the normal foot as a control, the parameters listed below were evaluated in both feet and the data obtained subjected to computer analysis. The paired t-test was used to assess statistical significance of the findings.

Tibia. The configuration of the distal tibia was studied in the anteroposterior and lateral projections.

Talus. On the lateral roentgenogram the length of the talus was measured and the shape of the dome of the talus, the angle of the neck with the body, and the size of the lateral tubercle were estimated. On the anteroposterior roentgenogram, the angle of the neck with the body and the shape of the talar head were studied.[7]

Navicular. Medial displacement of the navicular was evaluated by measuring the distance between the medial tuberosity of the navicular and the medial malleolus on the lateral roentgenogram (Fig. 1). Dorsal displacement of the navicular was

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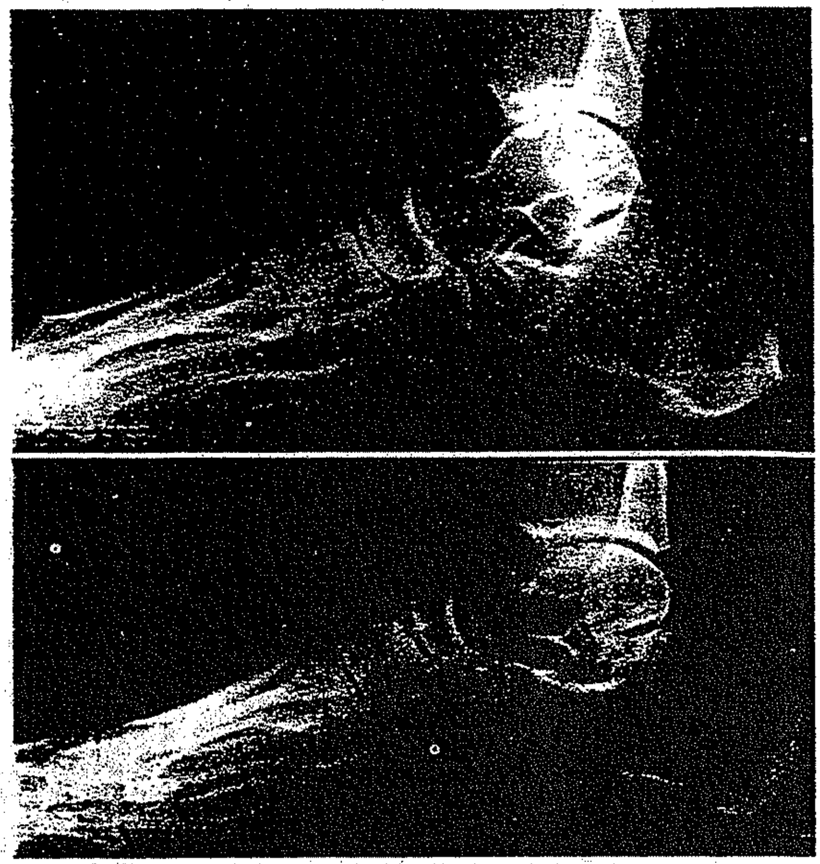


FIG. 1. Lateral roentgenograms of the feet of a 25-year-old female with right clubfoot deformity treated with five plaster casts during early infancy. At the age of eight years, the deformity tended to recur and was treated by a transfer of the tibialis anterior tendon to the third cuneiform. At present, her functional rating is 94. On the clubfoot site (bottom), there is notching of the anterior lip of the tibia. The talar dome is not as spherical in comparison with the normal foot (top). In the clubfoot, the head and lateral tubercle of the talus are small; the navicular is flat and the distance between the medial tubercle of the navicular and the medial malleolus is less than on the normal side.

also recorded when present. The degree of flattening and lateral wedging of the navicular were noted in the anteroposterior and lateral roentgenograms.

Calcaneus. The length of the calcaneus was measured on the lateral roentgenogram. The calcaneocuboid angle was measured on the anteroposterior roentgenogram. The angle was constructed by drawing straight lines through the long axes of the calcaneus and of the cuboid; a negative value indicated abduction of the cuboid (Fig. 2).

Cuneiforms. On the anteroposterior roentgenograms, lateral displacement of the cuneiforms with respect to the navicular was estimated and recorded (Fig. 3). Angular displacement of the cuneiforms was determined by the navicular first cuneiform angle. To construct this angle, a line was drawn through the long axis of the first cuneiform. The other limb of the angle was a line drawn perpendicular to the transverse axis of the navicular (Fig. 3). A positive value signifies abduction of the cuneiform.

Metatarsals. The length of the first and fifth metatarsals was measured.

Foot alignment. The alignment of the forefoot in relation with the hindfoot was evaluated on the anteroposterior roentgenograms on both the medial and lateral aspects of the foot. The talar–first metatarsal angle was constructed by drawing a line through the long axis of the talus and another line through the long axis of the first metatarsal; a positive angle signifies adduction of the first metatarsal. The calcaneal–fifth metatarsal angle was constructed by drawing a line through the long axis of the calcaneus and another line through the long axis of the fifth metatarsal; a positive angle signifies adduction of the fifth metatarsal (Fig. 4).

Other measurements. The distance between the posterior lip of the distal tibia and the opposing superior aspect of the calcaneus was measured on the lateral view. The degree of cavus was reflected by the angle between the longitudinal axis of the first metatarsal and the longitudinal axis of the fifth metatarsal on the lateral roentgenogram. In

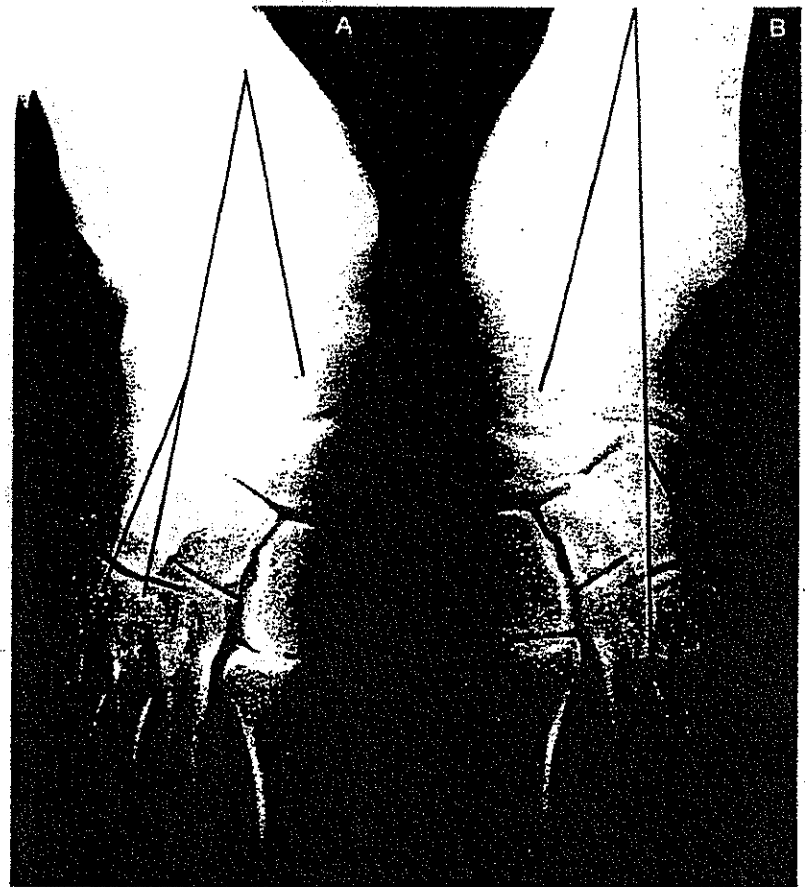


FIG. 2. Anteroposterior roentgenograms of the feet of a 25-year-old male with left clubfoot deformity treated by seven plaster casts during infancy. At present, his functional rating is 93. The calcaneocuboid angle is drawn to assess hindfoot–midfoot alignment and measures (A) −9° in the normal foot and (B) −27° in the clubfoot. The talocalcaneal angle measures 21° in the normal foot and 15° in the clubfoot. The incomplete correction of the talocalcaneal angle in the clubfoot is compensated by the increased abduction of the midfoot. In the clubfoot, the navicular is small and wedge shaped; it articulates with a talar head of diminished sphericity.

each patient, the size and configuration of the facets in the subtalar joint of the treated clubfoot were compared with the normal foot. The talocalcaneal angle was measured on both the anteroposterior and lateral projections.[14] The talocalcaneal index was computed for all the clubfeet and normal feet. The talocalcaneal index represents the sum of the talocalcaneal angles in the anteroposterior and in the lateral roentgenograms.[1]

RESULTS

Tibia. Two distinct features of the distal tibia were observed on the lateral roentgenograms in the clubfeet: posterior slanting of the articular surface was observed in 13 (39%) patients, and notching of the anterior lip of the distal tibia in 20 (63%) (Figs. 1 and 5). The anterior notch and posterior tibial slant were not seen in any of the normal feet.

Talus. In the clubfeet, the length of the talus ranged from 4.3 to 6.1 cm (mean, 5.4 cm); and in the normal feet from 4.3 to 6.8 cm (mean, 5.7 cm). This difference is statistically significant ($t = 6.87$).

Mild to moderate degrees of diminished convexity of the talar dome were observed in the lateral roentgenograms of 18 out of 32 (56%) clubfeet, but none had a flat-top talus[3] (Fig. 5). Anteroposterior roentgenograms of 12 clubfeet (37%) showed that the head was moderately flat in eight feet and dome-shaped in four (Figs. 2 and 3). In each patient, the angle of the neck with the body of the talus in the clubfoot was similar to that in the normal foot in the anteroposterior

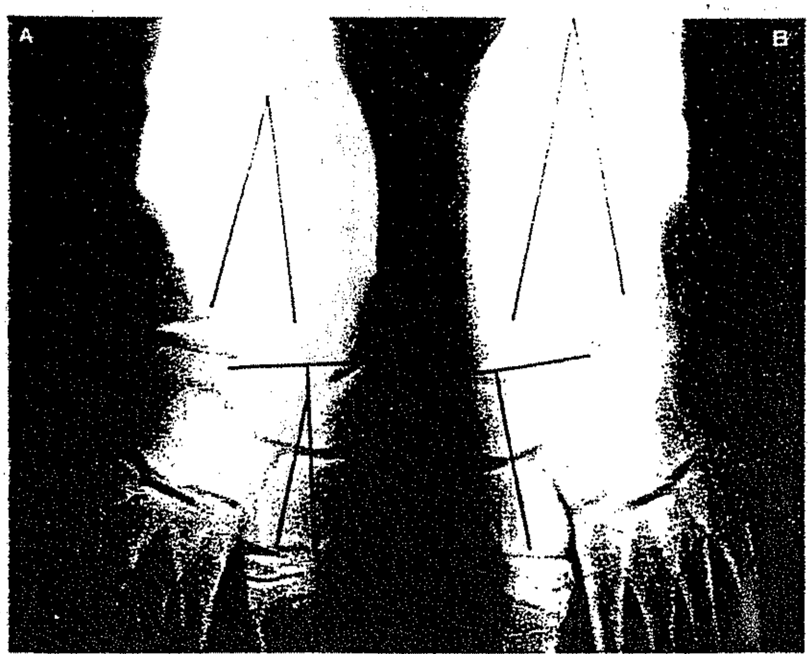


FIG. 3. Anteroposterior roentgenograms of the feet of a 13-year-old male with right clubfoot treated since birth with five plaster casts and percutaneous tendo-Achillis tenotomy. His current functional rating is 98. In the clubfoot (A) the navicular is medially displaced in relation to the head of the talus and is seen to approximate the medial malleolus; the talar head is dome shaped. The cuneiforms are laterally displaced and laterally angulated in relation with the navicular. The navicular-first cuneiform angle measures −14° on the clubfoot and 0° on the normal foot (B). The talocalcaneal angle measures 20° on the clubfoot and 23° on the normal foot.

and lateral roentgenograms.[7] On the lateral roentgenograms, the talar tubercle was small in 18 clubfeet (56%), when compared with the opposite normal feet (Figs. 1 and 5).

In the clubfeet, the talocalcaneal angle on the anteroposterior roentgenogram ranged from 4° to 25° (mean, 15.7°), and in the normal feet from 13° to 29° (mean, 20.7°). This difference is statistically significant ($t = 6.3$) (Fig. 3). The talocalcaneal angle in the clubfeet on the lateral roentgenogram ranged from 10° to 34° (mean, 23.1°), and in the normal feet from 17 to 46° (mean, 31.6°). This difference is statistically significant ($t = 6.1$).

Navicular. The configuration of the navicular was frequently abnormal in both the anteroposterior and lateral projections. The navicular was wedge-shaped on the anteroposterior roentgenogram in 17 clubfeet (53%), on the lateral roentgenograms in three clubfeet (9%), and in both the anteroposterior and lateral roentgenograms in 11 clubfeet (34%) (Fig. 2). The navicular was flattened on the anteroposterior roentgenograms in 13 clubfeet (40%), on the lateral roentgenogram in two clubfeet (6%), and on both the anteroposterior and lateral projection in seven clubfeet (21%).

The medial displacement of the navicular was seen in the majority of the clubfeet. The navicular–medial malleolar distance in the clubfeet ranged from 0.7 to 2.9 cm (mean, 2.4 cm); in the normal feet, from 1.8 to 3.0 cm (mean, 2.4 cm). This difference is statistically significant ($t = 9.2$) (Figs. 6A and 6B). Mild dorsal displacement of the navicular was also noted on the lateral roentgenograms in 11 clubfeet (34%).

Calcaneus. The length of the calcaneus in the clubfeet ranged from 6.5 to 8.8 cm (mean, 7.6 cm), and in the normal feet from 6.8 to 9.1 cm (mean, 7.8 cm). The difference is statistically significant ($t = 3.37$). On the

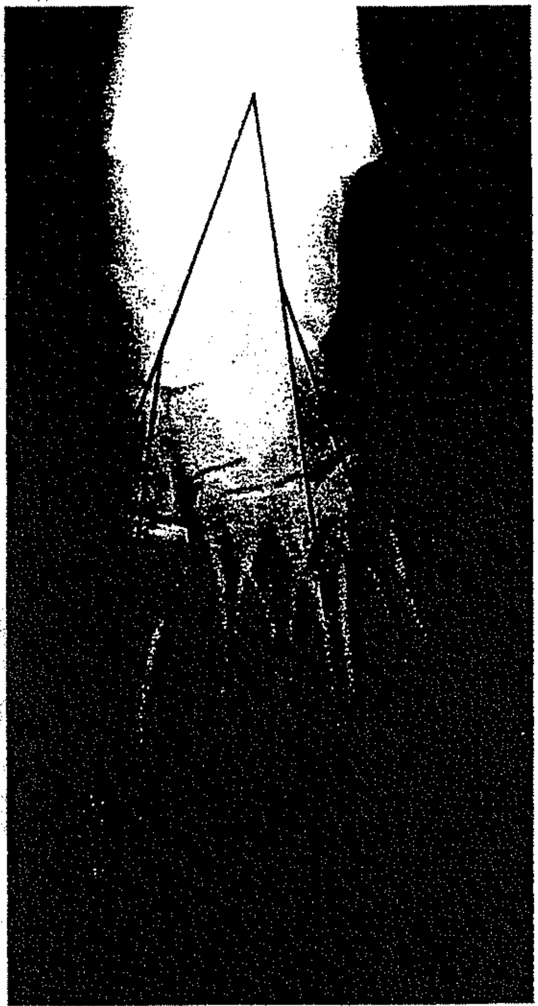


FIG. 4. Anteroposterior roentgenogram of a clubfoot in a 20-year-old female showing the calcaneus–fifth matatarsal and talus–first metatarsal angles. These angles were used to determine the hindfoot–forefoot alignment. Both angles measure −12°, indicating mild degree of abduction of the forefoot in relation to the hindfoot. The navicular is medially displaced and is wedge shaped.

anteroposterior roentgenograms the calcaneocuboid angle in the clubfoot ranged from −23° to +15° (mean, −4.15°); in the normal feet, from −18° to 0° (mean, −2.13°). The difference is not statistically significant (t = 1.92). The calcaneocuboid angle was positive in only one clubfoot.

Cuneiforms. The cuneiforms were laterally displaced and angulated in front of the navicular in 19 clubfeet. This deformity was not seen in any of the normal feet. The navicular–first cuneiform angle in the clubfeet ranged from −53° to 0° (mean, −17°); in the normal feet from −17° to +13° (mean, −1.7°). The difference is statistically significant (t = 6.76) (Figs. 3, 4, 6A and 6B).

Metatarsals. The length of the first metatarsal in the clubfeet ranged from 5.3 to 7.6 cm (mean, 6.54 cm) and in the normal feet from 5.5 to 7.9 cm (mean, 6.58 cm). The difference is not statistically significant (t = 0.6). The length of the fifth metatarsal in the clubfeet ranged from 5.5 to 9.4 cm (mean, 7.35 cm); in the normal feet from 5.5 to 9.4 cm (mean, 7.37 cm). The difference is not stataistically significant (t = 0.51).

Foot alignment. The talar–first metatarsal angle in the clubfeet ranged from −10° to +33° (mean, +3.28°); in the normal feet, from −20° to +11° (mean, −3.37°). The difference is statistically significant (t = −3.3) (Fig. 4).

The calcaneal–fifth metatarsal angle in the clubfeet ranged from −20° to +20° (mean, −4°); in the normal feet from −18° to +5° (mean, −3.37°). This difference is not significant (t = 0.49) (Fig. 4).

Other observations. The posterior tibiocalcaneal distance in the clubfeet ranged from 1.1 to 2.6 cm (mean, 1.76 cm), and in the normal feet ranged from 1.3 to 2.9 cm (mean, 2.02 cm). The difference is statistically significant (t = 4.58) (Figs. 1 and 5).

Cavus was observed in only four of the 32 clubfeet with the first–fifth metatarsal angle ranging from 17° to 39° (mean, 27.7°); in the other 28 clubfeet and in the normal feet, the mean was 12°.

The talocalcaneal index[1] in the clubfeet ranged from 16° to 51° (mean, 37.7°); in the normal feet from 37° to 64° (mean, 52.3°). This difference is statistically significant (t = 8.57).

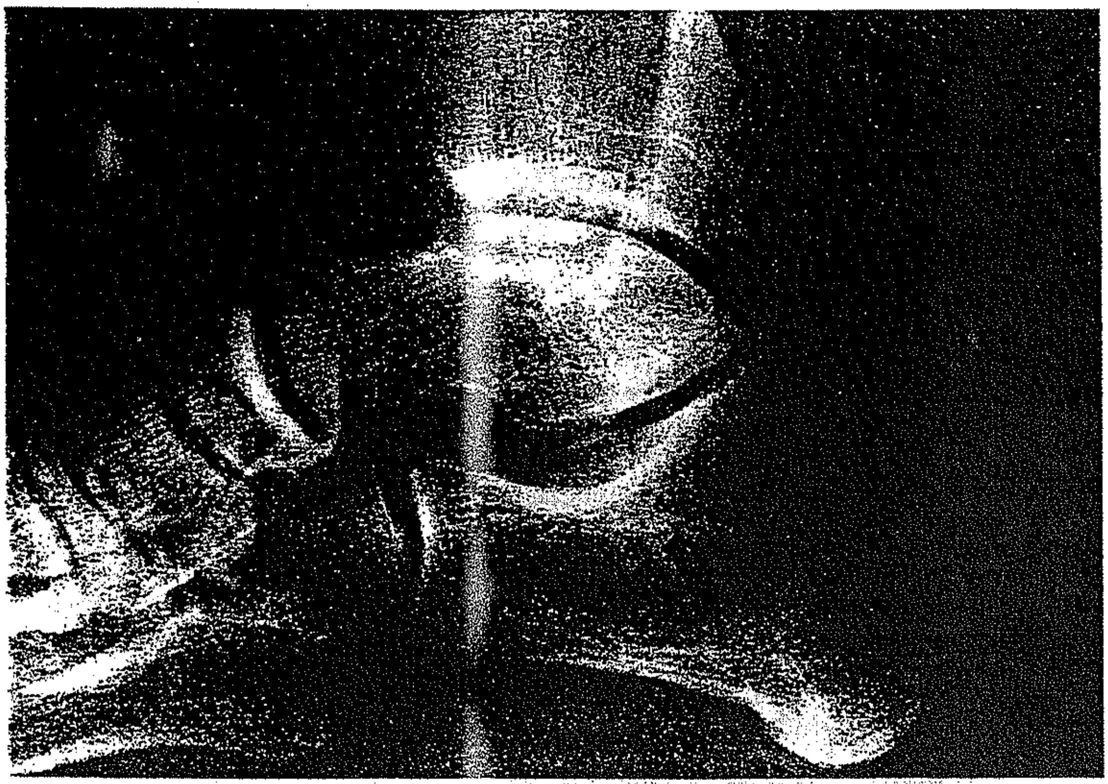


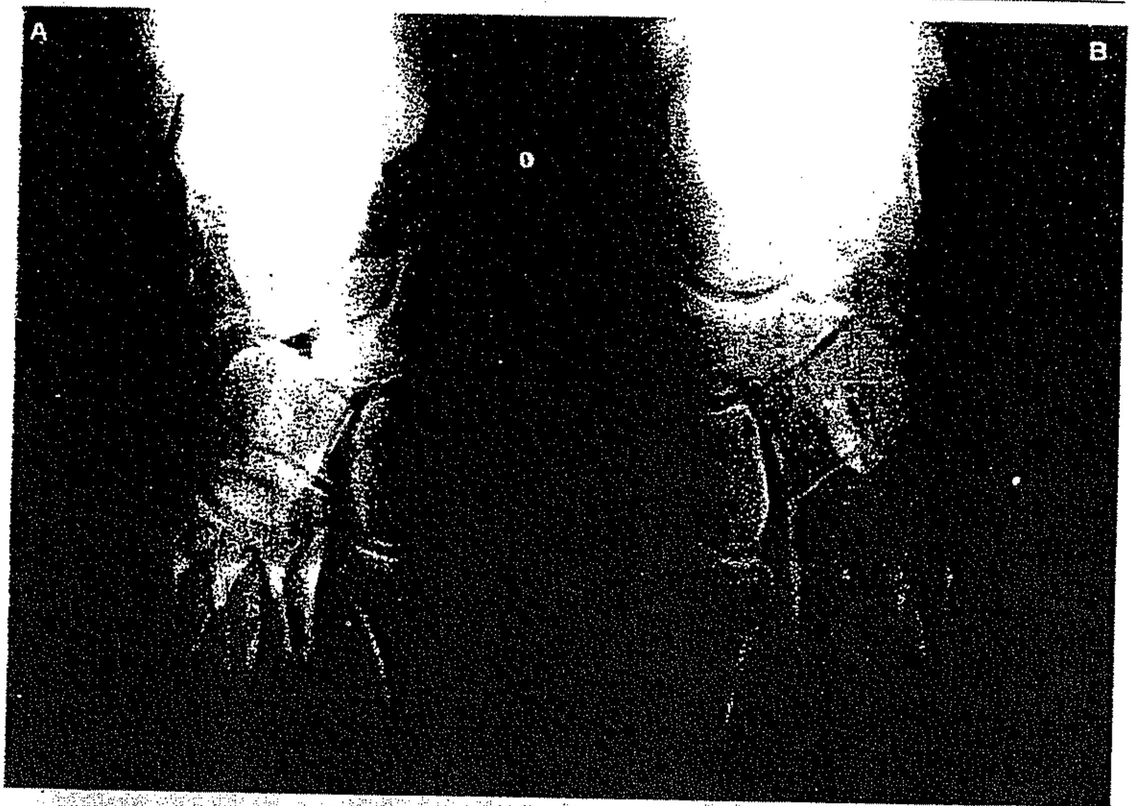
FIG. 5. Lateral roentgenogram of a clubfoot showing posterior slanting of the articulating surface of the tibia. The sphericity of the talar dome is diminished. The subtalar joint is markedly abnormal with continuous posterior and middle facets. There are no demonstrable anterior facets. The sinus tarsi is wide and the head of the talus is small.

Abnormalities in the size and configuration of the subtalar facet joints evidenced in 16 clubfeet were better delineated with the use of special views and tomography. Most striking was the small size of the posterior and middle facets, and the absence of the anterior facets (Figs. 7, 8A and 8B). In some clubfeet, the posterior joint facets spanned less than the medial half of the width of the talus and calcaneus. Often the narrow posterior facets merged with small middle facets[15] (Fig. 7). The sinus tarsi was always larger in the clubfoot (Fig. 8B).

Dynamic studies. In the ten patients examined, the posterior tibiocalcaneal distance measured on the lateral spot films, taken with the feet in maximum plantar flexion, was the same in the clubfoot as in the normal foot; however in maximum dorsiflexion, the posterior tibiocalcaneal distance was greater in the normal foot, and, in some patients, even five times greater.

Each patient was rated according to a 100-point functional scale.[6] Only four of the 32 clubfeet rated less than 90 points, of which three had the lowest values of the lateral talocalcaneal angle (under 16°) of all feet studied.[6]

The difference in the degree of subtalar motion between the normal and the clubfeet as depicted on the spot films obtained during fluoroscopy is noteworthy (Figs. 9A and 9B). The degree of sliding or scissoring motion between the talus and the calcaneus in the



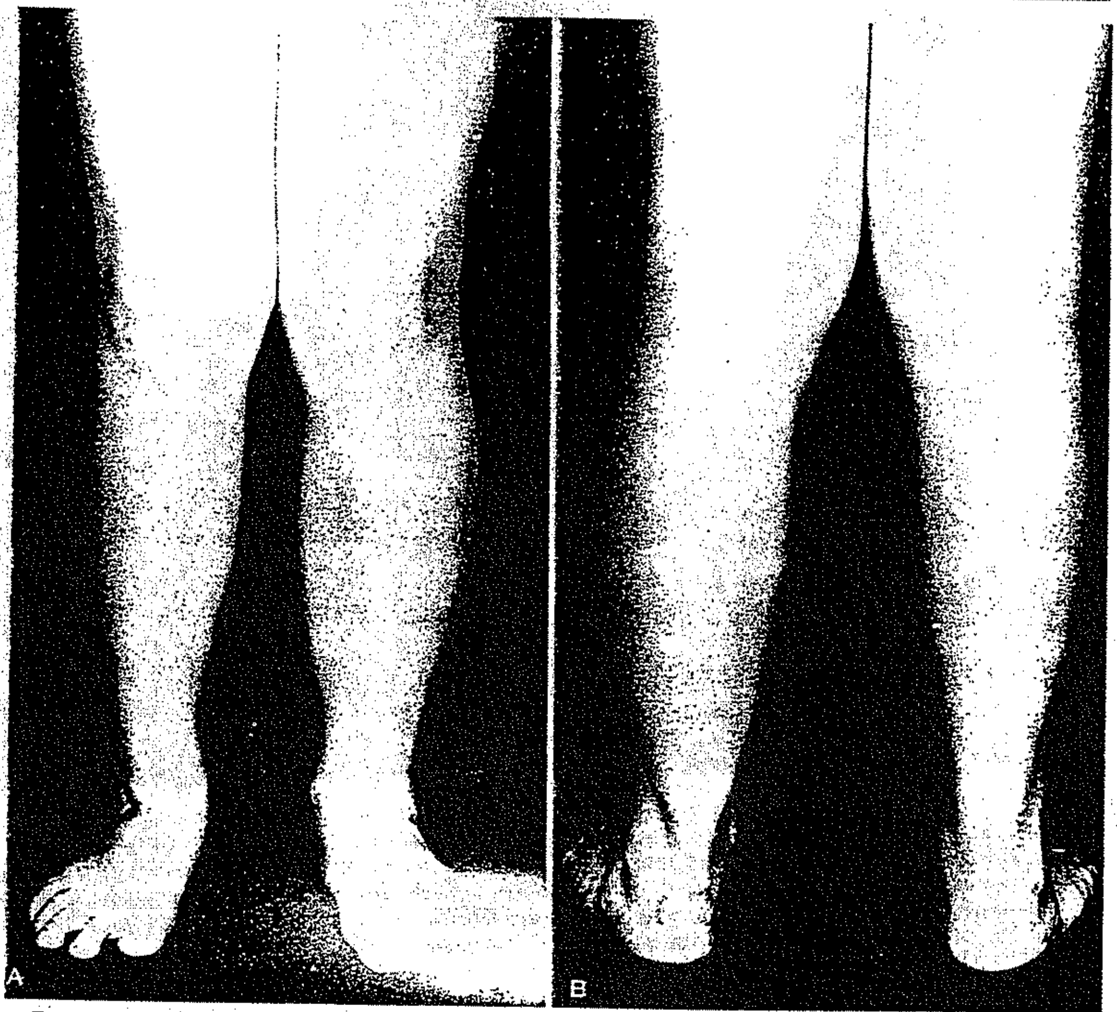
FIGS. 6A AND 6B. Anteroposterior roentgenogram of the feet of an 18-year-old female with right clubfoot treated by plaster casts in early infancy. Her current functional rating is 92. The most severe medial displacement of the navicular in our series is seen in this patient's clubfoot (A). The talocalcaneal angle measures 21° on the right and 28° on the left. On the right, there is inversion of the midfoot as evidenced by the superimposition of the cuneiforms and cuboid. The forefoot is not inverted and is well aligned with the hindfoot as observed in the roentgenograms.

subtalar joint of the clubfeet was comparable to the normal when supinated; however, when the feet were pronated, the gliding of the calcaneus under the talus was greatly restricted in the clubfeet. The range of ankle dorsiflexion and of subtalar motion was more restricted in the four feet with poor functional results than in the 28 feet with functional ratings greater than 90 points.[4]

The most notable finding on the spot films taken in maximum pronation and in maximum supination was the greater increase in the navicular–medial malleolar distance in pronation in the normal foot compared with the clubfoot. In many clubfeet the navicular remained medially displaced, even when the foot was pronated, and the head of the talus could not slide between the navicular socket and the sustentaculum tali as the foot was dorsiflexed.

DISCUSSION

Some of the residual abnormalities in treated clubfeet present after skeletal maturity are remnants of the treatment and some are a carry-over of the congenital anomaly in adulthood. In fact, several radiographic changes observed after skeletal maturity are reminiscent of the anomalies



FIGS. 6C AND 6D. Clinical photograph. The feet are well-aligned in spite of the severe midfoot inversion demonstrated radiographically in Fig. 6A. The circumference of the right calf is 2 cm smaller than the left.

present in the clubfeet of fetuses and newborns.[2,5,11,15]

In our studies, the notching in the anterior lip and the posterior slant of the distal tibia[7] appeared to be related to the tight ligaments and tendons in the posterior and medial aspects of the ankle and subtalar joints. These tight structures limited dorsiflexion and pronation of the heel. The talar head was consequently prevented from sliding downward between the navicular and the sustentaculum, thereby exerting excessive pressure on the anterior lip of the tibia, and stunting bone growth in the surrounding area. Similar compressive force applied to the dome of the talus can result in its diminished convexity. In addition, the total length of the talus was significantly shorter in the clubfeet, thereby increasing the chance of contact between the neck of the talus and the anterior lip of the tibia (Fig. 1).

In the clubfeet, the talus was smaller and

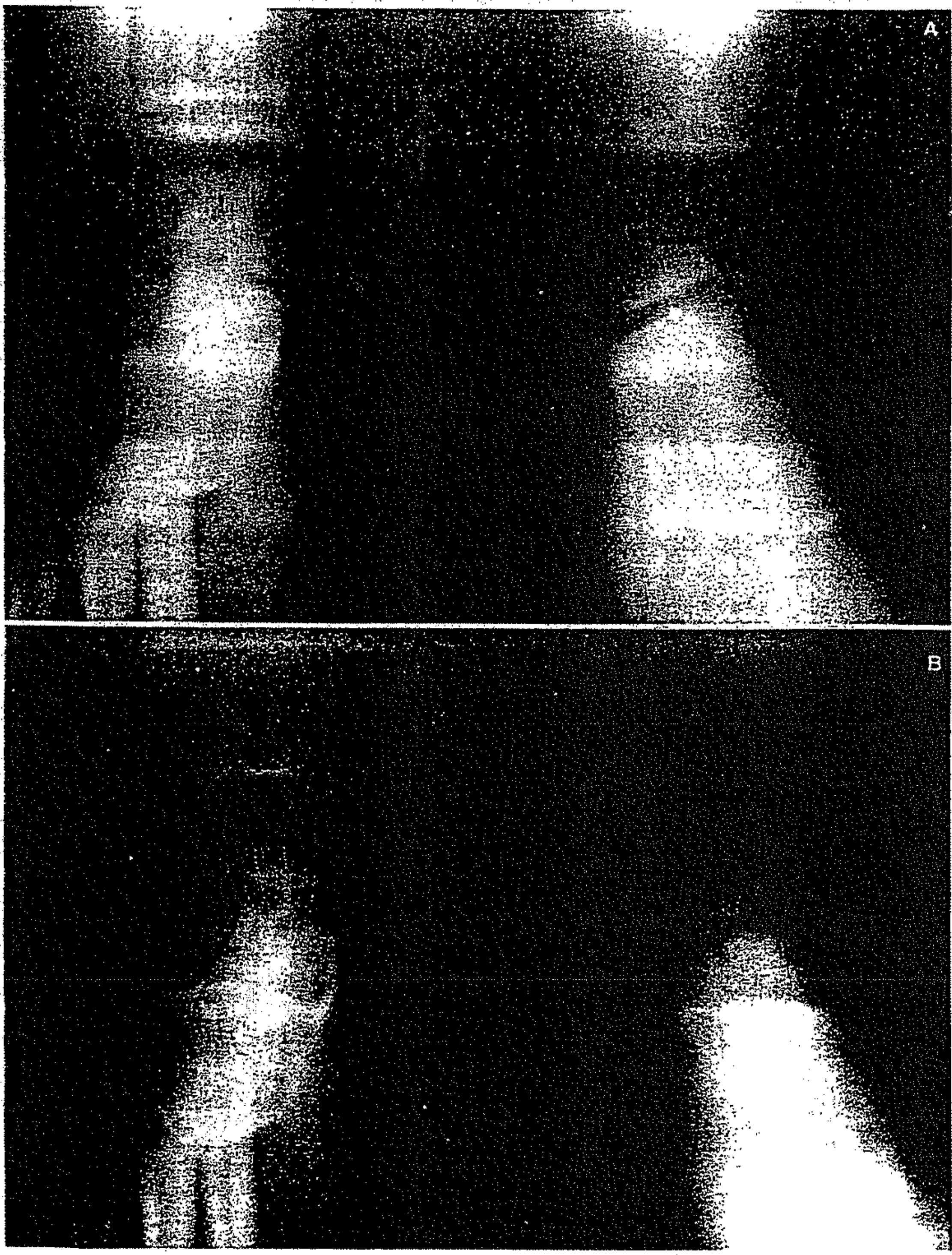
FIG. 7. Lateral roentgenogram of the ankle and subtalar joints of a normal (left) and clubfoot (right). Note the smaller size of the articular facets of the subtalar joint in the clubfoot.

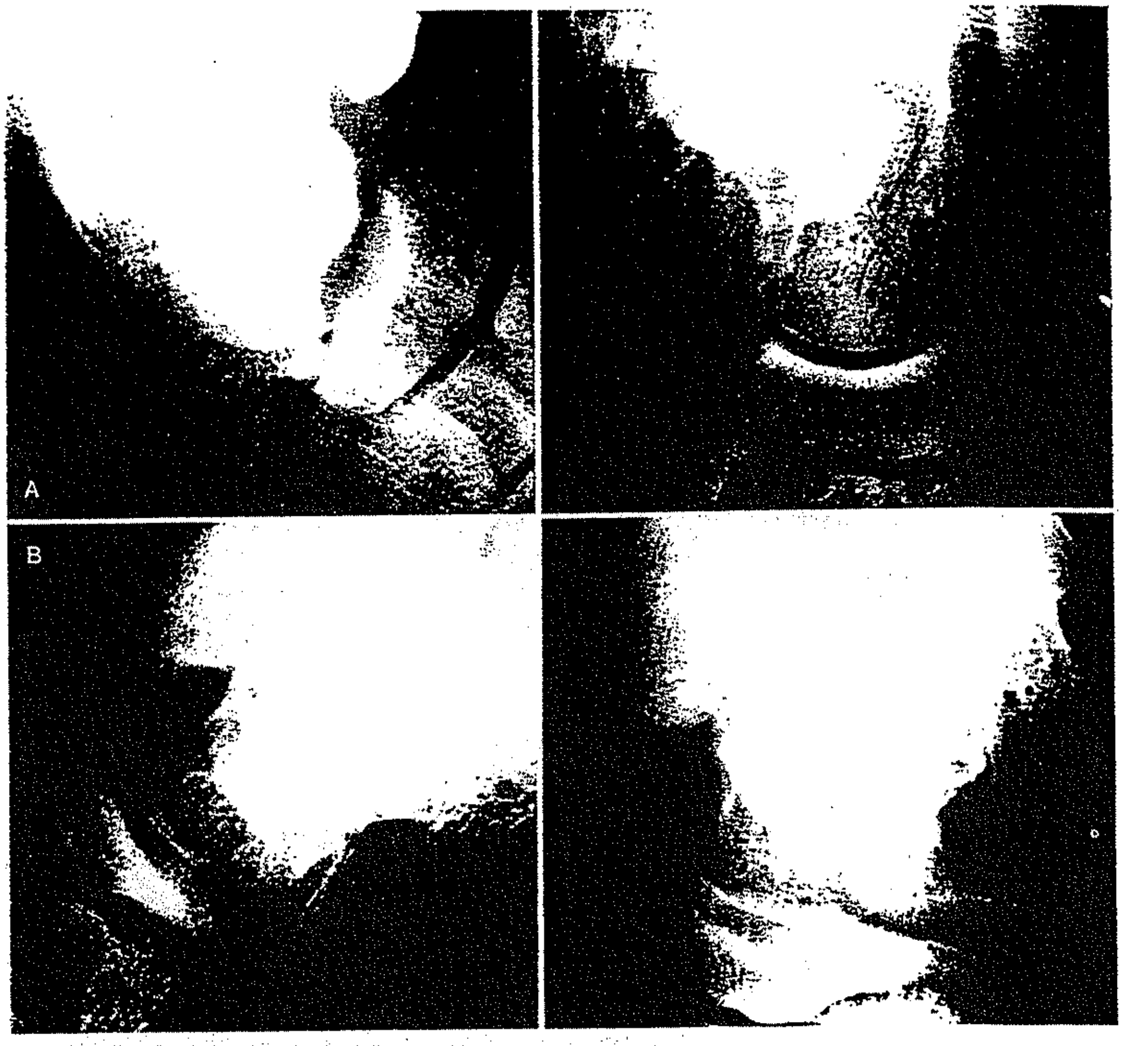
misshapened, and the navicular often wedge-shaped. Similar abnormalities have been observed in the clubfeet of fetuses and newborns.[2,5,11,15] The medial angulation of the neck of the talus observed in clubfeet earlier in life was not seen in any of our patients.

Abnormalities of the subtalar joint were severe.[9] Tomographically, the posterior facets of the subtalar joint were seen to span the entire width of the talus and calcaneus in the normal feet; however, in the clubfeet these facets were narrow and often spanned only the medial half of the width (Figs. 8A and 8B). The sustentaculum tali and the opposite articular facet of the talus were small and, in some cases, continuous with the facets of the posterior subtalar joint. The anterior facets of the subtalar joint were usually absent (Fig. 5).

All these changes in the subtalar joint of treated clubfeet have been observed in sections obtained from clubfeet of fetuses by Ippolito and Ponseti[5] and in infants by other researchers.[2,11] These findings compel us to conclude that the size and configuration of the subtalar joint facets are generally determined early in fetal life and that treatment will not result in the development of larger articulating facets nor in the formation of new facets. Moreover, the restricted motion observed at the subtalar joint in clubfeet following treatment appears to be due not only

FIGS. 8A AND 8B. Anteroposterior tomographic sections of both feet in a 19-year-old male with right clubfoot treated with six plaster casts during early infancy. The deformity recurred at the age of 4½ years and was treated by tendo-Achillis lengthening and transfer of the tibialis anterior tendon to the third cuneiform. His current functional rating is 99. (A) The posterior portion of the subtalar joint showing normal and wide posterior articular facets in the normal foot (right). In the clubfoot (left), the articulating facets are narrow and span only the medial one-third of the talus and calcaneus. (B) The midportion of the subtalar joint showing a normal and wide articulating facet at the level of the sustentaculum tali in the normal foot (right). In the clubfoot (left), the articulating facets are narrow and the sinus tarsi is very wide.


A
B



FIGS. 9A AND 9B. Fluoroscopic spot films taken during evaluation of motion at the subtalar joint. There is limited scissoring motion between the talus and calcaneus in the clubfoot (B) in comparison with the normal foot (A). The navicular is flat and wedge shaped in the clubfoot.

to the short ligaments and tendons posteriorly and medially but also to the abnormal size and configuration of the articular facets in the joint.[2,4,11,15]

The medial displacement of the navicular, observed in clubfeet of fetuses and stillborns, had been only partially corrected with our treatment. The navicular in most treated clubfeet remained medially displaced, as indicated by the shorter distance between the tuberosity of the navicular and the medial malleolus in comparison with the normal feet.[7] The cuboid, on the other hand, was approximately normal in position with respect to the anterior tuberosity of the calcaneus in all treated clubfeet (Figs. 2, 3 and 4).

The abnormal relationship between the talus and calcaneus was not fully corrected in our patients, as indicated by the smaller values of the talocalcaneal angles in the anteroposterior and lateral roentgenograms. It is noteworthy that the mean talocalcaneal index in our clubfeet is similar to that observed in surgically treated clubfeet by other authors.[8]

The range of ankle dorsiflexion, subtalar and midtarsal joint motions was less in the clubfeet than in the normal feet. The gliding between the talus and calcaneus and between the navicular and the head of the talus was restricted, limiting the degree of heel valgus and foot pronation in most clubfeet.

The lateral displacement and lateral angulation of the cuneiforms with respect to the navicular in effect compensated for the medial displacement of the navicular and for the decreased talocalcaneal angle in the anteroposterior roentgenograms. The metatarsals tended to align with the cuneiforms and the cuboid (Fig. 4). The cavus deformity was corrected in most clubfeet.

The anomalies observed in the serial sections from clubfeet of fetuses,[5] and in anatomical dissections[2,11,15] as well as in the present study attest to the fact that the clubfoot is a severe deformity affecting most of the skeletal elements of the posterior and middle parts of the foot as well as the soft tissues. Anatomical correction of all these anomalies appears to be infeasible even after extensive and repeated posteromedial surgical releases.[8]

In many of our treated clubfeet, the calcaneus did not slide fully into valgus, and the navicular remained medially displaced. Owing to this residual deformity, the anterior tibial tendon was a strong supinator and needed to be transferred to the third cuneiform to provide proper balance to the foot in a plantigrade position.[10] The spurious correction of the clubfoot deformity obtained in our cases depended in great measure on the lateral displacement and increased lateral angulation of the cuneiforms in relation to the navicular. Thus, in most feet, the forefoot was properly aligned with the hindfoot. Severe lateral rotation of the ankle with posterior displacement of the fibula described by some authors[12,13] was not observed in our patients. Although many of our treated clubfeet had small talocalcaneal angles and a variety of residual anatomic deformities, most patients evidenced good functional and cosmetic results (Figs. 6A–6D.)[6]

Our observations suggest that although an anatomical correction of the talocalcaneal angles and the medially displaced navicular is desirable, this is not necessary to ensure a good clinical outcome. The heel varus could be adequately corrected in spite of a persisting small talocalcaneal angle.[6] Proper hindfoot–forefoot alignment in the presence of a medially displaced navicular could be achieved by angulating and shifting the cuneiforms laterally. Although the range of subtalar motion in the clubfeet was restricted, most patients noticed little difference in the appearance and function between the normal and the treated clubfoot.

SUMMARY

Thirty-two patients with treated unilateral clubfoot deformity were followed for a period of 13 to 30 years. The functional results were satisfactory in 28 feet. A comparison of the skeletal features of the normal and the clubfeet was made on roentgenographs. Many clubfeet had small, slightly flattened talar heads, decreased talocalcaneal angles, undersized or misshapen facets of the subtalar joint, and medially displaced navicular. The residual deformity of the hindfoot was compensated by the lateral displacement and lateral angulation of the cuneiforms with respect to the navicular resulting in a normal alignment of the forefoot in relation to the hindfoot. The range of ankle dorsiflexion, subtalar and midtarsal joint motion was restricted in the clubfeet.

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Long-Term Results of Treatment of Congenital Club Foot*

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ABSTRACT: **In seventy patients with 104 club feet that were treated at our hospital and followed for ten to twenty-seven years after treatment, the functional results were satisfactory according to our rating system in 88.5 per cent of the feet, and 90 per cent of the patients were satisfied with both the appearance and function of the club foot. However, in the majority of the patients, foot and ankle motion was limited and the talocalcaneal angles as seen on the anteroposterior and lateral roentgenograms were not fully corrected. The amount of motion in the joints of the foot and ankle and the correction of the lateral talocalcaneal angle correlated with the degree of patient satisfaction and the functional rating of the club foot. Transfer of the anterior tibial tendon to the third cuneiform appeared to prevent relapse.**

The treatment of congenital club foot remains controversial. The results of any form of treatment vary according to the severity of the deformity. Usually, the orthopaedist's goal is to obtain anatomically and functionally normal feet in all patients, but this is not realistic because in many club feet the deformities of the bones, joints, and ligaments of the foot and ankle are too severe to be fully corrected[11]. Forceful and gentle manipulation; splinting; plaster casts; medial, posterior, and lateral release; osteotomy; and arthrodesis all have been used with limited success. In most clinics where club foot is treated, there is a reported incidence of resistant or relapsed club foot in 50 per cent or more of the patients[2,3,7,12,18,22,24,27].

Before 1950, extensive posteromedial soft-tissue releases were done commonly in our clinic to achieve an anatomical correction of the club-foot deformity. These operations often resulted in considerable stiffness of the foot and ankle, and recurrences or over-corrections of the deformity were observed. When one of us (I. V. P.) was placed in charge of the club-foot clinic in 1950, the aim of treatment was gradually changed and our goal was then to improve the functional results and to obtain plantigrade, mobile feet in the shortest time possible. Once we no longer tried to attain a perfect anatomical result, few soft-tissue releases were done.

In 1975, Bjönness reminded us that "the patient is the final judge of whether he has a good foot". A follow-up study of the patients with congenital club foot who were seen in our department since 1950 was designed to determine whether our treatment gave the patient a functional, painless foot. We attempted to correlate the patient's opinion of the appearance and function of the treated club foot with both the method of treatment and the clinical and roentgenographic findings that were seen ten years or more after treatment was begun.

Materials and Methods

Four hundred and ninety-eight patients with congenital club foot were seen between 1950 and 1967. One hundred and twenty-six of them had 189 club feet with no other congenital anomalies, were less than six months old when first seen, and either had had no previous treatment other than splinting or had had fewer than three plaster casts applied. All were treated under the direction of one of us (I. V. P.). Of the ninety-eight patients who were located for our study, twenty-six were unable to return and two had died. Seventy patients with a total of 104 club feet returned to our clinic for examination, and they were the basis of the present study.

The club foot was bilateral in thirty-four patients, and of the thirty-six patients in whom it was unilateral sixteen had a right and twenty, a left club foot. Eight patients with unilateral club foot had metatarsus adductus of the contralateral foot. Of the seventy patients, forty-eight (68.6 per cent) were male and twenty-two (31.4 per cent), female. The mean age at follow-up was 18.8 years, with a standard deviation of 4.9 years and a range of ten to twenty-seven years. The occupations of the returning patients were: forty-one students, eighteen manual laborers, and eleven white-collar workers.

Our treatment for club foot, which has been outlined previously[18,19], involves gentle manual manipulation of the foot without anesthesia as soon as possible after birth. The manipulation is followed by the application of a toe-to-groin plaster cast. We attempt to correct the deformity by abducting the foot distal to the talus while avoiding forced pronation. The fore part of a club foot is some-

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what everted with respect to the back of the foot, and this relationship causes the cavus deformity[19]. To correct the cavus deformity, the fore part of the foot is slightly inverted. The varus deformity of the heel is considered to be corrected when the anterior tuberosity of the calcaneus rotates laterally (abducts) underneath the head of the talus. In patients with severe cases, the heel is forced into a valgus position to stretch the deltoid ligament. The foot is remanipulated and a new cast is applied at approximately weekly intervals. To prevent recurrence of the cavus deformity, the anterior part of the foot is never everted while the foot is severely abducted. Before application of the last cast, if the equinus deformity remains uncorrected the tendo achillis is lengthened percutaneously using local anesthesia. The last plaster cast is worn for three to four weeks, and then the patient wears a modified Denis Browne bar[6] with the shoes attached in about 70 degrees of external rotation. The bar ranges in length from twenty to thirty centimeters, according to the size of the child. Except when it is removed daily for bathing, the bar is worn constantly for approximately three months. Then it is removed during the day for gradually increasing periods of time for approximately five months. Finally, the child wears the bar at night only for two to six years. The first relapse is usually treated by manipulation and the application of two to four toe-to-groin plaster casts, which are changed every two weeks. This treatment is often followed by lengthening of the tendo achillis. The anterior tibial tendon is transferred to the third cuneiform bone in children who are older than two and one-half years if this muscle is thought to have a strong supinatory action[11,19].

Of the 104 club feet, thirteen were treated with manipulation and plaster casts only; forty-two, with plaster casts and lengthening of the tendo achillis (93 per cent of the lengthenings were done subcutaneously with local anesthesia before the application of the last cast); forty-eight, with a transfer of the anterior tibial tendon to the third cuneiform bone without changing the position of the tendon underneath the ankle retinaculum except to provide a straight line of pull[19]; and one was treated with a transfer of the posterior tibial tendon to the dorsum of the foot through the interosseous membrane. Of the forty-eight feet that were treated by transfer of the anterior tibial tendon, two had no other procedure; twenty-nine also had lengthening of the tendo achillis; and seventeen had a variety of surgical procedures that included recession of the extensor hallucis longus tendon to the neck of the first metatarsal (ten feet), plantar fasciotomy (six feet), posteromedial release (four feet), posterior release of the ankle and subtalar joints (three feet), transfer of the extensor digitorum communis tendon to the metatarsals (three feet), triple arthrodesis (two feet), and transfer of the posterior tibial tendon to the dorsum of the foot through the interosseus membrane (two feet, with one relapse of the deformity which was treated by a transfer of the anterior tibial tendon to the third cuneiform).

The mean age of the seventy patients at the beginning of treatment was 6.9 weeks (standard deviation, 6.0 weeks); the mean number of casts used during their initial treatment was seven (standard deviation, 2.4); the mean duration of the initial treatment with plaster casts was 8.6 weeks (standard deviation, 10.0 weeks); the mean number of casts used for all treatment (initial treatment and treatment of relapses) was nine (standard deviation, 4.6); and the mean time that a Denis Browne bar was worn was 49.5 months (standard deviation, 26.4 months).

Each patient in the study filled out a questionnaire that provided information relative to his or her level of activity (including participation in sports), foot pain, problems with shoes, appearance of the foot, and satisfaction with the final result.

All seventy patients had an orthopaedic and neurological examination in which the strength of the muscles of

TABLE I

FUNCTIONAL RATING SYSTEM FOR CLUB FOOT

Category	Points
Satisfaction (20 points)	
I am	
a) very satisfied with the end result	20
b) satisfied with the end result	16
c) neither satisfied nor unsatisfied with the end result	12
d) unsatisfied with the end result	8
e) very unsatisfied with the end result	4
Function (20 points)	
In my daily living, my club foot	
a) does not limit my activities	20
b) occasionally limits my strenuous activities	16
c) usually limits me in strenuous activities	12
d) limits me occasionally in routine activities	8
e) limits me in walking	4
Pain (30 points)	
My club foot	
a) is never painful	30
b) occasionally causes mild pain during strenuous activities	24
c) usually is painful after strenuous activities only	18
d) is occasionally painful during routine activities	12
e) is painful during walking	6
Position of heel when standing (10 points)	
Heel varus, 0° or some heel valgus	10
Heel varus, 1-5°	5
Heel varus, 6-10°	3
Heel varus, greater than 10°	0
Passive motion (10 points)	
Dorsiflexion	1 point per 5° (up to 5 points)
Total varus-valgus motion of heel	1 point per 10° (up to 3 points)
Total anterior inversion-eversion of foot	1 point per 25° (up to 2 points)
Gait (10 points)	
Normal	6
Can toe-walk	2
Can heel-walk	2
Limp	−2
No heel-strike	−2
Abnormal toe-off	−2

TABLE II

MOTION OF THE ANKLE AND FOOT IN TWENTY-EIGHT NORMAL FEET AND ONE HUNDRED AND FOUR TREATED CLUB FEET

Group	Ankle Dorsiflexion			Varus-Valgus Motion of the Heel			Inversion-Eversion of Fore Part of Foot		
	Mean (Degrees)	Standard Deviation (Degrees)	Significance*	Mean (Degrees)	Standard Deviation (Degrees)	Significance*	Mean (Degrees)	Standard Deviation (Degrees)	Significance
Normal feet (28 feet)	31	9		39	7		65	10	
Club feet									
All (104 feet)	13	8.7		26.8	8.5		52.1	15.8	
Treated with plaster casts only (13 feet)	15.7	10.0		30.8	5.7		60.0	13.5	
Treated with plaster casts and tendo achillis lengthening (42 feet)	16.1	9.3	0.0096	30.1	7.0	0.0002	51.1	14.6	0.0002
Treated with anterior tibial tendon transfer (48 feet)	9.4	6.4		22.9	8.7		45.4	15.1	

* The differences between the three treatment groups as determined by the F test were significant at the 0.05 level.

the thigh, leg, and foot; stance; gait; and motion of the ankle and foot were recorded. The limb length, circumference of the leg, and length and width of the foot were all measured. The feet and legs were photographed with the patient standing. A force-plate analysis was done in the Orthopaedic Biomechanics Laboratories to determine the location of the resultant foot-floor reaction force for both feet during gait (the results of which will be presented in a subsequent paper).

A rating system for functional results was designed, with 100 points indicating a normal foot. This included a maximum score of 30 points for amount of pain; of 20 points each for level of activity and patient satisfaction; and of 10 points each for motion of the ankle and foot, position of the heel during stance, and gait (Table I).

Anteroposterior and lateral roentgenograms of the feet were made with the patient standing. The anteroposterior roentgenograms were made with the x-ray beam directed posteriorly at an angle of 25 degrees with the long axis of the tibia in the sagittal plane. On the anteroposterior roentgenograms we measured the angle between the longitudinal axes of the talus and calcaneus (the anteroposterior talocalcaneal angle) and the angle between the longitudinal axes of the calcaneus and fifth metatarsal, according to the method of Beatson and Pearson. Using the same method on the lateral roentgenograms, we measured the angle between the longitudinal axes of the talus and calcaneus (the lateral talocalcaneal angle) and the angle between the longitudinal axes of the first and fifth metatarsals. Finally we calculated the talocalcaneal index, which is the sum of the anteroposterior and lateral talocalcaneal angles as described by Beatson and Pearson. We also recorded any wedging of the lateral aspect of the navicular and any flattening of the trochlea of the talus. The anteroposterior talocalcaneal angle reflects the varus-valgus position of the heel; the anteroposterior angle between the calcaneus and the fifth metatarsal, any metatarsus adductus; and the lateral angle between the first and fifth metatarsals shows any pes cavus.

Of the seventy patients who returned to our clinic for this study, twenty-eight had one normal foot. For these feet we made the same tests for function and the same roentgenograms that we did for the treated club feet. We compared the clinical and roentgenographic variables in all of the normal feet and in all of the club feet in each treatment group by using the F test at the 0.05 level of significance to identify statistically significant differences in the results. We also analyzed each of the clinical and roentgenographic variables in relation to the ratings of function by using the F test at the 0.05 level of significance.

Using the T test, the rating of function and the patient's satisfaction with the result as indicated by his or her response to the questionnaire were each correlated with the following: the patient's ages at follow-up and initial treatment, total number of plaster casts, total time spent wearing the Denis Browne bar, number of relapses, amount of ankle dorsiflexion, amount of varus-valgus motion of the heel, inversion-eversion motion of the fore part of the foot, position of the heel while standing, adduction of the anterior part of the foot while standing, presence of pes cavus, anteroposterior and lateral talocalcaneal angles, and talocalcaneal index. Significant correlations were identified by the T test at a 0.05 level of significance.

Results

In all of the patients with unilateral club foot, the normal foot was longer and wider than the club foot and the circumference of the leg was greater on the normal side than on the side with the club foot. The limb lengths, on the other hand, were the same. The mean difference between the lengths of the feet was 1.3 centimeters; between the widths of the feet, 0.4 centimeter; and between the circumferences of the legs, 2.3 centimeters.

The strength of the muscles in the limb with the club foot, including the muscles whose tendon had been transferred, were rated 4.5 or 5.0 points on a 5-point scale.

For the purposes of this study, a relapse was defined as a club foot having a recurrent deformity that required further treatment. Fifty-five (53 per cent) of the club feet had no relapse; forty-nine (47 per cent) had one relapse at a mean age of thirty-nine months; twenty-five, a second re-

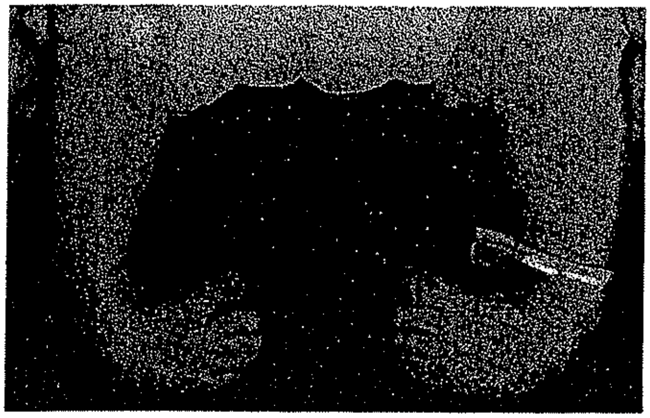

FIG. 1-A

Bilateral club-foot deformity in a male infant who was treated with six plaster casts for six weeks. The patient then wore a Denis Browne bar on his shoes for five years. A mild recurrence of the deformity occurred when he was two years old and was treated with three plaster casts that were changed at two-week intervals. When he was three and one-half years old, the deformity recurred again in the right foot. This was treated by transfer of the anterior tibial tendon to the third cuneiform.

lapse at a mean age of fifty-three months; ten, a third relapse at a mean age of sixty-three months; and three, a fourth relapse at a mean age of seventy-seven months.

The mean rating of function for all 104 club feet was 87.5 points, with a standard deviation of 11.7 points and a range of 50 to 100 points. The mean ratings for the feet in the three treatment groups were as follows: plaster casts, 93.1 points (standard deviation, 7.1 points); plaster casts and tendo achillis lengthening, 92.4 (standard deviation, 9.8); and transfer of the anterior tibial tendon, 80.5 (standard deviation, 11.1). The functional ratings in the three groups were significantly different (0.0001) as determined by the F test at the 0.05 level of significance. The feet that were treated by anterior tibial tendon transfer had a mean rating that was much lower than the mean ratings of the other two groups.

The results were classified according to the scores, as follows: excellent, 90 to 100 points; good, 80 to 89; fair, 70 to 79; and poor, less than 70 points. The results were rated as excellent in 54 per cent of the feet, good in 20 per cent, fair in 14 per cent, and poor in 12 per cent.

Fifty-nine per cent of the seventy patients stated that their club feet were never painful, 24 per cent had occasional mild pain after strenuous activities, 9 per cent had occasional pain during routine activities, and none had pain when walking. Seventy-two per cent had no limitation of activity due to the club foot, and 18 per cent had only mild limitation of activity. Only 7 per cent of the patients did not play on an athletic team because of discomfort in the club foot, although 36 per cent did not participate in organized sports by choice. Eighty-nine per cent of the patients stated that the club foot was normal or close to normal in appearance and that they experienced no embarrassment in public. Ninety-nine per cent were able to wear shoes of the same size. Seventy-two per cent of the patients were very satisfied with the end result of their treatment, 19 per cent were satisfied, and only 4 per cent of the patients were not satisfied.

The motions of the foot and ankle in the normal limbs were compared with those of the limbs with club foot (Table II). The mean amounts of dorsiflexion of the ankle, varus-valgus motion of the heel, and inversion-eversion of the anterior part of the foot were between one and two standard deviations lower in the limbs with a club foot than in the normal limbs. The feet that were treated by anterior tibial tendon transfer had significantly less motion than the feet in the other two treatment groups.

The mean position of the heel in the club feet during

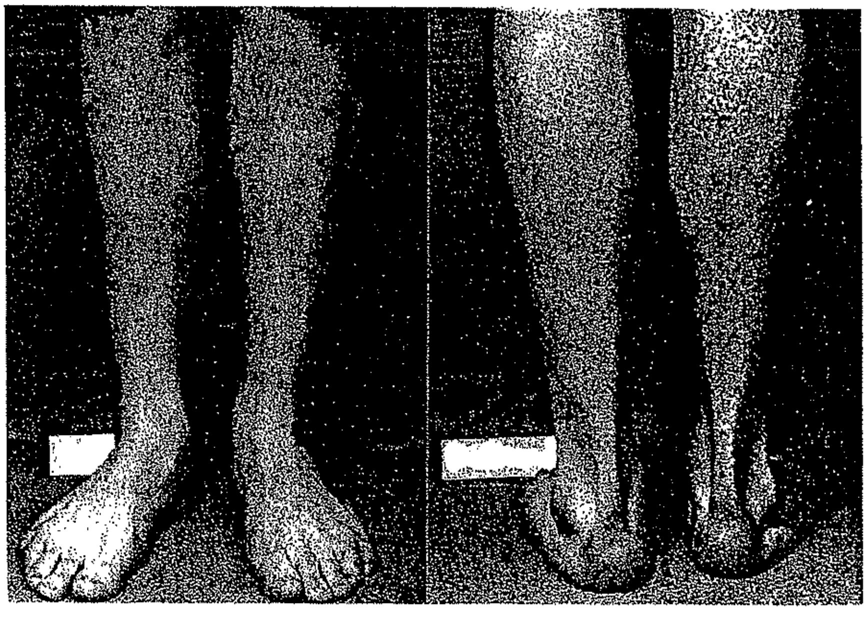

FIG. 1-B

When the patient was eighteen years old the feet appeared normal and were painless, and he was participating in all sports. In each foot he had 10 degrees of ankle dorsiflexion and 25 degrees of plantar flexion, 25 degrees of varus and 5 degrees of valgus motion of the heel, and 45 degrees of inversion and 10 degrees of eversion of the fore part of the foot. The functional rating of the club feet was 92 points.

TABLE III

FUNCTIONAL RATINGS RELATED TO RANGE OF MOTION AND POSITION WHEN STANDING IN ONE HUNDRED AND FOUR CLUB FEET

Motion and Position when Standing	No.	Functional Rating Mean (Degrees)	Functional Rating Standard Deviation (Degrees)	Significance*
Ankle dorsiflexion				
5° or less	35	81	11	
6 to 15°	34	87	11	0.0001
Greater than 15°	35	93	11	
Varus-valgus motion of heel				
32° or less	76	85	12	0.0013
Greater than 32°	28	93	9	
Inversion-eversion of fore part of foot				
55° or less	73	84	12	0.0001
Greater than 55°	31	94	7	
Position of heel when standing				
Varus	28	82	8	0.0286
Neutral or valgus	76	89	12	
Metatarsus adductus when standing				
Greater than 5°	7	78	12	0.0336
5° or less	97	88	11	

* There were significant differences between subgroups for motion and standing position as determined by the F test at the 0.05 level.

standing was 1 degree of valgus deviation, and there was no significant difference between the treatment groups. The mean metatarsus adductus while standing was 2.8 degrees.

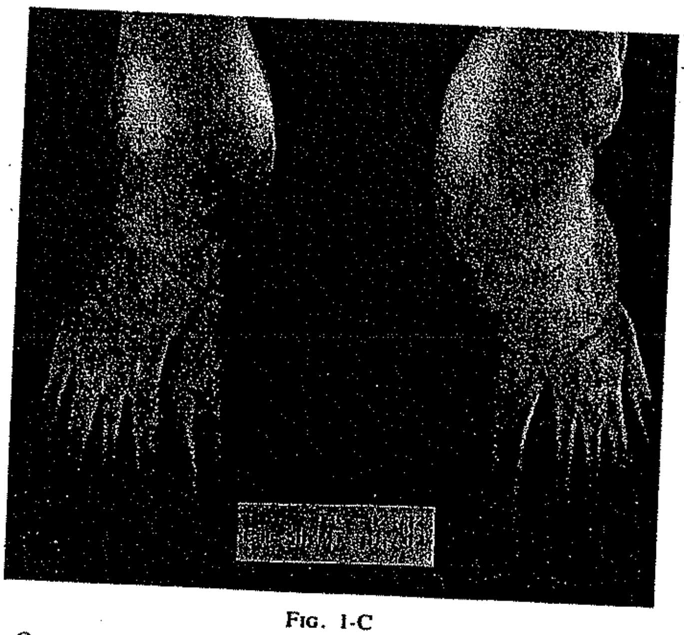

FIG. 1-C

On anteroposterior roentgenograms made when the patient was eighteen years old, the talocalcaneal angle is 12 degrees in both feet, the angle between the calcaneus and the fifth metatarsal is 1 degree in the right foot and −12 degrees in the left one, and the angle between the talus and the first metatarsal is zero degrees in both feet. The navicular is medially displaced and wedge-shaped and the cuneiforms are angulated laterally bilaterally.

The patients could walk on the toes of all of their 104 club feet and on the heels of seventy-nine (twenty-five, or 24 per cent, of the club feet did not permit heel-walking). Ninety-four (90 per cent) of the feet showed no pes cavus

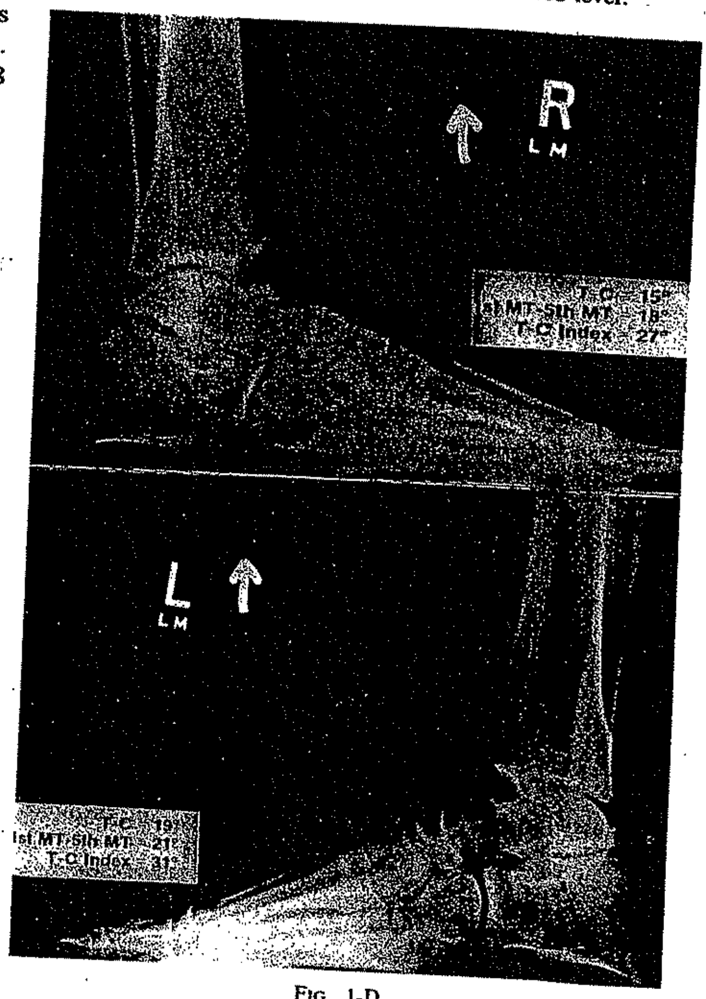

FIG. 1-D

On lateral roentgenograms, the talocalcaneal angle is 15 degrees in the right foot and 19 degrees in the left, and the talocalcaneal index is 27 degrees in the right foot and 31 degrees in the left. The body of the talus is small, the subtalar joints are distorted, and the navicular is wedge-shaped bilaterally.

TABLE

ANALYSIS OF ANGLES MEASURED ON ANTEROPOSTERIOR AND LATERAL ROENTGENOGRAMS IN TWENTY-EIGHT NORMAL

Group	Anteroposterior Talocalcaneal Angle		Lateral Talocalcaneal Angle	
	Mean (*Degrees*)	Standard Deviation (*Degrees*)	Mean (*Degrees*)	Standard Deviation (*Degrees*)
Normal feet (28 feet)	20	6	33	7
Club feet				
All (104 feet)	14.5	8.7	20.9	5.9
Treated with plaster casts only* (13 feet)	15.8	8.3	24.7	7.1
Treated with plaster casts with tendo achillis lengthening* (42 feet)	13.5	7.8	20.9	4.9
Treated with anterior tibial tendon transfer* (48 feet)	15.1	8.3	19.7	5.9

* There were no significant differences between the three treatment groups as determined by the F test at the 0.05 level.

deformity, while ten had a mild cavus deformity. None of the seventy patients limped.

The functional ratings of the feet were correlated with the ranges of motion of the foot and ankle and the standing positions of the heel and fore part of the foot. The feet were categorized into different subgroups according to the amount of motion or the severity of the malalignment of the foot in the standing position (Table III). The criteria for the different subgroups either were chosen arbitrarily or were based on one standard deviation below the mean for the normal feet. As seen in Table III, there were significant differences between the mean functional ratings of the subgroups. Decreased dorsiflexion of the ankle, varus-valgus motion of the heel, and inversion-eversion motion of the fore part of the foot showed significant correlations with a low functional rating. A varus position of the heel and metatarsus adductus when the patient was standing also were associated with a lower rating of function.

The roentgenograms revealed that the mean values for the anteroposterior talocalcaneal angle, lateral talocalcaneal angle, talocalcaneal index, and anteroposterior angle of the calcaneus and fifth metatarsal of the club feet were at least one standard deviation less than the corresponding mean values of the normal feet (Table IV). The mean angle between the first and fifth metatarsals on the lateral roentgenograms of the club feet was approximately equal to the same angle in the normal feet. There were no significant differences between the angles measured on the roentgenograms of the club feet in the different treatment groups.

On the anteroposterior and lateral roentgenograms of ninety-one (88 per cent) of the 104 club feet, the lateral half of the navicular bone appeared wedge-shaped to a varying degree and the cuneiforms in front of the navicular were laterally displaced and laterally angulated (Fig. 1-C). There was also moderate flattening of the trochlear articular surface of the talus in most of the club feet, although the degree of flattening could not be measured accurately since we did not control the amount of rotation of the limb adequately when the lateral roentgenograms were made. Some reduction of the height of the anterior part of the trochlear surface was also noted, but complete flattening of the trochlea was not seen in any patient and no rocker-bottom deformities were recognized either roentgenographically or clinically.

There were no significant differences between the mean anteroposterior talocalcaneal angles and talocalcaneal indexes of the feet with excellent, good, fair, and poor function ratings. The mean lateral talocalcaneal angles, on the other hand, were significantly different as determined by the F test (0.0114) at the 0.05 level of significance. The mean lateral angles for the feet in each rating group were: excellent rating, 22.4 degrees (standard deviation, 5.4 degrees); good, 20.5 degrees (standard deviation, 4.6 degrees); fair, 18.4 degrees (standard deviation, 7.5 degrees); and poor, 17.4 degrees (standard deviation, 6.3 degrees).

The functional ratings were correlated with the clinical and roentgenographic findings at follow-up (Table V), and the patient's degree of satisfaction with the results was correlated with the variables evaluated in this study as shown in Table VI. The functional rating and the patient's satisfaction correlated highly with the ranges of motion of the ankle and foot, the appearance of the club foot, the amount of pain, the level of activity, and the lateral talocalcaneal angle.

Discussion

The functional rating system that was designed for this study depended heavily on the patient's subjective response. Ninety per cent of our patients were satisfied with the appearance and function of the treated club foot. The force-plate analysis, to be reported in detail in a separate paper, showed that the location of the resultant foot-floor reaction force was more variable and somewhat more lateral compared with the normal location. However, in none of the patients did the reaction force show that the patient was walking on the outer part of the sole. The function and appearance of the treated club foot contrasted with the limitation of the motions of the foot and ankle observed at

IV

FEET AND IN ONE HUNDRED AND FOUR CLUB FEET IN THE STANDING POSITION

Talocalcaneal Index		Anteroposterior Angle of Calcaneus and Fifth Metatarsal		Lateral Angle of First and Fifth Metatarsals	
Mean (*Degrees*)	Standard Deviation (*Degrees*)	Mean (*Degrees*)	Standard Deviation (*Degrees*)	Mean (*Degrees*)	Standard Deviation (*Degrees*)
53	8	−12	4	12	7
35.5	10.2	−4.9	10.5	14.7	6.4
40.5	10.7	−3.5	9.5	16.7	8.5
34.6	10.6	−6.0	11.4	14.5	6.2
34.8	9.5	−4.1	10.0	14.6	6.0

our final examination and with the roentgenographic findings.

We observed significant differences between the treatment groups in terms of the functional rating, degree of ankle dorsiflexion, varus-valgus motion of the heel, and inversion-eversion motion of the anterior part of the foot. These differences most likely were related to the degree of resistance to treatment of the club feet in the different groups rather than to the treatment itself. The number of relapses had a highly significant negative correlation with the patient's functional rating. Obviously the resistant club feet required more treatment. Seventy-four per cent of the club feet had good to excellent functional results. Forty-seven per cent had a relapse after the first treatment. These results compared favorably with those reported in other series[2-4,7,9,10,12-14,16,19,20,22-24,27]. Many authors have placed special emphasis on the roentgenographic criteria of club-foot correction[1,12-21,26,27]. We found a strong correlation between the lateral talocalcaneal angle, the functional rating, and the patient's satisfaction with the results of treatment. This is in accordance with the observation of Turco that the lateral talocalcaneal angle is the more accurate indicator of club-foot correction. Templeton et al. measured the anteroposterior and lateral talocalcaneal angles in the normal feet of children older than five years. The values compared very closely with the ones found in the normal feet that we examined. In our patients, forty-three (41.4 per cent) of the club feet showed correction of the anteroposterior talocalcaneal angle and of the talocalcaneal index to within one standard deviation of the mean in the normal feet; however, correction of the lateral talocalcaneal angle to the same degree was observed in only twelve (11.5 per cent) of the club feet. A large proportion of the club feet that we treated had a wedge-shaped navicular as seen on roentgenograms. Since the mean anteroposterior and lateral talocalcaneal angles were 14.5 and 20.8 degrees, respectively, the majority of the club feet did not have complete correction of the deformity of the posterior part of the foot by roentgenographic criteria. Some correction of the deformity occurred at the mid-tarsal joint through lateral displacement and angulation of the cuneiforms and through wedging of the navicular. These roentgenographic changes will be discussed in detail in another paper.

The majority of the patients with pain complained of discomfort at the anterior aspect of the ankle joint and over the lateral aspect of the talonavicular joint after prolonged activity. This could have been due to abnormal loading of the mid-tarsal joints and the wedge-shaped navicular. Whether this deformity leads to early degenerative arthritis

TABLE V

SIGNIFICANT CORRELATIONS OF THE FUNCTIONAL RATINGS WITH CLINICAL AND ROENTGENOGRAPHIC FINDINGS

	Correlation	Significance*
Anterior inversion-eversion motion of the foot	0.59	0.001
Varus-valgus motion of the heel	0.47	0.001
Number of relapses	−0.46	0.001
Ankle dorsiflexion	0.45	0.001
Total number of plaster casts	−0.34	0.001
Lateral talocalcaneal angle	0.31	0.001
Anterior adduction of the foot	−0.20	0.023
Talocalcaneal index	0.16	0.049

* There were significant correlations between the functional rating and the specific variables listed as determined by the T test at the 0.05 level.

TABLE VI

SIGNIFICANT CORRELATIONS OF THE PATIENT'S SATISFACTION WITH CLINICAL AND ROENTGENOGRAPHIC FINDINGS

	Correlation	Significance*
Appearance	0.63	0.001
Pain	0.46	0.001
Activity	0.40	0.001
Lateral talocalcaneal angle	0.29	0.001
Cavus	−0.28	0.002
Anterior adduction of the foot	−0.24	0.008
Varus-valgus motion of the heel	0.10	0.034
Talocalcaneal index	0.17	0.041

* There were significant correlations between the patient's positive response to the question relative to satisfaction and the specific variables listed, as determined by the T test at the 0.05 level.

and further impairment of function in later life is uncertain.

In 1923, Dunn described lateral transfer of the anterior tibial tendon in the treatment of club foot and suggested that this transfer would be "helpful in preventing or delaying a recurrence of deformity". In 1947, Garceau and Manning also reported that the transfer had a "corrective influence". Whether anterior tibial tendon transfer has a corrective influence or merely prevents relapse when the muscle is removed as a dynamic deformer cannot be concluded from our study. Forty-six per cent of the patients had the anterior tibial tendon transferred to the third cuneiform after the first relapse and 56 per cent, after the second relapse. This transfer certainly appeared to prevent clinical relapse in our patients. Correction of the varus deformity of the heel can be clinically maintained by transfer of the anterior tibial tendon, and a large proportion of the club feet that were treated with this procedure had correction of the anteroposterior talocalcaneal angle as shown by their roentgenograms. However, the transferred anterior tibial tendon did not correct the lateral talocalcaneal angle, indicating that there was restriction of motion of the subtalar joint and of dorsiflexion of the ankle.

Our assumption that maintenance of flexibility of the foot improved the functional result was confirmed. The amount of motion of the foot and ankle made a significant difference in the final result of treatment. Subgroups based on the amount of motion of the joint and the position of the foot while the patient was standing had significantly different functional ratings. The larger the arcs of motion of the ankle, subtalar, and mid-tarsal joints, the better the functional result. There were strong positive statistical correlations between the functional rating of the club foot, the patient's satisfaction with the final result, and the motion of the joints of the foot and ankle.

This study, like all long-term follow-up studies, had limitations. It is regrettable that only seventy of the 126 patients returned for examination. The twenty-six patients who were located but who did not return all stated by letter or in telephone conversations that they were doing well, and their answers to our questions suggested that their results did not differ from those of the patients who returned for examination. Unfortunately, most roentgenograms made during the treatment period had been destroyed. Therefore we could not delineate when talocalcaneal angles changed or when wedging of the navicular bone increased. The trochlea of the talus was slightly flat in many feet, but the degree of flattening was compatible with that observed in the talus of newborns with club feet[11].

Recently many authors have advocated early posterior or posteromedial surgical release in the treatment of club foot[15,17,20,21,23,24,26]. Kuhlman and Bell found that club feet that were treated by anterior tibial tendon transfer had a much better result than feet that were treated by posteromedial release. Our results have been as good as or better than the results reported by others. Whether posterior or posteromedial release performed to correct the patient's lateral talocalcaneal angle on roentgenograms would improve our results needs further study. Very severe club foot may well benefit from early surgical treatment to improve the anatomical correction. We are concerned, however, that while a posteromedial release may correct the lateral talocalcaneal angle, it also may reduce motion of the foot and ankle and, therefore, not improve the functional result. This study has indicated that with proper manipulative and plaster-cast techniques, transfer of the anterior tibial tendon when indicated, and careful supervision, the orthopaedist can expect satisfactory functional results in a large percentage of congenital club feet.

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The Use of Plastic Jackets in the Non-Operative Treatment of Idiopathic Scoliosis

PRELIMINARY REPORT

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ABSTRACT: One method of treatment for scoliosis consists of using a custom-made plastic underarm jacket made of Orthoplast. The results of treatment in the first forty-eight patients with idiopathic scoliosis to complete the treatment program showed arrest of the progression of the curve in forty-two. Comparisons were made with the Milwaukee brace. The key prognostic factors for success appeared to be the severity and flexibility of the curve at the start of treatment.

Despite Hippocrates' description of scoliosis 2,400 years ago, it was not until 1914 that the first successful spine fusion was carried out for this condition. Thirty years ago the Milwaukee brace was introduced, and to date it remains the only proved successful method of non-operative treatment for scoliosis[3].

Emphasis on the early detection of scoliosis through such means as school screening programs and family surveys has resulted in the referral to scoliosis clinics of large numbers of young patients with mild curves. While the Milwaukee brace has been most effective in treating this group, it has the disadvantages of being expensive, inconvenient, and moderately objectionable in appearance to patients.

For these reasons, a search was started for a less expensive and more acceptable orthosis for the treatment of idiopathic curves of less than 40 degrees in the immature spine. After numerous modifications, a technique of fabricating a body jacket with Orthoplast was developed and a treatment protocol was established.

The purpose of this paper is to describe the method of fabrication of the jacket and the management program, and to report the preliminary results of treatment in the first forty-eight patients who completed the program.

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Technique of Fabrication

The patient is first placed on a suitable table and a cast (Risser or Cotrel type) is applied using strong corrective forces (average, twenty-seven kilograms of longitudinal traction). A roentgenogram is made while the patient is wearing the cast to determine either the amount of reduction of the curve or the improvement of the alignment, or both. The cast is then removed and filled with plaster to provide a positive mold that can be further modified to relieve pressure points and provide proper location of corrective forces. Orthoplast (or another suitable thermoplastic) is molded to this model. Trim lines are established at the levels of the pubic symphysis and greater trochanters to allow the patient to sit with the hips flexed, and the top is trimmed to fit high in the axillae. The jacket opens in the front for easy removal and is held closed by Velcro straps which provide a snug, adjustable fit (Figs. 1-A, 1-B, and 1-C). A roentgenogram is then made while the patient is wearing the jacket. The time for fabrication is about 50 per cent less for an Orthoplast jacket than it is for a standard Milwaukee brace. The cost of fabrication for the Orthoplast jacket averages 35 to 40 per cent less than that for a Milwaukee brace.

Treatment Protocol

Indications: Although the plastic jacket is not intended to completely replace the Milwaukee brace, the indications for its use are very similar. The curve should be less than 40 degrees and flexible, with an apex below the seventh thoracic vertebra; the patient should be skeletally immature and cooperative; and the physician and the

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Congenital Club Foot: The Results of Treatment

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Since 1948, a uniform system of treatment has been applied to all cases of congenital club foot on the Orthopedic Service of the State University of Iowa. Our aim has been to obtain a supple, well corrected foot in the shortest possible time. An end-result study of severe club-foot deformities in otherwise normal children treated initially in this department from 1948 to 1956, with a follow-up period from five to twelve years, is here presented.

Three hundred and twenty-two patients with club-foot deformity were treated during this period. The following were not included in this study: One hundred and forty-nine patients had been originally treated in other clinics and were referred to us for further correction. Ten patients had arthrogryposis; four had a complete or partial absence of the tibia; and eighteen had a myelomeningocele. The sacrum was absent in two and congenital constriction was present in the legs above the malleoli in two patients. In forty-six patients, the foot deformity was mild and was corrected by simple manipulations or the application of one to three plaster casts. Of the remaining ninety-one otherwise normal children with severe untreated club-foot deformities, twenty-four were lost to follow-up, usually at the end of the initial treatment.

We were able to evaluate the results of treatment in only sixty-seven patients with a total of ninety-four club feet. All these deformities were severe, although many variations in the degree of rigidity of the feet were present. The age of the patient at the onset of treatment ranged from one week to six months, and the average age was one month. Of the sixty-seven patients studied, ten were female and fifty-seven were male. The deformity was, therefore, almost six times as prevalent in male as in female children. Forty patients had only one foot deformed (60 per cent) and twenty-seven patients had both feet deformed (40 per cent). In the patients with unilateral involvement, the right foot was deformed in eighteen and the left foot in twenty-two cases. Anteroposterior and lateral roentgenograms and photographs of the feet of all patients were made at the onset of treatment and again at the time of the final examination.

METHOD OF TREATMENT

We aimed at an early and full correction of all the components of the deformity by gentle manipulation and well molded, thinly padded plaster casts which were changed every four to seven days. Anesthesia was never used. The plaster cast was applied in two sections, the first section extended from the toes to just below the knee and the second covered the knee and thigh. The knee was immobilized at a right angle while the leg was gently rotated outward to correct tibial torsion.

A clear understanding of the club-foot deformity is possible after identifying by palpation the position of the bones in the foot and their relationship to one another and to the leg. The foot is displaced and rotated medially beneath

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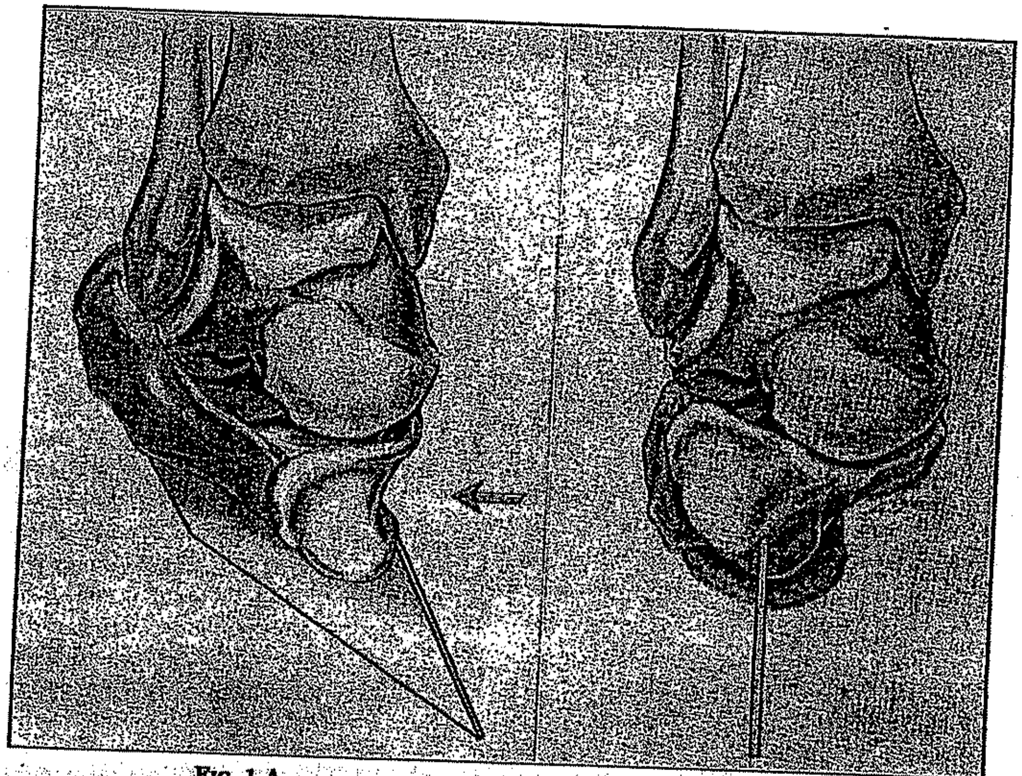

FIG. 1-A FIG. 1-B

Fig. 1-A: In club foot, the anterior portion of the calcaneus lies beneath the head of the talus. This position causes varus and some equinus deformity of the entire calcaneus.

Fig. 1-B: Lateral displacement of the anterior portion of the calcaneus to its normal relationship with the talus will correct the heel varus deformity of the club foot.

the talus. The head of the talus is palpable on the lateral aspect of the dorsum of the foot, owing to the inward and backward displacement of the navicular. The calcaneus is in severe equinus deformity with its anterior portion lying

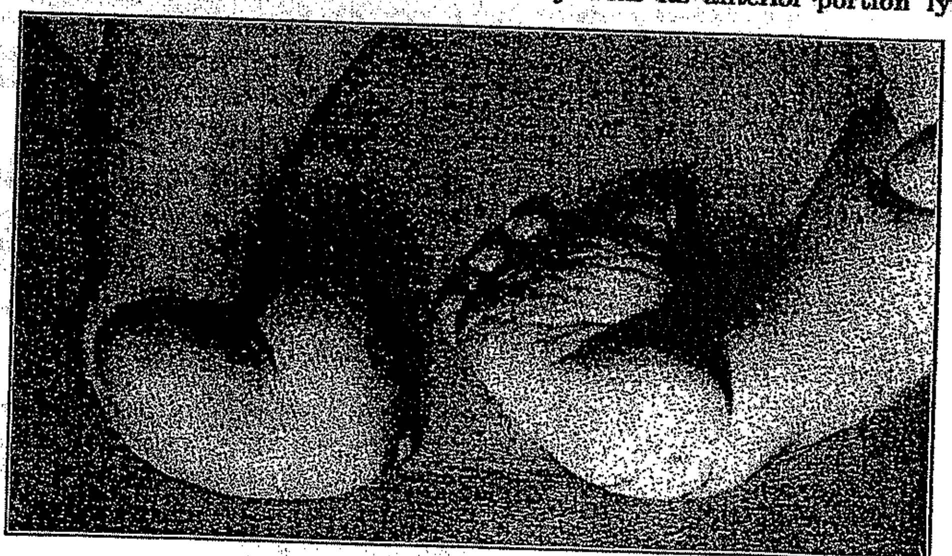

FIG. 2-A

Severe bilateral club-foot deformity in a six-week-old infant. The heel is in severe varus deformity. The fore part of the foot is adducted and inverted. The cavus deformity results from the slightly pronated position of the fore part of the foot in relation with the heel.

FIG. 2-B FIG. 2-C

Fig. 2-B: Manipulation to correct the cavus deformity. The fore part of the foot is slightly supinated to be placed in proper alignment with the hind part of the foot.

Fig. 2-C: Wrong maneuver to correct the inversion. This maneuver increases the cavus deformity and fails to correct the varus deformity of the heel.

FIG. 2-D FIG. 2-E FIG. 2-F

Fig. 2-D: The outlines of the bones were drawn on the skin. The head of the talus (*T*) was palpable in the dorsolateral aspect of the foot in front of the ankle joint. The navicular (*S*) was displaced medially and its tuberosity was palpable just anterior to the medial malleolus. The first metatarsal is almost in a straight line with the cuboid and calcaneus.

Figs. 2-E and 2-F: Manipulation to correct the inversion: outward pressure is exerted on the first metatarsal and counter pressure on the lateral aspect of the head of the talus (*T*). When the navicular and cuboid and the entire fore part of the foot are displaced laterally in relation with the head of the talus, the anterior portion of the calcaneus follows; thus, the heel varus deformity is corrected. While the inversion is corrected the fore part of the foot should not be pronated to prevent recurrence of the cavus deformity.

directly beneath the head of the talus. This displacement is responsible for the severe varus deformity of the heel (Figs. 1-A and 1-B). The cuboid is also displaced inward in front of the calcaneus. The cuneiforms are displaced downward and inward in front of the navicular. The medial displacements of the navicular, cuboid, cuneiforms, and metatarsals contribute in different degrees to the severe adduction deformity of the club foot. The varus deformity of the calcaneus and the adduction of the mid-tarsometatarsal bones together are responsible for the inversion. The fore part of the foot, although adducted and inverted, is not as severely inverted as the hind part. As a result, the front of the foot is somewhat pronated with respect to the back of the foot, and this relationship causes the cavus deformity. The cavus deformity is thus produced by the slight downward displacement of the cuneiforms and by the fact that the first metatarsal is plantar flexed to a greater degree than the fifth metatarsal. The cavus deformity is sometimes erroneously designated as equinus of the fore part of the foot. Excessive plantar flexion of the anterior part of the foot occurs primarily on its inner aspect. The plantar flexion of the outer aspect of the front part of the foot may be normal, as evidenced by the fact that the calcaneus, cuboid, and fifth metatarsal are in a straight line, even though the club-foot deformity is severe (Figs. 2-A through 2-F).

Brockman noted that in a club foot there is subluxation of the talocalcaneonavicular joint and alterations in position of the navicular and calcaneus with respect to the talus like those which occur in the normal foot when it is adducted, inverted, and plantar flexed, but they are exaggerated in degree. However, a normal foot cannot adopt a true club-foot position because even in the extreme degrees of plantar flexion and inversion, the fore part of the foot moves with the hind part, and a cavus deformity does not develop since there is no discrepancy in the degree of inversion of the front and back part of the foot.

The cavus deformity must be corrected with the first cast. Since the cavus deformity is related to the pronation of the fore part of the foot with respect to the hind part, the cavus is corrected by placing the fore part of the foot in supination in proper alignment with the hind part. An attempt to correct the inversion of the foot by forcible pronation of the anterior part of the foot will increase the cavus deformity as the first metatarsal is further plantar flexed. This common maneuver is harmful because it hinders greatly any correction of the club-foot deformity by increasing the pronation of the fore part of the foot and thus making it very difficult to mobilize the navicular and displace it laterally in relation to the head of the talus. The navicular, cuneiforms, and metatarsals should be placed in straight alignment to form the lever arm needed for the correction of the inversion (Figs. 2-B and 2-C).

To correct the inversion of the foot, all of the foot distal to the talus must be made to rotate laterally underneath the talus which is fixed in the ankle mortise. A thumb placed on the lateral aspect of the head of the talus is used as a fulcrum while outward pressure is exerted on the first metatarsal and first cuneiform. During this manipulation an attempt is made to realign properly and simultaneously the calcaneocuboid, the talocalcaneonavicular, and the posterior talocalcaneal joints. When the navicular and cuboid are displaced laterally, the anterior portion of the calcaneus will be displaced outward and upward from its initial position underneath the head of the talus, and thus the varus deformity of the heel will be corrected (Figs. 1-A and 1-B). Care is taken not to pronate the fore part of the foot during this manipulation to prevent recurrence of the cavus deformity (Fig. 2-E). The manipulations should be gentle and followed by the application of a well molded thinly padded light plaster cast. Four to five plaster-cast changes are usually sufficient to correct the inversion of the foot.

The equinus deformity is corrected next by dorsiflexing the foot with the heel in a neutral or slight valgus position. This is the most difficult deformity to correct because of the great shortening of the tendo achillis which resists stretching. Two to three casts are often applied after manipulations in an attempt to correct equinus deformity. If it then becomes evident that many more casts will be necessary for a complete correction, a simple subcutaneous tenotomy of the tendo achillis is performed with the patient under general anesthesia. A toe-to-groin cast with the foot in maximum dorsiflexion and the knee at a right angle is then applied for three weeks. The equinus deformity is thus immediately corrected, obviating a rocker-bottom deformity which often results from prolonged forceful manipulation. When the plaster cast is removed three weeks later, the defect in the tendon is healed. The scar in the tendon after this procedure is minimum, as observed in several instances where a tendo achillis lengthening was performed several years later to correct a recurrence.

Medial tibial torsion of variable degree is present in most patients with club feet and is a tenacious deformity if below-the-knee casts are used during treatment. Tibial torsion can be gradually corrected when toe-to-groin casts are applied with the knee in 90 degrees of flexion. To do this, the leg portion of the cast which includes the foot is held in slight outward rotation while the thigh portion hardens.

TABLE I

TREATMENT OF RECURRENCES

	First	Second	Third	Fourth
No. of Patients	37	12	7	1
No. of Feet	53	17	9	1
Average Age (*years*)	2½	3	4½	7
Treatment	No. of Feet	No. of Feet	No. of Feet	No. of Feet
Plaster casts	47 (6.4 wks.)	17 (8 wks.)	9 (7 wks.)	1 (6 wks.)
Denis Browne splints	6 (11 mos.)			
Subcutaneous section, tendo achillis	5*	4**	1*	
Tendo achillis lengthening	5**	1	1*	
Anterior tibial transfer	27	5	6	1
Recession, extensor hallucis longus	3	1		1
Recession, extensor digitorum longus		1		
Subcutaneous plantar fasciotomy	1	1		1
Medial release		1	2	
Lisfranc capsulotomy	1			

* One foot had subcutaneous tendo achillis tenotomy with the initial treatment.
** Two feet had subcutaneous tendo achillis tenotomy with the initial treatment.

From five to ten (average 7.6) plaster casts worn for periods of from five to twelve weeks (average 9.5 weeks) were necessary for the correction of all the club-foot components in our cases. A subcutaneous section of the tendo achillis was done in seventy-four of the ninety-four feet. To prevent recurrences of the deformity, Denis Browne splints with high-top shoes with well molded heels were applied after the plaster-cast treatment. These splints were left on full time for an average period of three months and at night for an average of twenty-one and a half months more (ranging from ten to thirty months)*. Ordinary high-top shoes were used for walking. No sole wedges were prescribed.

* For the past four years, Denis Browne splints have been worn at night until the age of three to five years.

First Recurrence

The deformity recurred in fifty-three feet (56 per cent) (Table I) at ages ranging from ten months to five years, with an average of two and one-half years. Some authors[1] stated that recurrences only occur when the club-foot deformity is not completely corrected at the initial treatment. However, when we reviewed the roentgenograms made at the end of the primary treatment, we found that the relationship of the talus to the calcanceus had not been completely corrected in only five cases. The causes for the recurrences are difficult to determine. In the forty-one feet permanently corrected with the first treatment the deformity tended to be less rigid, the leg muscles better developed, and the length of Denis Browne splint treatment longer than in the feet with recurrent deformities. Also, the family of patients without recurrence tended to be more cooperative. About half of the recurrences occurred from two to four months after the Denis Browne splints were discarded, usually on the family's own initiative; the recurrences could be blamed on the neglect of follow-up treatment with these splints. In other patients the recurrence was associated with a severe initial deformity and apparently poorly developed leg muscles; these recurrences seemed to be related to the severity of the primary aberration which caused the deformity.

In six patients the recurrence was treated with the Denis Browne splint worn at night and during napping hours. In forty-seven patients, the recurrence was more severe and was treated with manipulation and toe-to-groin plaster casts changed each week. The cast treatment lasted from three to twelve weeks (an average of 6.4 weeks). In the majority of recurrences, the equinus deformity was mild and responded to conservative treatment. Of the seventy-four feet treated with heel-cord section at primary treatment three required further surgery. The tendo achillis was sectioned subcutaneously again in one patient and was lengthened through a short medial longitudinal skin incision in the other two patients. The equinus deformity was resistant in seven feet not surgically treated initially. The tendo achillis was sectioned subcutaneously in four of these and lengthened in the other three. A subcutaneous section is preferred in patients under one year of age and tendo achillis lengthening in the older patients. In many of the recurrences, the varus deformity of the heel was more resistant to conservative treatment than the equinus deformity. A transfer of the anterior tibial tendon to the third cuneiform was done in twenty-seven feet in which there was a tendency for this muscle to supinate the foot strongly after the correction[2]. The tendon was transferred to the third cuneiform in nineteen feet and to the cuboid

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FIG. 3: PART I

Fig. 3, *A*, *B*, *C*, and *D*: Anteroposterior and lateral roentgenograms of the feet of a six-week-old baby boy with severe congenital club feet. In the anteroposterior roentgenograms, the talus and calcaneus are superimposed and their axes coincide indicating a severe heel varus deformity. The angle between the axis of the calcaneus and that of the fifth metatarsal (adduction of the fore part of the foot) measures 74 degrees. In the lateral views, the angle formed by the long axis of the calcaneus and that of the first metatarsal (cavus) measures 86 degrees. The calcaneus is in severe equinus and the talus is subluxated forward in relation with the tibial mortise. Treatment consisted in manipulation and application of five plaster casts for the correction of the cavus, the adduction, and the heel varus deformities. This took a total period of one month. A bilateral tenotomy of the tendo achillis was then performed followed by a plaster cast applied for three weeks.

Fig. 3, *E*, *F*, *G*, and *H*: Anteroposterior and lateral roentgenograms made after removal of the last plaster cast, seven weeks after onset of treatment. In the anteroposterior roentgenograms the angle between the long axis of the talus and that of the calcaneus measures 33 degrees, indicating correction of the heel varus deformity, and the angle between the calcaneus and the fifth metatarsal measures 13 degrees, indicating correction of the adduction of the fore part of the foot. In the lateral roentgenograms the equinus deformity appears corrected and the angle between the long axis of the calcaneus and that of the fifth metatarsal measures 7 degrees, indicating correction of the cavus deformity. Denis Browne splints on shoes were worn full time for ten months and at night until four and one-half years of age.

FIG. 3: PART

Fig. 3: Part II

in eight. The tendon was attached to the bone through a drill hole using a Bunnell pull-out suture in twenty-one feet and a silk suture and osteoperiosteal flap in six feet. Two skin incisions were made, one along the distal one or one and one-half inches of the anterior tibial tendon, the other shorter incision on the dorsum of the foot at the level of the third cuneiform. The tendon was transferred to its new attachment without changing its position underneath the ankle retinaculum. The foot was immobilized in a toe-to-groin plaster cast for four weeks. An over-correction of the club-foot deformity after this procedure was not observed in this series. In three feet in addition to the anterior tibial transfer the extensor hallucis longus was recessed to the neck of the first metatarsal after suturing its distal stump to the tendon of the short extensor of the big toe. The recession of the extensor hallucis longus was done in cases with severe plantar flexion of the first metatarsal and hyperextension of the first metatarsophalangeal joint. In one foot with severe cavus deformity, a subcutaneous plantar fasciotomy was performed. In another, a Lisfranc capsulotomy was done to correct a severe metatarsus adductus[4].

Second Recurrence

A second recurrence was observed in seventeen feet (18 per cent) at ages ranging from fourteen months to five years, the average being three years. In five of these seventeen feet the initial club-foot deformity was very rigid and the leg muscles were atrophic. Four other feet were short and stubby and hence difficult to treat. The first recurrence in these four feet and the first recurrence in three other feet with deformities of average severity had been incompletely corrected by the application of only two to four plaster casts. In the five remaining feet the second recurrence was observed shortly after the Denis Browne splint was discarded prematurely.

The second recurrence was treated with reapplication of toe-to-groin plaster casts changed every one to two weeks for periods ranging from four to twelve weeks (average, eight weeks). This was followed by a subcutaneous section of the tendo achillis in four feet, a lengthening of the tendo achillis in one foot, and a transfer of the anterior tibial to the third cuneiform in five feet. In one foot, the extensor hallucis longus was recessed to the neck of the first metatarsal, all the tendons of the extensor digitorum longus were recessed to the third cuneiform, and a subcutaneous plantar fasciotomy was done to relieve the cavus deformity. A medial release operation was necessary in another foot with a severe recurrence which had been treated previously by plaster-cast applications and transfer of the anterior tibial tendon.

Third Recurrence

The deformity recurred for the third time in nine feet (10 per cent) at an age ranging from three to eight years (average, four and a half years). In five of these feet, the recurrence was mild and was apparently caused by the strong

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FIG. 3: PART II

Fig. 3, *I*, *J*, *K*, and *L*: Anteroposterior and lateral roentgenograms made when the boy was seven years old. A good result was obtained in the right foot (*I* and *K*) and an acceptable result in the left (*J* and *L*). In the anteroposterior roentgenograms, the angle between the long axis of the calcaneus and that of the talus measures 28 degrees on the right and 22 degrees on the left, indicating correction of the heel varus deformity on the right and incomplete correction on the left. The angle between the calcaneus and fifth metatarsal measures —7 degrees on the right and 0 degree on the left, indicating correction of the adduction of the fore part of both feet. In the lateral roentgenograms the angle between the long axis of the calcaneus and that of the first metatarsal measures 32 degrees on the right and 24 degrees on the left, indicating correction of the cavus deformity in both feet.

TABLE II

RESULTS

Ankle Dorsiflexion (*Degrees*)	Heel Varus (*Degrees*)	Adduction of the Fore Part of the Foot (*Degrees*)	Tibial Torsion (*Degrees*)	Result
> 10	0	0–10	0	Good: 67 feet (71 per cent)
0–10	0–10	10–20	Moderate	Acceptable: 26 feet (28 per cent)
0	Over 10	Over 20	Severe	Poor: 1 foot (1 per cent)

supinatory action of the anterior tibial muscle. These recurrences were permanently corrected by lateral transfer of the anterior tibial tendon after the application of two or three plaster casts. The other four feet were somewhat rigid and the leg muscles were very atrophic. In one of these, a medial release operation, as well as a subcutaneous section of the tendo achillis, was necessary; in another, a medial release was combined with a transfer of the anterior tibial tendon to the third cuneiform; in the third, a tendo achillis lengthening was performed; and in the fourth treatment consisted in five plaster-cast changes which were followed by a recurrence of the deformity.

Fourth Recurrence

The last foot, just mentioned, was the only fourth recurrence observed (1 per cent). Treatment consisted in the application of one plaster cast followed by a subcutaneous plantar fasciotomy, a transfer of the anterior tibial tendon to the third cuneiform, and a recession of the extensor hallucis longus to the neck of the first metatarsal.

RESULTS

The correction obtained in each of the components of the club-foot deformity was evaluated clinically and roentgenographically. Both evaluations correlated closely with respect to ankle dorsiflexion, heel varus, and adduction of the fore part of the foot. Therefore only the clinical measurements of these components are charted (Table II). All the clinical measurements were performed by the senior author for the sake of uniformity.

On the anteroposterior roentgenograms, the degree of heel varus deformity was estimated by measuring the angle formed by the long axis of the talus and the calcaneus. A 30-degree angle was considered normal and was classified as 0 degree of heel varus deformity. Thus a measured talocalcaneal angle of 20 degrees corresponded to 10 degrees of heel varus deformity. The adduction of the fore part of the foot was also estimated on the anteroposterior roentgenograms by measuring the angle between the long axis of the calcaneus and that of the fifth metatarsal. On the lateral roentgenograms, the cavus deformity was estimated by measuring the angle between the long axis of the calcaneus and that of the first metatarsal (Fig. 3). The correction of the equinus deformity was estimated by measuring the degree of ankle dorsiflexion. The degree of tibial torsion was estimated clinically by having the patient seated on the edge of the examining table with the knees at 90 degrees of flexion and the feet in slight plantar flexion. In the normal foot, the head of the talus can be palpated in front of the ankle

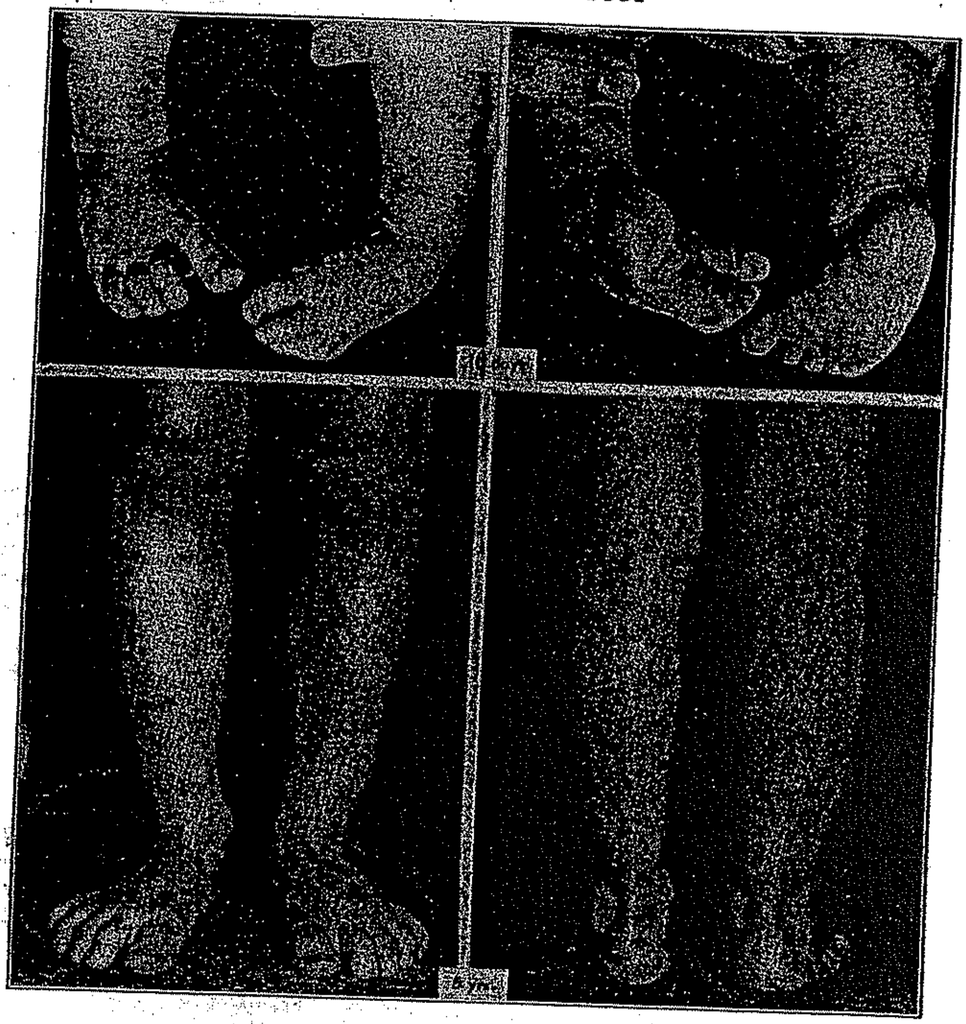

FIG. 4

Above: Club foot in a ten-day-old male infant. Photographs made after removal of the plaster casts which had been applied three days previously. Cavus deformity is completely corrected on the right side and partially corrected on the left side. Five more plaster casts were applied in a period of three weeks. The child wore Denis Browne splints part time for four years. *Below*: At five years of age both feet were well corrected.

mortise in the same plane as the axis of the thigh. Medial or lateral tibial torsion is indicated by the orientation of the head of the talus in respect to the patella and axis of the thigh.

The cavus deformity was corrected in most feet by the first plaster-cast application. The recurrences of this deformity were usually mild and responded to manipulation and plaster-cast applications with upward pressure on the first metatarsal head. However, a subcutaneous plantar fasciotomy was necessary in three feet with severe cavus deformity. In two of the three feet, this operation was combined with recession of the extensor hallucis longus tendon to the neck of the first metatarsal. Recession of this tendon was done in three other feet with severe plantar flexion of the first metatarsal. All these operations were successful, and in the final examination the cavus deformity was corrected in all cases.

The heel varus deformity was completely corrected in seventy feet (74 per cent). A slight degree of heel varus deformity of less than 10 degrees persisted in twenty-four feet (26 per cent). The heel varus deformity was corrected after

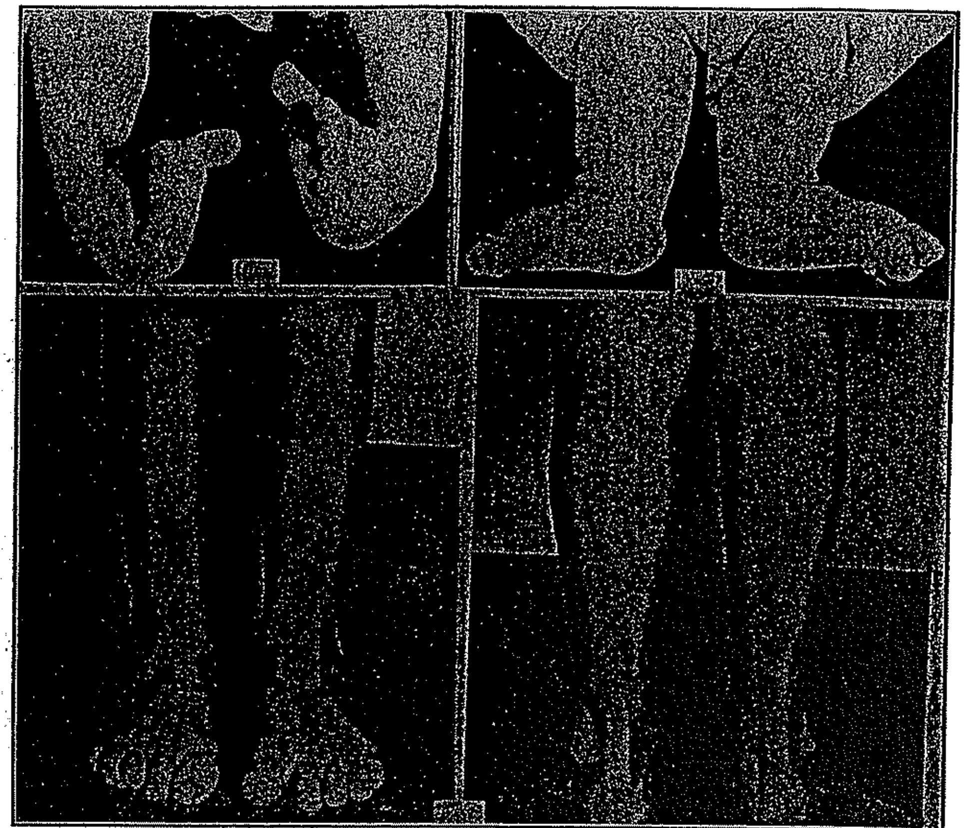

FIG. 5

Above, left: Bilateral club-foot deformities in a one-month-old female infant. Six plaster casts were applied in a period of one month, followed by bilateral subcutaneous tendo achillis tenotomy. *Above, right*: At three months of age both feet were corrected. At fourteen months of age, the deformity recurred on the left and was treated by application of two toe-to-groin plaster casts. A bilateral recurrence of the deformity occurred when the child was five years old and was treated by transfer of the anterior tibial tendon to the third cuneiform after the application of three plaster casts. *Below*: At eight years of age, both feet remained well corrected.

the initial treatment in all feet but it recurred in fifty-two. Anterior tibial transfer was done after plaster-cast correction in thirty-nine of these feet. The operation was successful in thirty feet but from 1 to 10 degrees of heel varus deformity persisted in nine feet. In six of these feet, the tendon pulled loose from its insertion (in three the wire broke and in the other three the silk stitches apparently came loose). In three feet the tendon was transferred to the third cuneiform and probably should have been transferred to the cuboid. The thirteen remaining recurrences had slight residual heel varus that did not require treatment.

Adduction of the fore part of the foot was completely corrected in seventy-two feet (77 per cent), was less than 20 degrees in twenty-one feet (22 per cent), and was severe in one foot. In one foot with severe adduction, the deformity was corrected by capsulotomy of the Lisfranc joint. Of the twenty-two feet with residual adduction, seven had an anterior tibial transfer and fifteen did not. It appears then that anterior tibial transfer may help to correct not only the heel varus deformity but also the adduction of the fore part of the foot.

Tibial torsion was completely corrected in seventy-eight feet (83 per cent). In fifteen feet (16 per cent) a moderate residual medial tibial torsion of less than 10 degrees was observed, and in one there was tibial torsion of 20 degrees. In no instance was an osteotomy of the tibia performed.

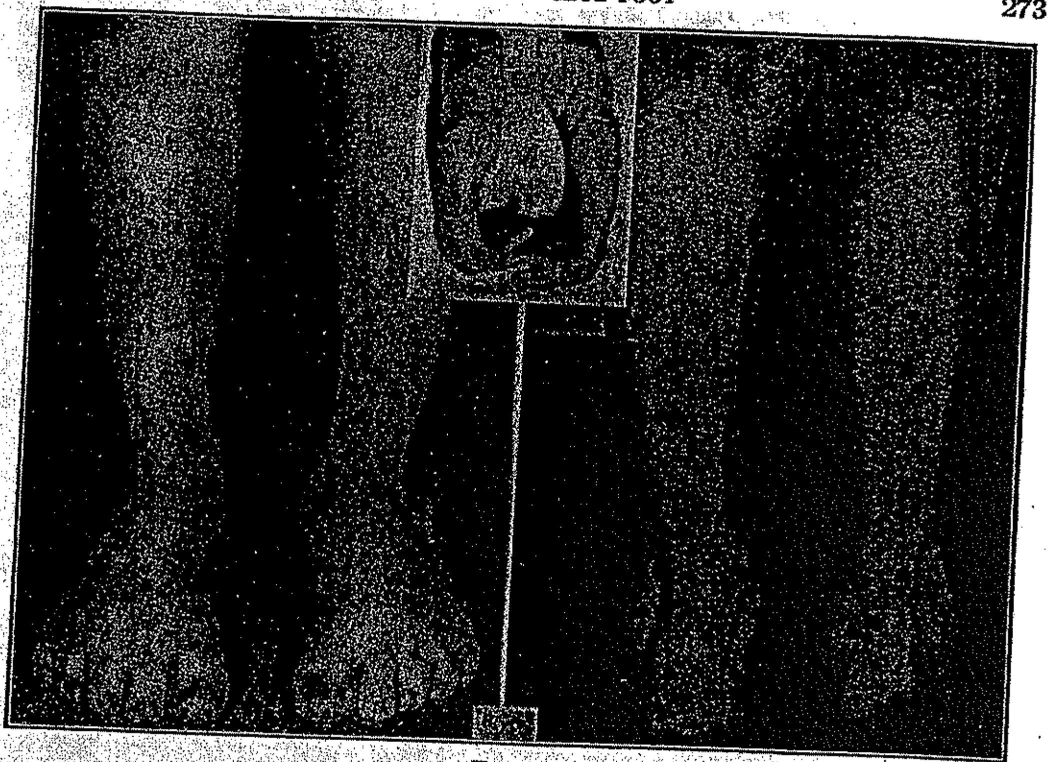

FIG. 6

Bilateral club-foot deformities in a five-day-old male infant treated with the application of ten plaster casts in a period of two months. A recurrence of the equinus deformity at one year of age was treated by the application of two toe-to-groin plaster casts and subcutaneous tenotomy. All the components of the club-foot deformity recurred at three years of age. Three plaster casts were then applied, followed by the transfer of the anterior tibial tendon to the third cuneiform. When the child was eight years old the left foot was well corrected. On the right a 20-degree metatarsus adductus and 10-degree heel varus deformity persisted.

Dorsiflexion of the ankle of more than 10 degrees above a right angle with the knee in extension was observed in seventy-five feet (80 per cent). In this group are included ten feet in which neither section nor lengthening of the tendo achillis was performed and sixty-five feet which had this tendon sectioned at the initial treatment. In eighteen feet (19 per cent) dorsiflexion of the ankle was limited to from 0 to 10 degrees. Eight of these feet had the tendo achillis sectioned at the initial treatment. A second section of the tendon was done in four to treat a recurrence, and in three the tendon was lengthened. The other ten feet of this group had either a section or a lengthening of the tendo achillis at the time of the first or second recurrence. One foot in which the heel cord was sectioned at the initial treatment and sectioned again at the third recurrence had a 5-degree residual equinus deformity. Mild flattening of the superior articular surface of the talus was observed in the final roentgenograms of this last foot and in fourteen feet of the preceding group. The over-all rating of results is summarized in Table II. Good results were obtained in 71 per cent of the feet (Figs. 4 and 5), acceptable in 28 per cent (Figs. 6 and 7), and poor in 1 per cent.

DISCUSSION

Although the treatment of a mild congenital club foot may be easy, the complete and permanent correction of a severe and rigid club foot is often difficult. In this study, we have been concerned with the severe cases only. The early months of life offer a golden opportunity for the correction of club feet since the

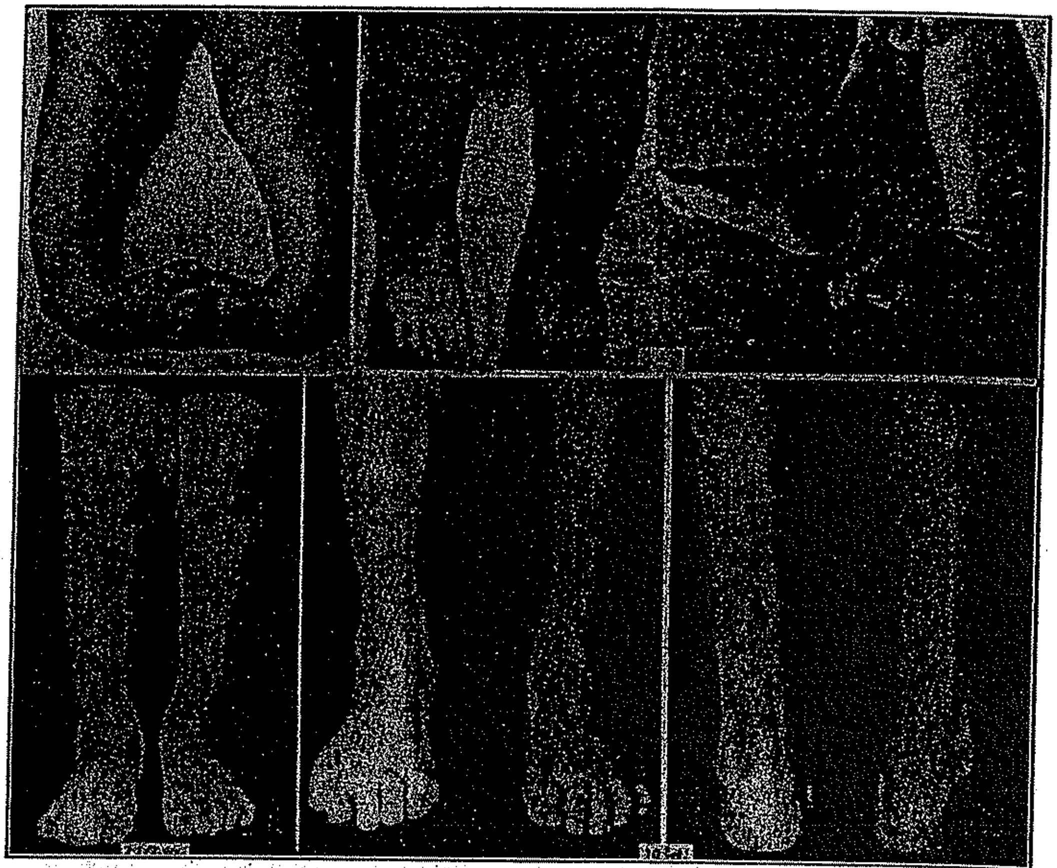

FIG. 7

Bilateral club-foot deformities in a female infant treated at two months with six plaster casts in a period of six weeks, followed by a bilateral subcutaneous tendo achillis tenotomy. Denis Browne splints on shoes were worn for four years. Photographs made when she was five months old, and later, when she was two and one-half years old, show all the components of the deformity well corrected. A mild recurrence of the deformity occurred when she was five years old, which was treated by the application of four plaster casts which were changed every ten days. Then, Denis Browne splints on the shoes were worn for three years. When she was nine years old the deformity recurred again. The left foot was treated by lengthening of the heel cord and transfer of the anterior tibial to the third cuneiform. *Below, right*: In the photographs made four months after operation, the deformity is well corrected on the left side. A 15-degree varus deformity of the heel and 5-degree equinus deformity persisted on the right. Subsequently, a lengthening of the heel cord and transfer of the anterior tibial tendon was done on the right foot.

skeleton, which is to a great extent cartilaginous, is little deformed, and the joint capsules, ligaments, tendons, and muscles can be stretched without damage. Early correction of all the components of the deformity in the shortest possible time is necessary for the proper development of the foot, since plaster-cast treatment prolonged for many months interferes with growth and may cause stiffness of the joints.

Correction of a severe equinus deformity can be radically shortened by subcutaneous section of the heel cord followed by the application of a plaster cast (with the foot in maximum dorsiflexion) for three weeks. After this procedure, the tendon always heals with little scarring; and, if it is done early, a posterior capsulotomy of the ankle joint is unnecessary and rocker bottom and flattening of the upper articular surface of the talus are prevented. However, the heel cord should be sectioned only after the other components of the club-foot deformity are completely corrected. Of seventy-four feet with severe equinus deformity treated with a subcutaneous section of the heel cord in the primary treatment, only eight required further surgery to treat a recurrent equinus deformity. Only seven tendo achillis lengthening operations were performed in the entire series.

Recurrence of the heel varus deformity and adduction of the fore part of the foot are common even after complete correction. Denis Browne splints on shoes worn full time for the first two or three months after correction, and part time thereafter until the child is from three to five years of age, are useful to prevent recurrences in many cases. However, only half of the recurrences could be blamed on the neglect of follow-up treatment; often these could be corrected by the reapplication of a few plaster casts. Some form of surgical treatment was necessary to prevent further recurrence in the more severe cases. A transfer of the anterior [2] or posterior [2] tibial tendons to the third cuneiform or to the cuboid in these feet seems to be the most effective procedure to prevent further recurrence of the heel varus deformity. The tendon transfer should be performed only after the foot is well corrected either by the application of several corrective plaster casts or, if necessary, by a medial release operation. However, the medial release operation often leaves extensive scarring and stiffness in the mid-tarsal joints and, when possible, should be avoided. Early transfer of the anterior tibial tendon in the very severe cases reduces greatly the need for this operation. It was performed in only three of our feet. The anterior tibial tendon was preferred over the posterior tibial for transfer because the operation is easier to perform and the anterior tibial functions in phase with the foot dorsiflexors, thereby making unnecessary postoperative training. Excessive plantar flexion on the first metatarsal and cock-up of the big toe was observed in only six of our feet; three of them before and three after anterior tibial transfer. This deformity was corrected by the transfer of the long extensor of the big toe to the neck of the first metatarsal. The nine failures of the anterior tibial transfer to correct permanently the varus deformity of the heel could be blamed on surgical errors.

Tibial osteotomy was not necessary in our patients because medial tibial torsion was corrected during the application of toe-to-groin plaster casts followed by the use of Denis Browne splints. Tibial torsion will remain uncorrected if below-the-knee plaster casts are inadvisably used in the treatment.

SUMMARY

The results of treatment in sixty-seven patients with a total of ninety-four severe congenital club feet were evaluated five to thirteen years after the initial treatment. The primary treatment consisted in the application of several plaster casts changed frequently for an average period of 9.5 weeks. In many instances a subcutaneous tendo achillis tenotomy was performed in the primary treatment to obtain a complete correction of the equinus deformity. Denis Browne splints were used in the follow-up care in all patients.

In fifty-three feet the deformity recurred and required further treatment. The recurrences of the equinus deformity were usually mild and responded to conservative treatment. Only seven tendo achillis lengthening operations were performed. A transfer of the anterior tibial tendon to the dorsolateral aspect of the foot was performed in thirty-nine feet to prevent further recurrences of the heel varus deformity. Medial release operations were necessary in only three feet. In no case was bone surgery performed.

The results in 71 per cent of the feet were good; in 28 per cent a slight residual deformity persisted; and in one foot a poor result was obtained.

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THE PONSETI METHOD OF CLUBFOOT TREATMENT

The orthopaedist must have a sensitive and kind approach to babies. After a General examination to rule out non-idiopathic clubfeet, parents must be reassured that their baby's deformity will be corrected in two months and that the baby will have a normal-looking and functional foot throughout life. Photos of the feet are taken for the chart. Radiographs are not necessary.

Foot examination and corrective manipulations are best done with the baby resting on the mother's lap. When applying the plaster cast, the baby is placed at one end of the table to provide room for the mother and assistant on either side. A bottle of milk and toys with soothing music relax the baby.

All components of the clubfoot deformity must be corrected simultaneously, not in sequence, except for the equinus which should be corrected last.

1. The cavus is corrected as the foot is abducted by supinating the forefoot, which elevates the first ray thereby placing the forefoot in proper alignment with the hindfoot. Since the cavus usually is not a fixed deformity at birth correction often occurs with the first cast. Correction of severe cavus in a stiff foot will need 2 or 3 cast changes with the forefoot in forced supination.

2. While the whole foot is held in supination and in flexion, it must be gently and gradually abducted under the talus secured against rotation in the ankle mortise by applying counter-pressure with the thumb against the lateral aspect of the head of the talus, **not the calcaneus**.

Use gentle, continuous pressure for a few seconds. Repeat one or two more times when the baby is relaxed. Do not struggle with the baby.

3. When the foot is abducted, the heel varus will correct as the calcaneus abducts by rotating under the talus. When the calcaneus abducts, it simultaneously extends and everts owing to the curvature profiles of the subtalar joint. The calcaneous cannot evert unless it is abducted. The heel should not be touched.

4. The improvements obtained by each manipulation are maintained by immobilizing the foot in a well molded plaster cast for 5 to 7 days. One or two layers of soft roll are applied over the foot and leg. The soft roll as well as the plaster cast that follows should be wrapped snugly over the foot and ankle for better molding and loosely over the calf and thigh to prevent unnecessary pressure on the muscles. The toes should be covered by the tips of your thumb and index finger to prevent crowding the toes. The plaster should extend to below the knee first. The plaster is molded with gentleness and anatomic precision. The heel prominence should be emphasized by molding around it instead of pressing on it. The heel should never even rest on the surgeon's hand so as not to flatten it. While the foot is held in abduction and supination, the thumb should never rest for long over the lateral aspect of the head of the talus to avoid a dent on the plaster as it sets. The correction is maintained not through pressure but through molding. At the same time the ankle and malleoli should be gently molded.

The plaster cast is extended to the upper thigh with the knee at 90 degrees of flexion and the leg in slight external rotation. The plaster cast over the toes and on the side of the big toe and the little toe should be trimmed away to allow all the toes to extend freely.

5. In the final manipulation usually done after 4 or 5 casts the entire foot is abducted between 50 to 60 degrees under the talus and is no longer supinated. The foot should never be everted. The navicular moves laterally away from the medial malleolus to a distance of 1 ½ cm. The lateral aspect of the head of the talus cannot be palpated since it is covered by the navicular. The heel is in some valgus.

6. Now the equinus can be corrected by dorsiflexing the foot. The tendo Achilles may need to be percutaneously sectioned to facilitate this correction if at least 10 degrees of dorsiflexion cannot be obtained. Ninety per cent of babies will require a tenotomy.

Tenotomy: One needs a foot holder and a tenotomist. The foot holder grips the leg below the knee and the midfoot. A generous betadine preop of the heel and ankle is applied, extending medially and laterally. A small amount of local anesthetic is placed medial to the Achilles tendon. (Do not use a lot or the tendon is difficult to feel.) Insert the knife (we use a cataract blade) parallel and beneath (anterior) to the tendon approximately one centimeter above its insertion into the calcaneus. Turn the sharp edge of the knife to the tendon and perform the tenotomy. The "release" obtained after a complete tenotomy is easily felt. Ten to 20 degrees of additional dorsiflexion will be obtained. Clean skin with alcohol to remove the betadine. Place a small square of adaptic or zerofoam over the wound. Wrap with sterile soft roll. Place a well molded plaster cast with the foot in 20 degrees of dorsiflexion and 70 degrees of abduction (with no eversion). This last cast is worn for 2 ½ to 3 weeks.

Foot abduction bar: This is critical for the success of the treatment program. **No other device will work** (we have tried). The prescription should read as follows:

Foot abduction bar with a distance from one shoe heel to the other equal to the width of the child's shoulders. The shoes for the involved foot or feet are externally rotated 70 degrees. The normal foot is externally rotated 30 degrees. The bar is bent to give approximately 10 degrees of dorsiflexion. **A plastizote heel counter should be glued into the shoe to prevent the foot from slipping out of the shoe.**

The bar is worn full time except for bathing for two to three months. It is then worn at night and nap time until the child is 3 to 4 years old. A line drawn at the tips of the toes helps the parents know when the foot has slipped backwards and the foot needs to be repositioned in the shoe.

Suggestions on helping with compliance:

The importance of the brace must be explained to the parents. Parents have to teach the baby to kick both feet simultaneously by holding the bar while playing with the baby. Consistent usage will make for a compliant child. Intermittent usage will make for a child that fights the brace. Make sure the feet have sufficient dorsiflexion at the ankle. If there is not enough dorsiflexion, the feet may pull out of the shoes.

The children should be followed every 3 to 4 months for the first couple of years, then every 6 months til age 5 to 7, then annually, increasing to biannually.

EARLY (FIRST AND SECOND YEAR OF LIFE) RECURRENCE

Recurrence is almost always due to failure of brace wear. It is accompanied by a loss of dorsiflexion, followed by the development of heel varus and often some adductus. The cavus rarely recurs.

The importance of the brace must be explained to the parents. **Early recognition is important. If the foot is not easily dorsiflexed or the child is walking on the outside of the foot (even if the foot is passively correctable), treatment should be instituted.**

Treatment consists of 2 to 3 more casts at 1 to 2 week intervals. The manipulation is the same. If dorsiflexion is limited, the tendo Achilles tenotomy may be repeated up to one year. (After one year of age an open TAL (tendo Achilles lengthening) is generally done.) A second recurrence is treated the same way.

If recurrence is in the second year of life, the child will often need an anterior tibial tendon transfer. Repeated casting may not fully correct the foot but will buy time until a TAL and anterior tibial tendon transfer (ATT) to the third cuneiform can be performed.

LATE RECURRENCE – 2 ½ TO 5 YEARS OLD

Recurrence is extremely rare after 5 years of age. A dynamic supination may develop at this age. The foot can still be passively positioned with the heel in valgus, but the child supinates the foot in swing phase and is on the outside border of the foot in stance phase. Variable amounts of dorsiflexion/plantarflexion are present. If the foot easily dorsiflexes 10 degrees, an ATT alone is needed. If less dorsiflexion is present, a TAL and rarely posterior release are required.

Don't hesitate to recommend ATT in this age group. Long term follow-up results are as good in patients undergoing ATT as those who did not need it. If the foot is not passively correctable, serial casting should be done to get the heel into valgus before the tendon transfer.

DEFINITIONS OF MOVEMENTS OF THE TARSAL BONES AND OF THE FOOT

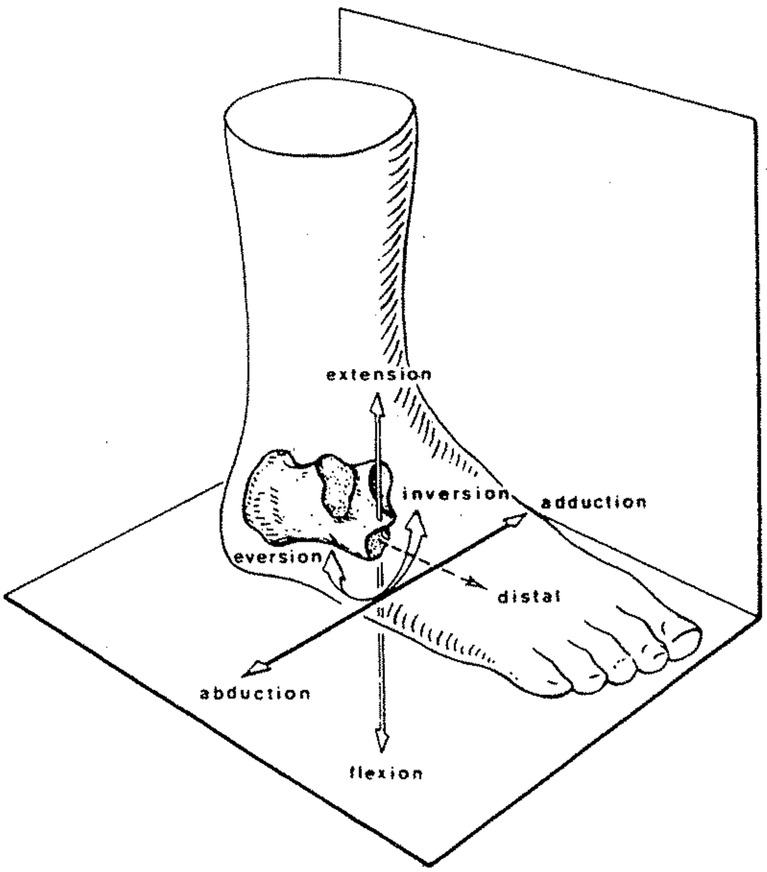


Figure 1.

Adduction is the movement of a tarsal bone in which the distal part of this bone moves towards the median body plane

Abduction is the movement in the opposite direction

Flexion is the movement of a tarsal bone in which the distal part of that bone moves in the plantar direction

Extension is the movement in the opposite direction

Inversion is the movement of a tarsal bone in which the undersurface of the bone moves towards the median body plane
Eversion is the movement in the opposite direction

Supination is the combined movements of adduction, flexion, and inversion.
Pronation is the combined movements of abduction, extension and eversion.
Heel varus results from the movements of inversion and adduction of the calcaneus
Heel valgus results from movements of eversion and abduction of the calcaneus.
Forefoot supination is a combined movement of inversion and adduction of the forepart of the foot
Forefoot pronation is a combined movement of eversion and abduction of the forepart of the foot.
Equinus is an increase of the plantar flexion of the foot.
Cavus is an increase in the height of the vault of the foot.

FOOT EXAMINATION

In the clubfoot the calcaneus, the navicular and the cuboid are medially displaced in relation to the talus and are firmly held in adduction and inversion by very tight ligaments and tendons.

Orthopaedists must know how to identify by palpation the position of the main bones of the foot in relation to the malleoli. The toes and metatarsals are grasped with one hand while the malleoli are felt from the front with the thumb and the index finger of the other hand. (Figure 2)

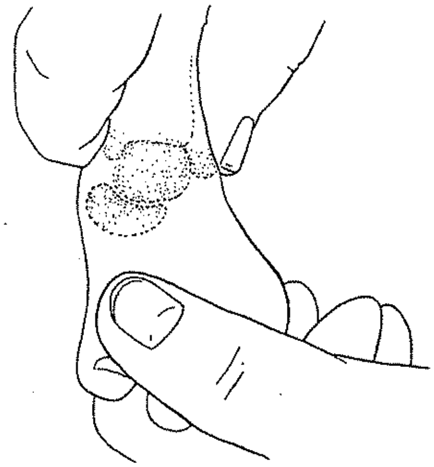


Figure 2

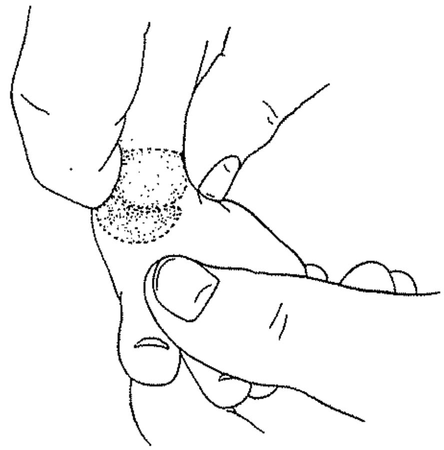


Figure 3

The thumb and the index finger slide downwards to feel the head of the talus. In the clubfoot, the navicular is close or in contact with the medial malleolus. (Figure 3) The lateral aspect of the head of the talus is palpated in front of the lateral malleolus. With the hand holding the toes and metatarsals the foot is abducted resulting in abduction in the navicular. The resistance of the navicular to be moved away from the medial malleolus so as to cover the head of the talus correlates with the severity of the deformity.

It is easy to identify by palpation the calcaneo-cuboid joint and assess the degree of the medial displacement of the cuboid. The severity of the equinus is also easily assessed by palpation. Although the whole foot is in extreme supination, the forefoot is pronated in relation to the hind foot and this causes the cavus, the first metatarsal being in more plantar flexion than the lateral metatarsals.

Kinematics of The Subtalar Joint
How the manipulation method of Ponseti works

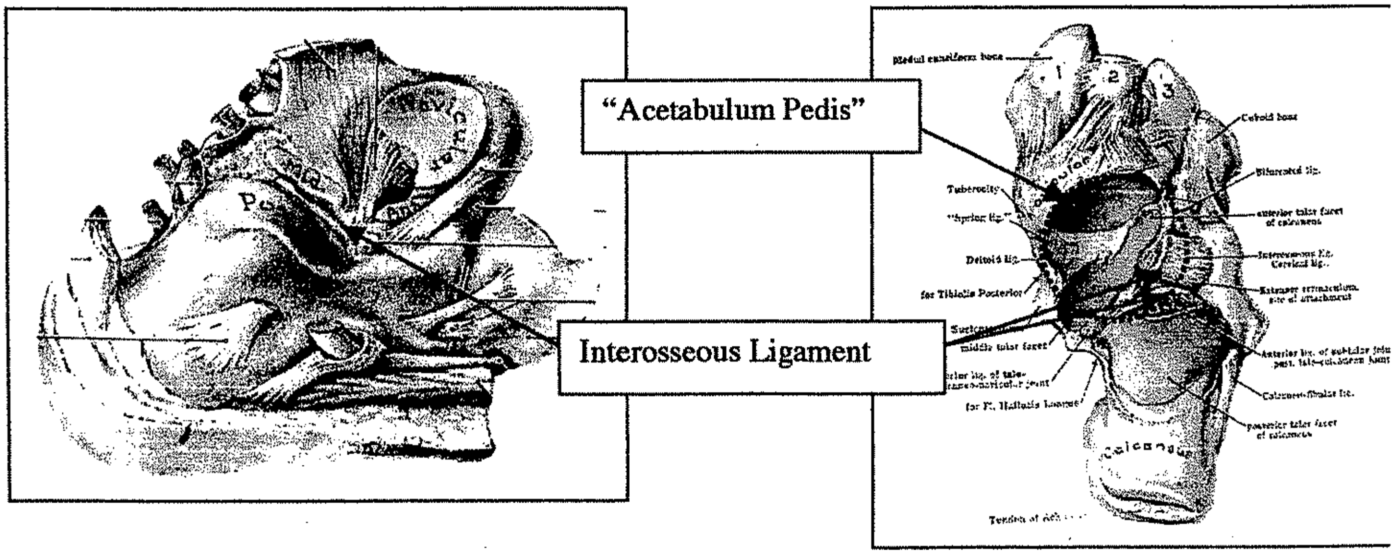
J. Norgrove Penny, MD, FRCS(C)

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

Anatomy

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

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



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

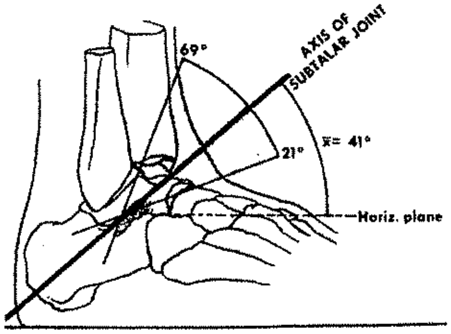
Kinematics

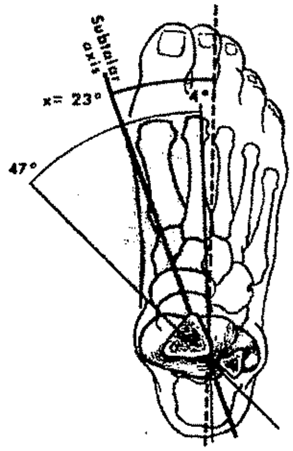
Functionally, all the bones of the foot move as a unit around the talus. There is very little intertarsal motion . (Inman 1976)

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

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

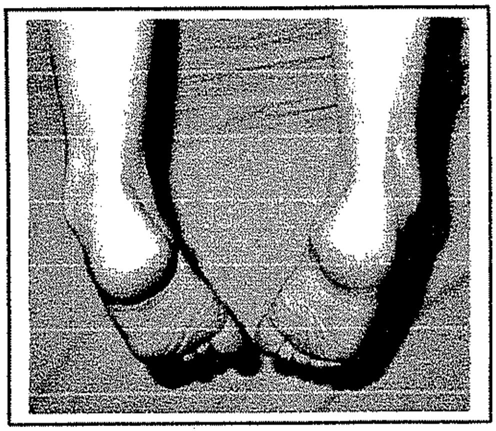
The subtalar axis is not a fixed point, but a mobile axis allowing shift and glide around the constraint mechanism of the interosseous ligaments. (Husen, Van Langelann) Inman resolved this mobile axis axis to **the oblique plane**



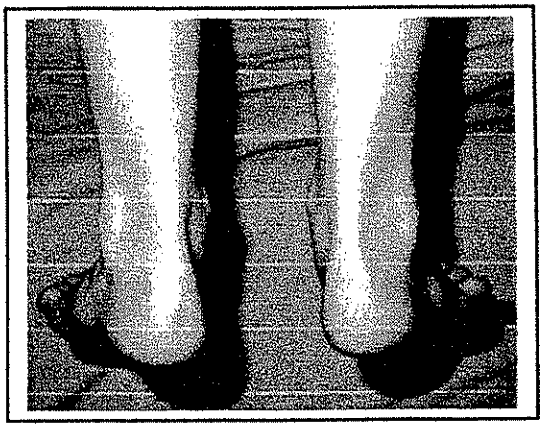


The motion of the subtalar joint in this oblique plane is **supination** and **pronation**.
Supination consists of the kinematically coupled motions of adduction, inversion and flexion.
Pronation consists of the kinematically coupled motions of abduction, eversion and extension (dorsiflexion)

Normal subtalar motion:



Subtalar Supination
- Adduction
- Inversion
- Flexion
- Heel Varus



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

Kinematic coupling

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

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

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

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

Maximum Abduction:

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

Normal abduction in a baby

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

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The Ponseti Method of Clubfoot care:
A vision for the developing world

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Project Team Members: Dr. Shafique Pirani, MD, FRCS(C)
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The Problem: The neglected clubfoot deformity worldwide. 100,000 newborns annually with the clubfoot deformity, 80% in the developing world, most with little or no access to orthopaedic care

The Solution: Implementation of an inexpensive, effective, low technology system of treatment (The Ponseti Method) on a country-wide basis

The Field Trial: The Uganda Clubfoot Project

The Vision: Introduction of the Ponseti method into every country in the developing world as part of their national preventative/public health strategy

THE PROBLEM OF THE NEGLECTED CLUBFOOT:

Any orthopaedic surgeon volunteer to the developing world cannot but be struck by the large numbers of cases of neglected clubfoot deformity presenting to outreach clinics. Why so many cases? Is the incidence greater, or is it the prevalence? The worldwide incidence is thought to be approximately 1 in 1000 live births per year, occurring in both girls and boys. In some populations the studied incidence is higher (Malawi: 1 in 500 births) More likely, we are seeing a prevalence effect. Uganda & Malawi, typical of most sub-saharan African countries, have among the highest birth rates in the World with together an estimated 1.5 million births a year. Therefore, 1500 to 3000 of these infants will have clubfeet. Because of poverty and inadequate resources, few cases are treated and so the cumulative numbers of clubfoot disabled children grows.
Regardless, the clubfoot deformity is the most common congenital cause of locomotor disability in the developing world, yet is eminently treatable.

The management of clubfoot has traditionally been a trial of manipulation & casting by the method of Kite, or modifications, with surgical release for resistant cases. Typically, only 5-10% of clubfeet respond satisfactorily to Kite's method, with the remainder coming to surgery, if sufficient surgical resources are available. In poorer countries, the majority of infants born with clubfeet receive no attention and remain neglected. Moreover, for those who are identified and receive some medical attention, surgical resources are unattainable. For example, in Uganda in 2002, there were less than 12 orthopaedic surgeons for a population approaching 25 million people, and most of their efforts were directed towards coping with large numbers of trauma cases.
With the limited number of surgeons and hospital resources in developing countries, the majority of clubfeet in developing countries have remained inadequately treated or neglected.

Neglected clubfeet can have a dramatic effect on quality of life, particularly in developing countries where effective treatment is seldom available and rehabilitation for people with disabilities is limited. Physical impairment results in decreased ambulation and the inability to perform basic tasks such as obtaining food and water. Disability leads to dependency in activities of daily living with significant economic impact on both the family and the village. Furthermore, the visible physical and functional differences in individuals with clubfoot are associated with considerable social stigma. Children with locomotor disability are less likely to be able to access education. Girl children are vulnerable to social, physical and sexual abuse, and are even less likely to achieve education than boys with the disability.

As a non-invasive technique for the management of congenital clubfoot, the Ponseti method has been proven in the developed world to be a superior method of correcting clubfoot deformity and avoids major surgical intervention. With this method, a long term study by Cooper and Diez reported 78% good & excellent results at a minimum follow-up of 25 years.

The Uganda Clubfoot Project – implementing the Ponseti Method on a country-wide scale.

For six years, between 1996 and 2002, I lived and worked in Uganda, helping establish a children's orthopaedic surgery and rehabilitation program for the rural communities which was called the "Children's Orthopaedic Rehabilitation Project (CORP)". One quarter of all surgical cases were focused on the neglected clubfoot deformity, and this effort was not making a significant impact on the prevalence. In 1998 I began a collaboration with Dr. Shafique Pirani, a fellow Canadian paediatric orthopaedic surgeon with an interest in clubfeet. We realized that a strategic public health type of approach was needed to encourage early awareness and treatment by conservative methods. In 1999, we established a Rotary funded, Ponseti treatment program for clubfoot in collaboration with the Disability Section of the Ministry of Health, the Dept of Orthopaedics at Makerere University, & CORP. This was called "The Uganda Clubfoot Project" (UCP). After an initial 2 year field trial which showed remarkable success, an early intervention and Ponseti method program was incorporated into the official primary health policy of the Ministry of Health in Uganda, the first such national policy that we are aware of.

The hallmarks of the program constituted:

- A national strategic plan incorporating all levels of health care in the country, from rural dispensaries, through regional clinics and hospitals, through to the national tertiary referral orthopaedic center.
- A Community and public awareness program using posters
- Sensitization of maternity units and traditional birth attendants and establishment of referral pathways for casting
- Training of trainers in the Ponseti method in the main referral center
- Training of orthopaedic officers in every administrative district (53) in the Ponseti method
- Training of medical officers (primary care physicians) in tenotomy technique
- Development and distribution of a locally made inexpensive abduction-foot-orthoses

Rural health care workers, including midwives and traditional birth attendants, coming into regular contact with mothers and infants were sensitized as to how to diagnose a clubfoot and refer infants with this deformity to local orthopedic officers, who in turn were trained to treat these patients by the method of Ponseti. A key to the program were orthopaedic officers, paramedical personnel assigned to all district and regional hospitals, who perform a valuable role in basic fracture care in countries where physicians are in short supply. Over 4 years in Uganda, more than 100 orthopaedic officers and physiotherapists were trained, blanketing the country with skilled personnel.

Taking a cue from effective workshop training programs such as the AO course and ATLS course, a didactic training syllabus and manual was developed. This allowed standardization of training. Training sessions typically involved one full day of classroom work utilizing the manual and the Ponseti teaching models, and a half day live casting clinic during which each trainee put on at least 2 casts. Typically 6-10 students were trained in each session. The clubfoot clinic at the national teaching hospital, Mulago Hospital, was a major resource since up to 40 babies with clubfoot deformity were treated weekly, providing a large and concentrated experience. A considerable portion of the curriculum focused on the Pirani-Columbian foot scoring method since it was felt that standardization was crucial, and the timing of tenotomy could be accurately predicted.

An appropriate technology Foot Abduction Brace (FAB) was necessary to complete the Ponseti program since the Iowa experience suggests that the risk of recurrence of deformity is 90% if the brace is not used, compared to 10% with proper brace use. The brace used in North America (available from Markell, USA) is too costly ($US 200) to be used extensively in developing countries. A brace was developed in Uganda (SFAB: the Steenbeek Foot Abduction Brace-$US 12) made from locally available materials and technology, and distributed "off the shelf" to working locations. A manufacturing template was developed such that any basic workshop, or an artisan anywhere with basic materials, could produce an effective orthoses.

Local anaesthetic tenotomy procedure was taught to general medial officers (physicians) and implemented by them once the orthopaedic officer felt the foot was ready on the basis of the Pirani-Columbian foot score.

Pilot Study of the Ponseti Method in Uganda

From Nov 1999 – Oct 2002, a pilot study was performed primarily at the Mulago Hospital Clubfoot Clinic by the Dept of Orthopaedics & CORP, looking specifically at the rate of correction of deformity.

- 236 clubfeet in 155 consecutive patients aged 9 months or less at start of treatment were treated by 8 trained orthopaedic officers.
- 118 infants with 182 clubfeet completed corrective phase of treatment.
- 176/182 clubfeet (96.7%) corrected with the Ponseti Method.
- 6/182 clubfeet did not correct & were referred for surgery.
- 37 infants (23.4%) with 54 clubfeet (22.9%) did not complete the corrective phase of treatment.

The results were presented at the 2003 POSNA meeting in Florida.

The pilot data suggested that the rate of correction of deformity in the hands of orthopaedic officers was over 90% in those infants who completed manipulation, casting and tenotomy. This rate far exceeds the rate of success of previous treatment by the method of Kite in these institutions, giving children a better functioning foot while reducing pressure on the hospital surgical resources.

Despite the physical and social benefits of the early intervention program, the pilot study showed that almost 25% of children did not complete the initial course of treatment. As a fourth phase to the project, in 2004, we will be examining the social, cultural and logistical factors associated with non-compliance in an effort to understand factors common to poor and underdeveloped societies.

Other Africa Initiatives

As the Uganda Clubfoot Project gained international attention as a pioneer national effort to combat neglected clubfoot deformity, other African countries became involved. A pilot project was undertaken in Malawi in 2000 at the national referral hospital in Blantyre. After one year of experience using the technique, surgical referral rates dropped by almost 90%. In 2002 a national training scheme, similar to Uganda's, was introduced.
Other more limited training projects have been undertaken in Tanzania, Zambia, Rwanda and Congo.

Lessons learned from the Africa experience with the Ponseti method:

- The method can be made to be effective in the context of the impoverished developing world situation
- The method can be taught to non-specialists or paramedical personnel
- A standardized didactic teaching method is effective
- Hands-on experience with the Ponseti foot models is crucial to the understanding of the technique
- Including the Pirani-Columbian foot score brought a level of standardization and refined timing of tenotomy
- Simple foot orthoses can be manufactured using local materials, and are effective.
- The "African clubfoot", often thought to be a more resistant clubfoot deformity, corrects in precisely the same manner and in the same time as the non-african clubfoot.
- Treatment does not have to start at birth to be effective. We routinely salvaged feet presenting for the first time up to one year of age, and occasionally in the second year.

International initiatives

The successes of the Ponseti projects in Africa spurred the concept of a global initiative to introduce the Ponseti method into all needy developing countries.
Preliminary discussions have taken place with the World Health Organization to explore their collaboration.
Projects are currently developing in Brazil, 3 states in India, Cambodia, and several Central American countries.
The concept of an International Clubfoot Project, patterned on the Uganda Clubfoot Project, has been endorsed by:

- The "Bone and Joint Decade"
- The Pediatric Society of North America (POSNA)
- The Canadian Orthopaedic Association (COA)

A preliminary plan is underway to gain the endorsement of all the international Pediatric Orthopaedic Societies at the combined meeting in Salvador, Brazil, in 2004.
It is understood that every region, or country, will have specific cultural, logistical and socio-economic factors which will require adaptation and modification of the implementation methods while, at the same time, keeping true to the fundamentals of the Ponseti method. India, for example, has a large and highly skilled professional workforce with respect to Africa, with sophisticated private medical resources, yet has a large unreached impoverished sector of their society.

Our Vision:

- A global initiative to erradicate the problem of the neglected clubfoot worldwide, specifically in poorer developing nations, by introducing broad-based training in the Ponseti method. This initiative would be under the umbrella of the World Health Organization and be incorporated into the preventive public health programs of all developing nations. There would be endorsement, academic and logistical support from numerous partners, including professional orthopaedic societies and the Bone & Joint Decade.
- That, by the end of the Bone and Joint Decade, every country would have developed and initiated a strategic plan to eliminate the congenital clubfoot deformity as a source of chronic disability amongst it's children.
- That skilled national professionals in each country be empowered to strategize and implement their national plan, with assistance, support and collaboration from the international partners.

The role of orthopaedic surgeons in the developed world:

- Catch the vision of eliminating the clubfoot disability worldwide
- Volunteer your skills and training potential to poorer countries
- Collaborate on developing clubfoot projects where you visit
- Empower national colleagues to develop projects
- Be a bridge of logistical support and encouragement
- Cooperate on a standardized approach internationally

A Method Of Clubfoot Evaluation

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A. Abstract

This paper outlines a method of virgin clubfoot assessment using 6 well described simple clinical signs. We have tested its reliability and found it to be substantial to almost perfect. When used during serial casting it charts whether deformity correction is continuing or has plateaued, and indicates the area of residual contracture for surgical release.

B. Background

Although numerous well described signs differentiate between the mild and severe virgin clubfoot deformity such as a deep medial crease, there is neither consensus nor reliability in current methods of clubfoot assessment

"A universally accepted method of classification of the severity is lacking..."

R.J.Cummings & Wood W. Lovell. Operative Treatment of Congenital Idiopathic Club Foot, Current Concepts Review, J.B.J.S. 70A 1108, 1988.

" The literature on clubfeet is inadequate because a common method language for assessing the deformity is lacking . . ."

A.J.Catterall, A Method of Assessment of The Clubfoot Deformity. C.O.R.R. 264, p 48-53, 1991.

"It is now recognized that one of our major endeavors for the next few years must be to establish a common set of criteria for the evaluation of the unoperated CTEV."

George Simons. The Clubfoot - The Present and a View to the Future. 1994.

C. General Principles

This evaluation method is based on 6 well described clinical signs of contracture characterizing a severe clubfoot. Each sign on the abnormal foot is compared to the same area on the normal foot (if the deformity is not bilateral). Each sign is scored according to the principle:

0 ....if there is no abnormality,
0.5 ....if there is a moderate abnormality,
1 ....if there is severe abnormality (Fig. 1)

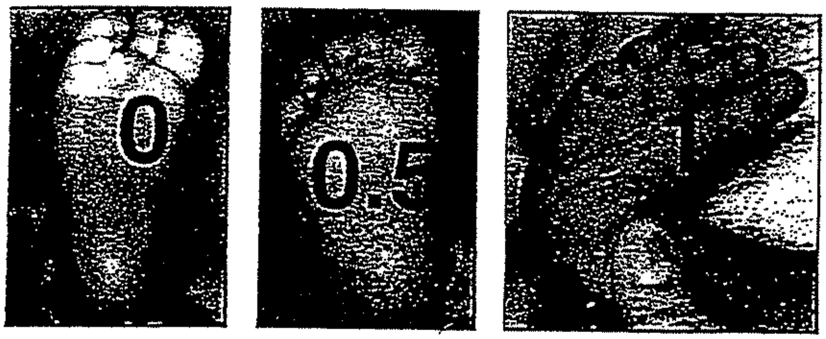


Figure 1

Curvature of the lateral border of the clubfoot is one indicator of the severity of the deformity. This illustrates the principle of our method of scoring.

0 = No Abnormality
0.5 = Moderate Abnormality
1 = Severe Abnormality

These 6 signs are divided by area of involvement into 2 groups of 3 signs.

1. Posterior contracture (Hindfoot contracture)

-	Posterior Crease	(PC)
-	Empty Heel	(EH)
-	Rigid Equinus	(RE)

2. Medial contracture (Midfoot contracture)

-	Curvature of Lateral Border of Foot	(CLB)
-	Medial Crease	(MC)
-	Lateral part of the Head of the Talus	(LHT)

Hence, each foot can receive:

-	a Hindfoot contracture score	(HFCS)	between 0 and 3
-	a Midfoot contracture score	(MFCS)	between 0 and 3
-	a Total Score	(TS)	between 0 and 6

A higher score indicates a more severe deformity

The virgin clubfoot may be "scored" using this method at each clinic visit during manipulation and cast treatment and "the score" plotted against time (age in weeks). This shows the response of the deformity to manipulation and cast treatment, and can also indicate areas of persisting contracture that may need to be addressed surgically.

D. Technique of Examination

This technique is used at The Royal Columbian Hospital Clubfoot Clinic. We find the information it gives us most useful if performed regularly at every weekly clinic visit prior to casting the clubfoot during the first 3-4 months of life. The infant is positioned supine at the end of the examination table. The examiner is seated. A feeding relaxed infant allows for a more precise examination.

The Signs

i.) The **Curvature** of the **Lateral Border** of **the** foot **(CLB). (Fig. 2 a-c)**

Scarpa drew attention to the curvature of the lateral border of the clubfoot as one indicator of the severity of the deformity.

> *"...A line drawn from the posterior projection of the os calcis where the tendo achilles is inserted, by the outer side of the foot, forms a very wide semicircle...."*

He also noted that angulation of the lateral border of the foot at the level of the calcaneocuboid joint indicated medial calcaneocuboid subluxation.

> *"...At the place where the cuboid is in contact with the anterior tuberosity of the os calcis it makes an angle obtuse externally....leaves uncovered on the outer margin of the foot, a portion of the articular surface of the anterior tuberosity of the os calcis....contributes very much to give to the whole foot the semicircular shape from below the external malleolus forwards as far as the little toe."*

A Memoir on the Congenital Clubfeet of Children, and of the Mode of Correcting That Deformity. Antonio Scarpa. Archibald Constable and Co. Edinburgh. 1818.

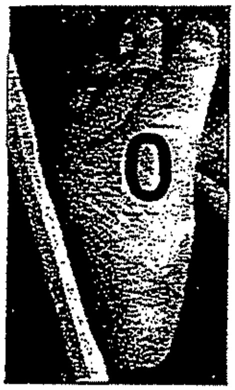


Figure 2a

Look at the plantar surface of the foot and gauge the curvature of the lateral border. Normally the lateral border of the foot is straight from the heel to the head of the 5th metatarsal. A straight edge placed along the lateral border of the hindfoot may assist in the estimation of the curvature. (Fig. 2a) A straight lateral border of the foot is given a score of 0.

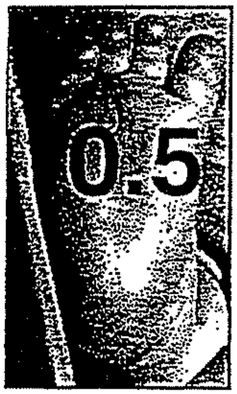


Figure 2b

In the abnormal foot the lateral border of the forefoot moves away from the straight edge. A mildly curved lateral border is scored 0.5 (The curvature appears to be in the distal part of the foot in the area of the metatarsals). (Fig. 2b)

Figure 2c

A pronounced curvature of the lateral border is given a score of 1. (The curvature appears to be at the level of the calcaneocuboid joint.) (Fig. 2c) ii.) The Medial Crease of the foot (MC). (Fig. 3a-c)

Figure 3a

Look at the medial arch of the foot with the foot in the position of maximum correction. Normally one sees multiple fine creases that do not change the contour of the arch and the MC sign is scored 0. (Fig. 3a)

Figure 3b

In the abnormal foot there are one or two deep creases. If these deep creases do not appreciably change the contour of the arch, the Medial Crease sign is scored as a 0.5. **(Fig. 3b)**

Figure 3c

If these deep creases appreciably change the contour of the arch, the Medial Crease sign is scored as a 1. **(Fig. 3c)** iii.) The Posterior Crease of the ankle (PC). (Fig. 4a-c)

Figure 4a

Look at the back of the heel with the foot in the position of maximum correction. Normally one sees multiple fine creases that do not change the contour of the heel. They allow the skin to adjust and stretch as the ankle dorsiflexes. In this case the Posterior Crease sign is scored as 0. (Fig. 4a)

Figure 4b

In the abnormal foot there are one or two deep creases. If these deep creases do not appreciably change the contour of the heel, the Posterior Crease sign is scored as 0.5. (Fig. 4b)

Figure 4c

If these deep creases appreciably change the contour of the heel, the Posterior Crease sign is scored as 1. (Fig. 4c) iv.) The Lateral part of the Head of the Talus (LHT).

Coleman, has drawn attention to the bony prominences and depressions palpable on a normal child's foot. (Fig. 5a)

Figure 5a

". . . On the lateral side, the most important topographic feature is the depression in the sinus tarsi, created by the normal divergence of the talus and the calcaneus . . ."

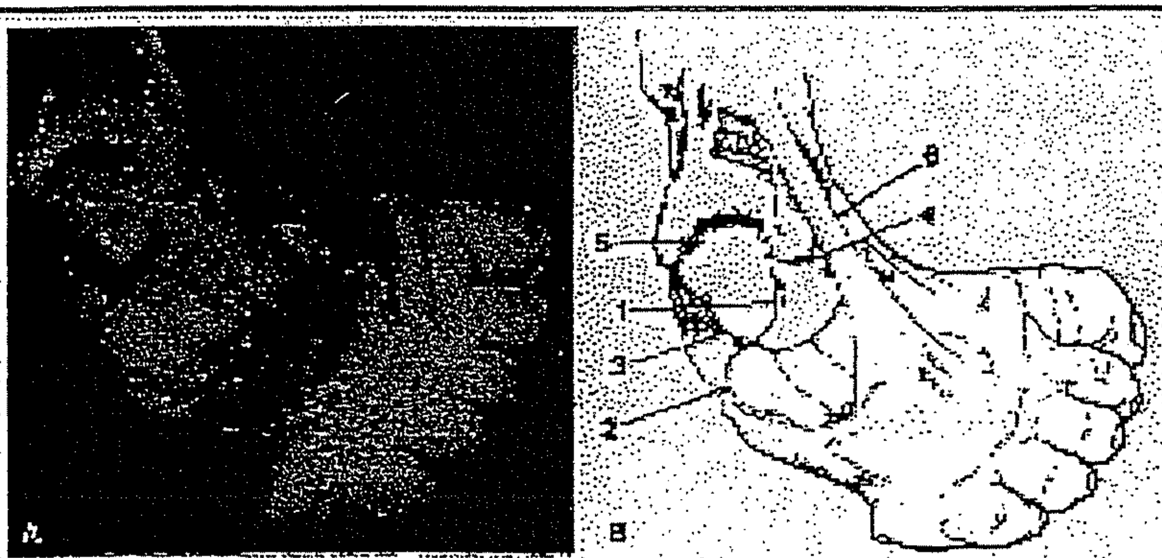


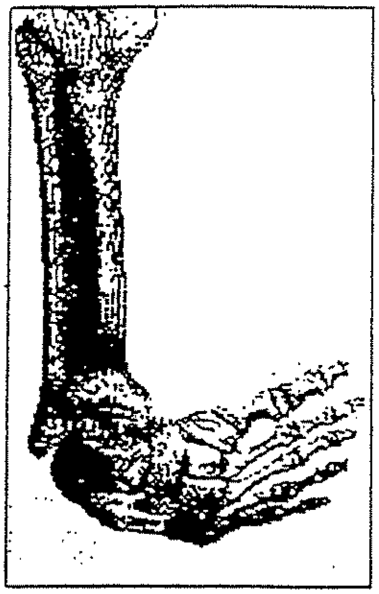
Fig. 2-1. A. The [illegible] pathologic findings in congenital clubfoot are shown in this [illegible] photograph of a [illegible] specimen in a newborn. B. The artist's interpretation. The characteristic [illegible] 1, 2, and 3. [illegible] 4. [illegible] 5. [illegible] 6. [illegible] (Courtesy of I. V. Ponseti, Iowa City, Iowa.)

Sherman Coleman. Complex foot deformities in Children, p 11-12, Lea & Febiger, 1983

Figure 5b

His text also shows a picture of the salient pathologic findings in a dissection of a congenital clubfoot in a newborn, especially the medially subluxed navicular, resulting in *uncovering of the lateral part of the head of the talus.* (Fig. 5b)

Scarpa, in his description of equinovarus congenita in 1818, recognized a prominence of the lateral part of the head of the talus as a sign of the medial talo-navicular subluxation described above. (Fig. 5c)



"...The smooth articular head of the astralagus being no longer included and covered by the cavity of the os naviculare .... forms with that part of it which remains uncovered, an unusual prominence on the upper part of the foot . . ." ". . . this prominence does not depend on the wrong position of the astralagus, but on the morbid rotation of the naviculare round its smaller axis, leaving the articular head of the astralagus denuded."

". . . When we endeavor, with our hands, to turn gently the point of the foot from within outwards, the prominence on the upper part of the foot disappears entirely or in great measure, not because the articular head of the astralagus is restored to its situation, but because the naviculare is brought back to cover the articular head of the astralagus . . ."

Antonio Scarpa. A Memoir on the Congenital Clubfeet of Children, and of the Mode of Correcting That Deformity. Archibald Constable and Co. Edinburgh. 1818

Figure 5c

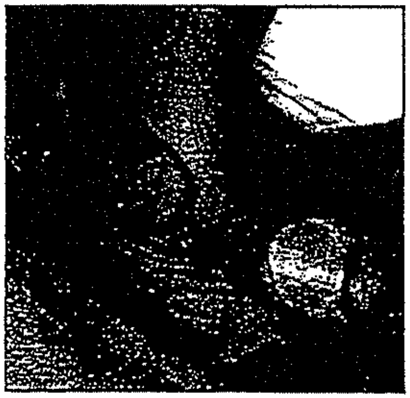


Figure 5d

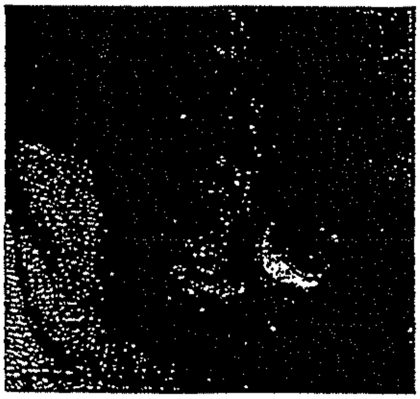


Figure 5e

Hold the foot deformed and palpate the lateral part of the head of the talus. Evert the foot. (Fig. 5d,e) Note if the navicular reduces onto the head of the talus. The LHT sign is scored 0 if there is complete reduction of the navicular onto the head of the talus as indicated by loss of the ability to palpate the lateral edge of the head of the talus in the sinus tarsi. The LHT sign is scored 0.5 if there is partial reduction of the navicular onto the head of the talus as indicated by reduction of the ability to palpate the lateral edge of the head of the talus in the sinus tarsi. The LHT sign is scored 1 if there is fixed medial subluxation of the navicular as characterized by an easily palpable talar head, even with the forefoot in as much correction as is allowed by the deformity.

abduct

part

above

v.) The Emptiness of the Heel (EH). (Fig. 6a,b)

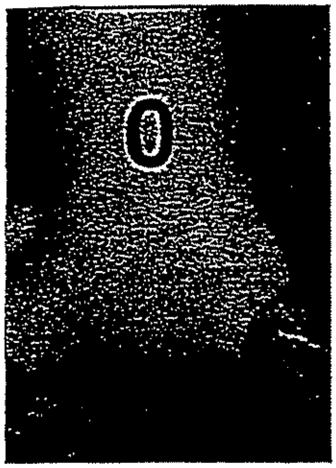


Figure 6a

The foot is placed in the maximal corrected position, and the examining finger is placed on the corner of the heel. Gentle pressure is applied with the finger. Normally the tuberosity of the calcaneus is immediately palpable and the EHS is scored 0. (Fig. 6a)

Empty heel sign

Figure 6b

The EHS sign is scored 0.5 when the heel pad feels somewhat empty to the examining digit. The tuberosity however, remains palpable deep within the heel pad.

The EHS sign is scored 1 when the heel pad feels empty to the examining digit. No bony prominences can be appreciated within the heel pad. (Fig. 6b) vi.) Move the ankle joint to gauge the Rigidity of Equinus (RE). (Fig. 7a-c)

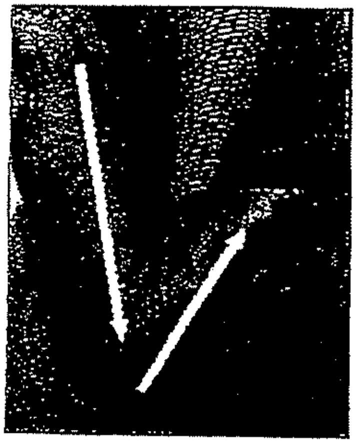


Figure 7a

The RE sign is scored 0 when the ankle dorsiflexes fully (the dorsum of the foot almost touches the front of the shin.) (Fig. 7a)

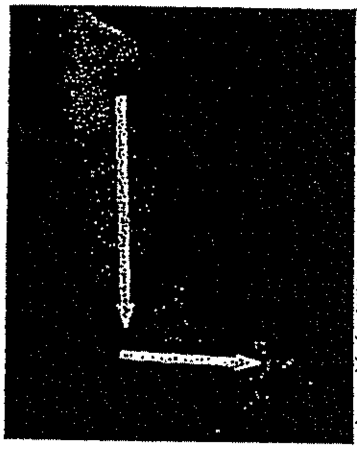


Figure 7b

The RE sign is scored 0.5 when the ankle dorsiflexion is not full but sufficient to allow the lateral border of the foot to make an angle of 90 degrees or less with respect to the long axis of the leg as viewed from the lateral side. **(Fig. 7b)**

? how many degrees less

Figure 7c

The RE sign is scored 1 when the ankle dorsiflexion is severely limited and the lateral border of the foot makes an angle of greater than 90 degrees with respect to the long axis of the leg as viewed from the lateral side. (Fig. 7c)

E. Recording the Information

We have developed a form that records and displays the pertinent history and physical examination features during the first few months of life. **(See attached)**

F. Statistical Analysis

A consecutive series of 100 clubfeet in 70 infants, aged 0-9 weeks at start of serial casting at our clinic, had their feet evaluated at weekly intervals by 3 independent & blinded observers. The observers were 2 fellowship trained paediatric orthopaedic surgeons and either a resident or a physiotherapist. There were 2080 patient encounters and 12,480 individual data points. Each foot received a **Total Score (TS), Hind Foot Contracture Score (HFCS) and Mid Foot Contracture Score (MFCS)** by each observer at every clinic visit.

All scores were recorded on an excel spreadsheet, and analyzed for the Kappa Statistic. This measures the pairwise agreement between observers.

Kappa statistic Interpretation (Inter-observer reliability)

if K = 0.21-0.40 Reliability is Fair
if K = 0.41-0.60 Reliability is Moderate
if K = 0.61-0.80 Reliability is Substantial
if K = 0.81-1.00 Reliability is Almost Perfect

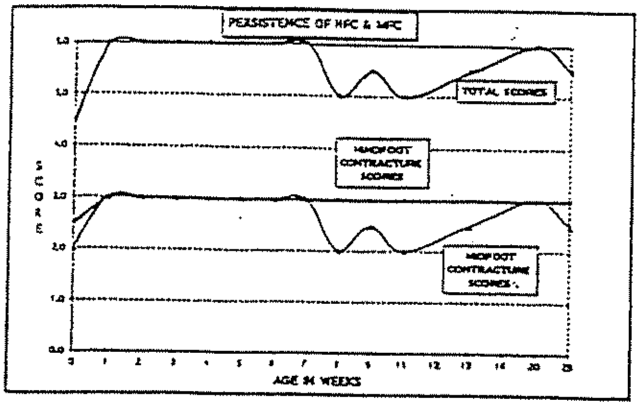
For this method of evaluation of the virgin clubfoot pairwise agreement between observers was;

MC	-	0.76	
PC	-	0.74	
CLB	-	0.84	
EH	-	0.76	
LHT	-	0.74	
RE	-	0.87	
TS	-	0.92	(Weighted Kappa)
MFCS	-	0.91	(Weighted Kappa)
HFCS	-	0.86	(Weighted Kappa)

G. Interpretation of Scores

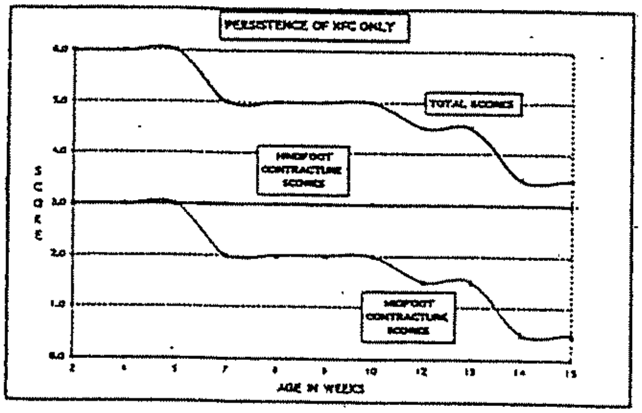
We used the attached *Virgin Clubfoot Assessment Record* to document our findings, as well as the **Total Score, Hind Foot & Mid Foot Contracture Scores.** Scores for individual feet are plotted against time. We have found 3 patterns of response to manipulation and cast treatment.

Pattern 1 - Persistence of HFC and MFC.



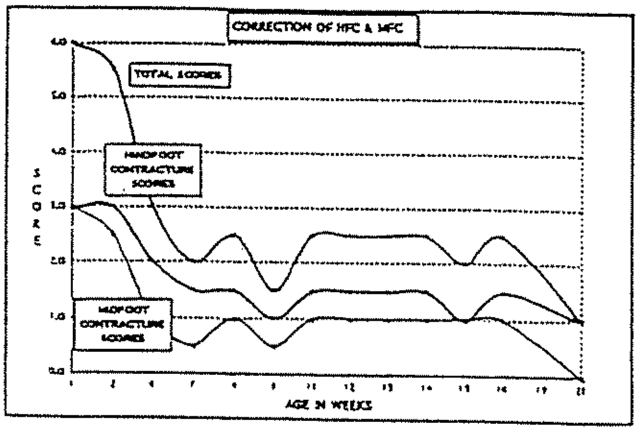
In Pattern 1, the TS remains high, as does the HFCS and the MFCS. In this group we normally perform an extended posteromedial release.

Pattern 2 - Persistence of HFC only.



In Pattern 2, the TS improves, as does the MFCS. The HFCS remains high. In this group we normally perform a percutaneous tenotomy of the tendo achilles under local anaesthesia.

Pattern 3 - Correction of HFC and MFC.



In Pattern 3, all scores improve. In this group we normally do not perform surgery and the foot is braced.

VIRGIN CLUBFOOT ASSESSMENT RECORD

1. DEMOGRAPHICS

Name: ______________________ Sex: F M

Address: ______________________ DOB: ______________

______________________ MRN: ______________

Postal Code: ______________________ Telephone: ______________

PHN: ______________________

Parent Names: ______________ Occupation: ______________ Wk. telephone: ______________

____

Family Doctory: ______________ Paediatrician: ______________ Ortho Surgeon: ______________

2. HISTORY

Pregnancy: ____

____

Delivery: ____

____

Post Delivery: ____

____

Family History: ____

____

Treatment to Date: ____

____

3. EXAMINATION

General: ____

____

Orthopaedic: - Spine ____

____

- Hips ____

____

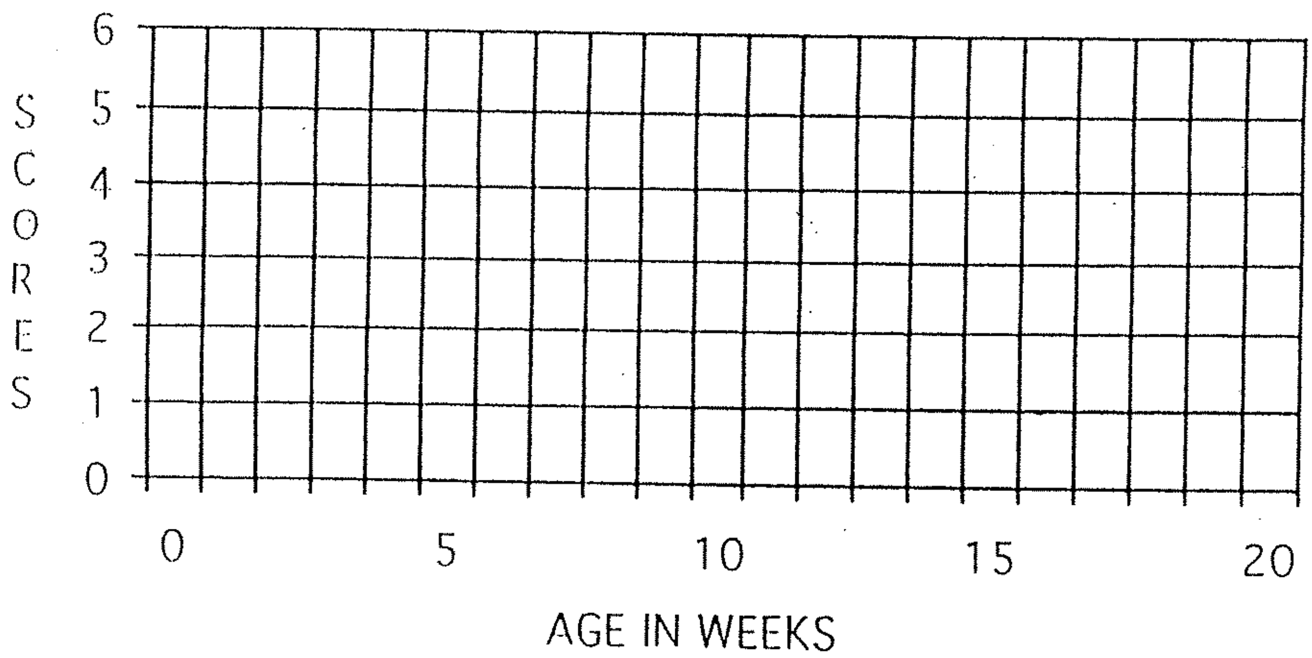
- Upper extremities ____

____

- Lower extremities ____

____

DATE																																								
SIDE	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
PC																																								
MC																																								
CLB																																								
EH																																								
LHT																																								
RE																																								
HFCS																																								
MFCS																																								
TS																																								



X = MFCS
0 = HFCS
* = TS

PATIENT NAME: