2 Review of the literature

2.1 General remarks

Clubfoot, talipes equinovarus adductus, was introduced in the medical literature by Hippocrates in 400 B.C. (1). The trias can also appear in connection with congenital syndromes (5,6,7,8,9,10,11,12), or be of acquired character.

The congenital idiopathic clubfoot deformity comprises two types, which differ as regards etiology, anatomy, and especially adequate treament and its results: the true and the postural clubfoot.

2.2 Nomenclature

The word "talipes" is traditionally used of a congenital deformity of foot (13).

The rigid type of idiopathic clubfoot is often combined with structural divergence and is called the true clubfoot, the intrinsic type, type II or structural clubfoot (14,15,16,17,18,). The pliant type with normal anatomy is called the extrinsic type, type I, the clinical or postural clubfoot (14,15,16,17,18,19). Characteristics of the two types are presented in Table 1, page 9.

Concerning the etiology of clubfoot "intrinsic" and "extrinsic" factors have been mentioned. Using the same words of clubfoot in different connections is confusing. Nor can calling the two somewhat different conditions types I and II be regarded as very descriptive.

The names true clubfoot (20) and postural clubfoot (19) will be used in this study, together with the abbreviation TEV (talipes equinovarus) for all clubfeet. There is a standardized and clear terminology using the words varus, valgus, equinus, calcaneus, adductus and abductus (21), which is likewise adopted in this study.

Table 1. Characteristics of the true and the postural clubfoot*

Matter of difference	*The true clubfoot*	*The postural clubfoot*
Etiology	Hereditary or teratogenic background	Possibly malposition in late pregnancy
Severity	Severe, at most partly reponable	Mild, can be manipulated into normal posture
Calf	Thinned	Normal
Foot	Shortened, adducted, considerable varus	Normal shape and size, mild varus
Heel	Small, in varus, non-reponable equinus	Mild varus, normal size, reponable
Medial side of ankle	Deep creases	Normal creases
Lateral side of ankle	No creases, reduced subcutis	Creases exist
Fibrose	Exists	None
Shape of bones	Malformations	Normal
Conservative therapy	May fail	Successful; however, if neglected may become more rigid with time

*(15,17,22,23)

2.3 Incidence

In Europe the frequency of clubfoot is 1—1.2/1000 babies born alive, in the Far East the incidence is half of this, while Caucasians run a six times higher risk of being born with a clubfoot than Europeans. The ratio of male to female is 2.17 to 1 (19). In cases of multiple pregnancy the risk has been estimated at four times higher compared with cases of single pregnancy (24).

A child of a clubfoot parent runs a 2.3—8.8 per cent risk of having a similar deformity (lower percentage refers to the father, higher to the mother, 19). The siblings of a child with TEV have a risk of 2—2.9 per cent, respectively. For the siblings of a girl the risk is higher (boys 1/16, girls 1/40) than for those of a boy (boys 1/42, girls: a very low risk, 19). Figures on the indicence are presented in Table 2. overleaf. The matter is further discussed in Chapter 5.1, page 43.

Table 2. Incidence of TEV

Author		Year	Incidence*	Boys*	Girls*	Bilateral*	l.dx.[1]*	l.sin.[1]*	Number of patients
Ehrenfried	(24)	1912	0.1	69	31	56	59	41	185
Kite	(25)	1932	—	68	32	54	44	56	169
Frosch	(26)	1935	—	66	34	42	58	42	311
Solonen Parkkulainen	(27)	1958	—	69	31	46	70	30	74
MacEven, Scott & Shands	(28)	1961	—	66	34	59	56	44	149
Ponseti & Smoley	(29)	1963	—	85	15	40	45	55	67
Wynne-Davis	(19)	1964	0.1	73	27	44	—	—	340
Kite	(30)	1964	—	71	29	49	55	45	1447
Chung, Nemechek, Larsen & Ching	(31)	1969	0.13	66	34	56	60	40	801
Yamoto	(32)	1979	0.08	67	33	50	—	—	185
Gray & Katz	(33)	1981	—	76	24	50	49	51	78
Total			0.11	69	31	50	56	44	3806

[1] In 1605 patients the division dx/sin was treated

* Per cent

2.4 Associated anomalies

Like many other congenital deformities, the clubfoot appears rather frequently in connection with other anomalies such as dislocated hip, hernia, multianomalies, platoschisis, syndactyly, aplasia radi, amniotic stricture, mental retardation, scoliosis, syndroma Pierre-Robin, hydrocephalus, webbed toes, mongolism, and pectus carinatum (17,19,24,26,28,30,31,32,34,35,36).

More will be said of the associated anomalies in Chapter 5.2, page 43—44.

2.5 Etiology

2.5.1 General remarks

In respect of etiology one must set apart the true and the postural clubfoot (14,18,23,37). The latter is assumed to be caused by an intrauterine malposition

similar to that in talipes calcaneus (14,23). The etiology of the true clubfoot is complex (19). The incidence of TEV points to the existence of genetic factors. The lack of a clear model of inheritance indicates, however, that other factors are involved. Such factors have been specifically identified, as pointed out in the ensuing pages.

2.5.2 Genetic background

Already in the 19th century referrence was made to heredity in connection with the clubfoot (38,39). Today "multifactorial system inheritance" is regarded as forming the most probable hereditary background to TEV (7,32,40). Thus there were a group of genes, able to produce a clubfoot. TEV becomes manifest when the amount of these genes exceeds a given threshold, perhaps triggered off by an additional environmental factor (41). The matter is touched upon in Chapter 5.3, page 44, as well as in Table 3, below.

Table 3. Family history and TEV

Author		Year	Number of patients	Patients with heredity	Per cent	Note
Ehrenfried	(24)	1912	185	14	8	—
Schrader	(42)	1928	61	15	25	—
Kite	(25)	1932	166	37	22	Consanguinity 13 per cent
Frosch	(26)	1935	80	13	16	—
Fredenhagen	(43)	1954	297	43	15	—
Crabbe	(35)	1960	164	—	10	—
MacEven, Scott & Shands	(28)	1961	149	—	19	—
Kite	(30)	1964	1447	54	4	—
Steno	(44)	1978	174	—	26	—
Gray & Katz	(33)	1981	41	15	37	Polynesians
Gray & Katz	(33)	1981	37	7	19	Caucasians
Total			2801	287	10	

2.5.3 Extrinsic factors affecting the embryo from outside

In the 19th century it was assumed that a strong emotional reaction of the mother in the early stage of pregnancy could unsettle the mother-embryo balance and produce a TEV on the basis of a central nervous error (38,45). A foetal malposition and increased mechanic or hydrostatic pressure have also been suggested (1,39,46,47,48,49,50,51,52) and rejected (5,53,54). Intrauterine pressure on the peroneal nerve has been suspected to be able to create TEV on a paretic basis (55). These theories have been neither definitely proved nor excluded.

A simultaneous occurrence of amniotic strictures and TEV has been observed (56,57,58,59). Both have been assumed separately to be due to amniotic leakage and changes in the amount and composition of the amniotic fluid.

The TEV-producing effects of some diseases, such as diabetes (35,60,61) and maternal hyperthermia (62), certain drugs like aminopterin (63), d-tubocurarine (64), methotrexate (66) etc., and oligohydramnion (67) have been proved clinically and in animal experiments.

The human embryo seems to be vulnerable to the teratogenic effects of irradiation, drugs and viruses during the first 8 gestational weeks. Later on, malnutrition, multiple pregnancy, placental errors and environmental changes dominate as possible TEV-creating factors (66).

2.5.4 Anatomic, intrinsic theories

The TEV-inducing factors in the embryo itself have been discussed at length. Malposition of bones or arrest in the development of the foot at the level of 2—4 gestational months has been suggested (48,53,68). Both theories have been criticized (37,38,39,54,69). Irani and Sherman (70), supported by others (54), supposed that a germplasm defect on the anterior cartilagenous anlage of the talus forms a basis for the development of TEV. Waisbrod (18) suspected a blastemal error, affecting the talar circulation. His theory was, in a way, supported by authors (71,72,73) who found a hypoplasia or absence of the tibialis anterior and dorsalis pedis arteries connected with clubfeet, but rejected by others (74).

The primary bone theories were rendered controversial by authors (37,38,75,76,77,78,79,80,81) who, for the most part, thought that the growth failure of bones was due to muscular imbalance (Hüter-Volkmann's law, 76).

The possibility of a neural background has been mentioned frequently (33,37,45,82) and has likewise met with considerable opposition (5,49,52,53,70,83).

A theory on anomalous tendon insertions has been suggested (77,80,84,85) and opposed (52,70,78,86), as have theories on errors in the muscle itself (14,75,76,84) and (33,52,53,70,86), respectively. Keith (87) thought that the TEV was a form of Streeter's foetal dysplasia, caused by a local error in circulation, necrosis, and a

fibrotic mass. Scheel (88) proposed anomalous mesenchyme as a stiffening element, which, however, was considered secondary to the motoric apparatus by Debrunner (76).

Referring to the anatomic theories one must point out that none of the aberrancies has been proved to be constant; they can often be considered to belong to the pathology rather than to the etiology.

2.6 Pathologic anatomy

Attention has been focused on divergences of bones, tendons and their sheaths, ligaments, arteries, and nerves. The materials are variable: samples gathered from museums, operative biopsies, embryos, foetuses and animal experiments.

2.6.1 Soft tissues

Anamalous tendon insertions have been observed (18,37,77,80,85,89,90) or again their existence has been denied (52,78,86). Increased fibrosis and contraction of ligaments, especially in the deltoid, talonavicular, navicular-medial malleol, and calcaneonavicular area, the medial tendon sheaths, and the plantar fascia have been mentioned (78,88,90,91,92,93,95). Turco and Spinella (81) regarded the talocalcaneo-navicular ball and socket joint as a consistent whole and assumed that the TEV was a congenital dislocation in this joint. Contracted and rigid soft tissues maintain the deformity and resist correction of the abnormal relationships of the bones. The result is an overgrowth of the anterior dome of the trochlea and the neck of the talus as well as a medial deviation of the latter. These obstruct the entrance of the talus into the ankle mortise. Turco found more severe changes in older patients, indicating a progressive tendency (95).

The muscle bellies of gatrocnemius, tibialis posterior, the long flexors of toes, and peroneus longus and brevis have also been found thinned and shortened (18,77,78,89,92).

Histologic findings have been of somewhat complex character. Degeneration of myofilaments, proliferation of fibrous connective tissue, features of arthrogryposis, and signs of inhibited development, partially originating in the central nervous system, have been observed (37,51,77,78).

Ippolito and Ponseti (78) noted that neuromuscular imbalance did not belong to the picture of an idiopathic TEV and that there was neither clinical nor electromyographic evidence of neural origin. They did not, however, use electron microscopy or muscle enzyme studies.

A flexor and supinator contracture has also been suspected but not proved to be the primary reason for TEV (96,97).

Isaacs et al. (82), using histologic, histochemical and electron-microscopic methods, observed calf changes which corresponded to the findings in arthrogryposis. Preoperative immobilization did not produce these changes (98). Gray and Katz (33) were not able to find similar changes and assumed that they had been of secondary character. The atrophy found by Wiley (52) could according to them be due to a lacking neural stimulus.

2.6.2 Bone changes

The main features in changes in the bones have been well-known since the 19th century. (Many authors atribute to them a central role in the pathogenesis of TEV: 17,18,48,70,86,91,92,99,100,101,102,103. Others, of course, have regarded them as secondary: 38,39,80,104,105,106,107). Opinions have divided as to the dominance of individual bones and their abnormalities. The main changes seem to concern the talus, calcaneum, navicular and cuboid. Changes in the cuneiforms, metatarsals and phalanges seem to be adaptative. Stewart (80) regarded the calcaneum as essential for TEV. Others (17,39,86,99,103,108,109, 110) emphasize the primary importance of the talus. Hüter (48,102) and Attenborough (14,20) noted that even in normal feet equinus, adductus and varus and on the other hand calcaneus, valgus and abductus positions, are associated. They considered that the talus was of central importance. Attention was also drawn to dislocation in Chopart's joint, especially to the subluxation of the navicular (38,81,86,91,100,101,111,112).

Garceau (84), supported by others (29), believed that there was a medial torsion of the distal tibia. Wynne-Davies (113), on the basis of her own and Le Damany's (114) investigations, could not agree. Her opinion has also been supported (115).

2.6.3 General remarks

A shortening of the foot and hypoplasia of the calf are constant and permanent symptoms of all true clubfeet. Wynne-Davies (113) observed shortening of the affected leg in 39 per cent of boys and in all girls. All had atrophy of the calf and 86 per cent atrophy of the affected foot.

Some differences between the anatomy of a true and a postural clubfoot are presented on page 9, Table 1.

The development of bones seems to follow Hüter-Volkmann's law: the part of a bone which is subjected to pressure retards in development whilst the part which is free or under traction, develops more rapidly. It seems natural that the changes should be more marked if the situation has lasted longer, i.e. the TEV is the worse the earlier the maldevelopment has commenced (116).

There always seem to be changes in: —1. shape, size, posture and articular facets of the talus, —2. posture, more seldom in the size or shape of the calcaneum, —3. shape, size and location of the navicular and cuboid, —4. position of the cuneiforms and metatarsals, especially concerning MI, —5. distal tibia. The tibial torsion is, however, to be regarded as controversial. In the case of the soft tissues, changes have been observed in tendons, ligaments, joint capsules, muscles and arteries.

2.7 Radiology

In 1896 Barwell introduced the use of X-rays in order to register the exact status of a clubfoot (117). The most reliable and informative projections and positions of foot have since been sought. A double arthrography has been used to visualize the X-ray negative structures and the joint cavities as a whole (118). Ono (119), supported by others, (120) turned attention to the advantages of tomography.

2.7.1 Exposures

Antero-posterior and lateral projections have been used (21,99,103,121,122,123, 124), as well as the suroplantar view (53,76,125). Denis and Paquot (126) used lateral projection only.

In the a-p exposure a 30° equinus (53,103,121,127), a 10° equinus (128), a 15° calcaneus (129), a standing (21,99,113,120,123,124) and a neutral middle position (76,117) have been suggested. Debrunner (76) wanted a suroplantar projection with maximal correction.

In the lateral exposure a calcaneus (23,103,112,124), a 30° plantar flexion (121), a standing (21,84,99,120,123,127) and a neutral middle or free position (76,117,128) have been proposed as well as a serial of middle, maximal equinus and maximal calcaneus positions (126,130).

It is important to avoid errors caused by rotation in the evaluation of the shape and size of talus and calcaneum in the lateral projection. This is achieved by rotating the calf 30°—60° inwards (115), turning the patella and tuberositas tibiae straight forwards (53) or projecting the tibia and fibula one on top of the other (103). Simons (129), in order to avoid such error, wanted the hindfoot and the film to be kept parallel.

In the lateral projection the X-ray tube is directed at right angles to the cassette (129). In the a-p projection the X-ray tube is directed to the head of the talus at 30 degrees to vertical (123,129).

2.7.2 Subjects for radiological measurements

The most commonly used subjects are the talocalcaneal angle in lateral and a-p projections and their sum, called the talocalcaneal index. Beatson and Pearson (121) noted a considerable overlap of talocalcaneal angles in normal and clubfeet which was not found with the talocalcaneal index. They emphasized the significance of the talocalcaneal index as a radiological criterion in clubfeet, its' lowest acceptable value being 40°.

Other subjects suggested for measurement are: —1. In the a-p projection calcaneum-MV angle, talonavicular angle, talus-M I angle, calcaneum-M I angle, talar neck angle and the navicular-M I angle (29,53,76,99,103,124,127,131). Main and Crider (132) emphasized the significance of the talo-navicular angle in the evaluation of TEV. —2. In the lateral projection the calcaneum-M I and M V angles, tibiotalar and tibiocalcaneal angles, talus-M I and the M I-M V angle have been recommended (21,53,76,103,124,126).

Normal values of the subjects mentioned are presented in Table 4, page 11.

The results of treatment have also been examined radiologically. The classification of talar changes drawn up by Keim and Ritchie (133) is of special importance. Observations on radiological results are dealt with in Chapter 2.8.4, pages 22—23.

2.7.3 General remarks

It must be mentioned that the radiography of clubfoot is regarded as useful only after the age of 3 months (121) and the a-p projection after the age of one year, and it is felt that an evaluation of the navicular on the basis of a native radiograph cannot be done until after the age of 2—3 years (99). Furthermore: —1. arthrography in the newborn is not plain routine, —2. the correlation between X-ray findings and the clinical status is not 100 per cent (128), especially in newborns (134). —3. one should carefully avoid jumping to conclusions on the basis of a single projection, angle etc. (21).

Table 4. Radiologic normal values

Author		Year	Talocalcaneal angle, a-p	Talocalcaneal angle, lateral	Talocalcaneal index	Note
Debrunner	(76)	1956	30°—45°	30°—40°	—	Suroplantar
Ponseti & Smoley	(29)	1963	>20°	—	—	—
Heywood	(130)	1964	20°—40°	35°—50°	—	Suroplantar
Templeton	(21)	1965	15°—50°	>40°	—	Newborns: 30°—50°
Beatson &		1966	10°—50°	15°—55°	40°—85°	4 yrs 20°—40°
Pearson	(121)		0°—45°*	5°—40°*	0°—55°*	6 yrs 15°—30°
Taylor	(23)	1970	>30°	>30°	—	—
Lloyd-Roberts	(110)	1971	30°	30°	—	Newborns: >40°
Ponseti & Campos	(135)	1972	—	—	40°—85°	In 79 per cent
Debrunner	(122)	1973	>30°	40°	—	
Denis & Paquot	(126)	1974	—	40°—60°	—	—
Simons	(129)	1978	20°—40°	35°—50°	—	—
Price	(103)	1979	20°—40°	35°—50°	—	—

Other values:

Tibiocalcaneal angle 115—50° (Denis & Paquot 126), 130° (Debrunner 122)
Tibiotalar angle 90° (Debrunner 122)
In children under 1 year there is a 76° angle between the extreme positions of the talus in the lateral projection. In older children the angle is 60° (in the TEV 40° and 30° resp.) (Heywood 130).
A-P projection: Calcaneum/M V angle: —12° (in TEV —4°—6°) (Laaveg & Ponseti 123).
Lat projection: M I/M V angle: 12° (in TEV 24.6°—16.7°) (Laaveg & Ponseti 123)
Talus-M I angle in a-p projecton: 10° (Reiman & Becker-Andersen; = abductus 131), —20°—0° (Simons 124, + = adductus)
Lat.projection, calcaneum/M I angle is over 131 (Tayton & Thompson 127)
A-P projection: Talonavicular angle —15°—+10° (Tayton & Thompson as the author measures 127)
Talar neck/body angle 30°—40° (about 15 in adults) (Bleck 99).

* In TEV

2.8 Treatment of clubfoot

2.8.1 General remarks

A mode of treatment directed to the originator of an ailment must be regarded as ideal. The etiology and treatment of TEV have hardly any interdependence. Therapy in accordance with the etiology (i.e. within the first 8 gestational weeks!) can at present be aimed at only by means of family counselling and maternity care. The treatment of clubfoot is today directed to secondary changes. The capability of the infantile skeleton to shape itself in a healthy way if the normal anatomy is re-established, offers possibilities of success (107).

The aim of therapy is to accomplish normal suppleness, a normal muscle balance, a plantigrade foot, reasonably straight outer and inner borders of the foot, a slight calcaneovalgus and absence of callosities (53).

Hippocrates (1) emphasized early and gentle treatment: "It is therefore best to treat such cases as soon as possible, before there is any very great deficiency in the bones of the foot and before the like occurs in the tissues of the leg." and: "In a word as in wax modelling, one should bring the parts into their true natural position, both those that are twisted and those that are abnormally contracted, adjusting them in this way both with the hands and by bandaging in like manner; but draw them into position by gentle means and not violently" (translation by Withington 1927). Combined with gentle redressing and bandaging Hippocrates used special boots in order to avoid the recurrence of TEV.

Turning-points in the therapy were later on marked by the utilization of anaesthesia (Morton 1846, 136), aseptic and antiseptic techniques (Semmelweis 1861, 137, and Lister 1867, 138), and the tourniquet (Esmarch 1873, 139).

After the sound principles of Hippocrates there was a school which preferred correction of the deformity in one session, disregarding fractures and ruptures of the ligaments (92). The latest advocate of force was Perkins 1961 (140). Of apparatuses used for this purpose that of Lorenz of Frankfurt (141) might be mentioned, also the "Thomas Wrench" (142), the clamp of Forrester Brown (143,144) and the "nutcracker" apparatus of Dennis Browne (145).

The forceful methods have provoked considerable opposition (4,108, 133,146,147,148). Brockman (108) noted that every violent manipulation increased future rigidity and that prolonged immobilization was apt to spoil the muscles. Van Assen (149) paid special attention to damage to tibial and fibular epiphysis due to force. Today violent methods have been abandoned in most clinics (53).

2.8.2 Conservative treatment

The teaching of Hippocrates has been followed, with small personal variations, by many. Büschelberger (2) emphasized immediate postnatal therapy in order to take advantage of the physiologic period of muscular hypotony. Moser (106) believed that local anaesthesia could, at least partially, replace the elongation of the tendo achillei. Kite (25,30,150,151) started with staged wedging of plasters but later adopted gentle manipulation methods. Between manipulations the position of the foot was maintained with plasters. Kite devoted primary attention to the forefoot, the equinus was dealt with later.

A kind of "functional splint", which was planned to correct all components of a clubfoot deformity, was first described by Arcaeus (152) and Paré (153) and later by Adams (38). Similar devices, of which that of Dennis Browne (154) deserves separate mention, were later on used by several others. An attempt to combine the advantages of Kite's originally passive and Dennis Browne's active methods has also been made (155). Dennis Browne's method and splinting generally have been criticized for their results, which have not been considered entirely encouraging (53,156).

Immobilization, used as a sole or supportive method, became markedly easier when plaster casting was included in the treatment of clubfeet by Guerin in 1835 (157), Mathysen (158), and others (e.g. 91,159). As alternatives to plaster casting different types of adhesive bandages have been used (143,159,160) and even considered superior to it (160).

The importance of reflex stimulation in order to accomplish muscular balance has also been underlined (161).

Advocates of the non-operative treatment of clubfoot are Jones and Lovett (159), Lange (162 "The treatment of a newborn clubfoot is always bloodless") and Rabl (163 "Only a person who does not master a conservative technique, operates a clubfoot").

The principles of solely conservative treatment were questioned by Scheel (148), Debrunner (76 "Conservative treatment of clubfoot from outside does not alter the continuous effect of the powers which created the deformity. There will be a recidive if those powers are not eliminated for the phase of the most intensive development, i.e. the first 3—4 years of life") and Imhäuser (146,165 "The equinus must always be corrected operatively").

2.8.3 Operative treatment

Excluding tenotomies the operative treatment of clubfoot was started as anaesthesia, aseptic and antiseptic methods became available. Prior to that, bleeding, aneurhysms, wound infection, tenosynovites, and general septicemia were often seen.

The first elongation of the achilles tendon was performed by Lorenz 1784 (166). He was followed by Sartorius (167), and Delpech (168), but for reasons that have been mentioned, Stromeyer (169) and Little (45) in 1831 and 1839, respectively, were first in making a routine of it. Little added tenotomies of the tibialis posterior and hallucis longus tendons to the method. He and his contemporaries generally recommended operation only when the child started walking. They wanted to take advantage of the conservative methods and regarded earlier operation as hazardous. Adams (38) and Hüter (48,102) disagreed with Little. Hüter believed that an achilles tenotomy removed the compression, which he felt was necessary for the correction of bone deformities, while Adams preferred an early operation.

Elaborators of the present individual release operations have been many (e.g. 38,92,95,108,170,171,172,173). Fergusson (171) performed a subcutaneous division of achilles, tibialis posterior, flexor and extensor hallucis, flexor and extensor digitorum tendons and the plantar fascia. Adams (38) paid special attention to the necessity of dividing the tightening talo-calcaneo-navicular ligaments. Codivilla (174) worked out a useful posteromedial release operation which, in principle, corresponds to the later technique of Turco (112). Dwyer (170) proposed a Z-plasty of the tendo achillei and the release of its medial calcaneal insertion. In this way not only the equinus, but the varus as well, would be corrected as the active powers shift laterally.

As mentioned, Adams (38), believing that the muscles of an uncorrected foot degenerate, was an advocate of early surgery. His opinion was later on shared by several others (e.g. 88,90,148). Pasila and Sulamaa (176), Somppi and Sulamaa (36), Pous and Dimeglio (93) as well as Ryöppy and Sairanen (3) have recommended a release operaton in the neonatal period, without a previous period of conservative therapy.

At present the optimal age for operation is regarded to be 1—12 weeks (20,38,81,128,131,177,178), 4—6 months (18,76,179,180), 1/2—2 years (95, 181,182,183), 3—4 years (184,185) or even 6 years (127). Preoperative conservative therapeutic measures are urged by authors, who noted that in the easier cases they suffice and that even in the more severe ones the tissues are softened, and complications caused by skin, vascular and nervous stretch prevented (131).

Some authors (29,38,91,123,151,164,180,186,187,188,189,190) have given primary attention to the adductus and varus of the forefoot, others (2,8,20,28,48,76,93,110,143,156,191,192,193) consider that the correction of the equinus is of basic importance. The latter note that correction without release of the equinus means violence.

Internal fixation with pins has been used by some authors (2,95, 103,178,180,183,193,194,195) but not by others (20,93,110,123,128,182).

There are even other individual methods suggested by several authors (e.g. 18,29,80,88,124,148,164,193,196).

2.8.3.2 Tendon transfers

Great weight has been attached to complete correction of the deformity previous to tendon transfers (190), the sole purpose of which is to create muscular balance and to prevent recurrence (197,198,199). For this purpose tibialis anterior (123,135,183,200,201,202,203), tibialis posterior (196,198,204), and flexor hallucis longus tendons (14) have been used. The tendon is reinserted laterally to the middle line of the foot, to cuneiforms, cuboid, the basis of M V or to the peroneus tendon. The risk of overcorrection is considered smaller if the attachment is made to cuneiform II or III (135).

Re-transfer of the tendon close to its original attachment within 1—3 years has been suggested (165) but also regarded as unnecessary (201).

An age of 3—7 years is considered optimal for tendon transfer (165,199,203).

A reserved attitude to tendon transfers has been adopted by some authors (2,30,96,181,198). It is considered to be of no value if bone deformities already exist (55). Some authors (96) believed that the tibialis anterior muscle, as an antagonist to the m. triceps surae, should not be weakened. They also believe that peroneal insufficiency is temporary.

2.8.3.3 Operations on bones

Total and partial extirpations of bones have been proposed up to the present time. Their effects have often been better cosmetically than functionally.

Dwyer (170) introduced wedge osteotomy of the calcaneum, which gained wide popularity. He paid more attention to function than appearance. The optimal age for operation was 3—4 years, previous to which the risk of growth error was too high and after which the effects of treatment decreased.

Tibial and fibular osteotomies have been done and criticized as well (205).

Arthrodesis is more appropriate in older age groups. Ryerson (206) is well known for his triple arthrodesis and Evans (100) for his combination of medial release and calcaneo-cuboidal wedge osteotomy with arthrodesis. The age proposed by Evans for his operation was 4—8 years.

Referring to bone operations Jones and Lovett (159) noted that the removal of bone is always to be avoided if possible, especially in younger patients. Brockman (108) for his part disapproved of talectomies and rotation osteotomies, feeling they were simply masking one fault with another.

2.8.3.4 Postoperative care

Immobilization of the foot in a corrected (not overcorrected) position for a couple of months is generally accepted. Modern materials used for splints allow the wound area to be left uncovered (special attention can and must be given to the prevention of skin necrosis and wound infection, 36,108) and make it possible to remove the splint for short periods of bathing, reflex stimulation (161,165) etc, Splinting in one or another form is suggested to be continued until walking age, whereafter the treatment is continued with night splints, special boots and physiotherapy to the age of at least 2 years (3,112).

2.8.4 Complications in treatment

Complications in treatment result in a failing late status. They arise mainly from the resistance of the deformity (defective therapy) or a therapeutic trauma.

Concerning shape, rockerbottom foot, beanshaped foot, overcorrected foot, genu recurvatum and valgum as well as outwards rotated hip have been mentioned (20,93,95,110,113,115,126,165,184,207,208,209,210).

Of damage to individual bones one might mention deformities of the distal tibial and fibular growth zones, posteromedial bending of the distal tibia and fibula, deformities of the talus (especially flat-topped talus), and deviation in shape and retarded development of the navicular and cuboid (147,149,209,210, 211). As an example of an external complication decubitus might be mentioned. Henkel (209) compared a group of conservatively treated patients with another group treated with early surgery. The frequency of complications was close to 100 per cent and 17.5 per cent, respectively. Henkel noted that even a wide arthrolysis did not seem to harm the growing bones. The risks of conservative treatment are stressed by others (95,203,208) as well.

Complications of the operative treatment are mainly those of any operative procedure: hematoma, dehiscence of the wound, infection, and skin necrosis.

Parker (49) pointed out that blood in the tendon sheaths could spoil the eventual result. Pasila and Sulamaa (176) believed that infection was due to hematoma and the low immunologic resistance of the newborn. The simultaneous dissection of the talus from both sides is a notorious method: 14.3 per cent of cases have resulted in an avascular necrosis of the talus (212).

Recurrence due to fibrosis, peroneal paresis, and overcorrection combined with flat foot have also been mentioned as operative complications (91,95,110,183).

Tönnis and Bikadorov (96) noted that only 6.6 per cent of treated patients did not have navicular changes, that 5.2 per cent had a reduction of cuneiform I and II, and that 2.6 per cent had an enlarged cuneiform III and cuboid

(Evans and Hüter-Volkmann's law). Aberrancies were found not only in clinically poor feet but even in good ones. The authors observed sclerosis of the articular facets in 50 per cent of patients between 10 and 15 years of age, and arthrotic changes in 2/3 of patients between 15 and 20 years of age.

Herwig and Schieman (213) found radiological changes in 60 per cent of treated patients, corresponding to the severity of the primary situation. Similar changes are reported by others (135,207). Somppi ja Sulamaa (36) connected a horizontal talus and a talocalcaneal angle of less than 15°, with poor clinical results.

Main and Crider (132) drew attention to the fibular retroposition which, according to them, existed even in 40 per cent of normal feet. They regarded navicular subluxation as being in direct correlation with the forefoot adductus, tarsal outwards rotation and the flat-topped talus. Navicular subluxation was proportional to age at operation, and the result of therapy inversely proportional to it.

2.8.5 Results of treatment

Comparing results achieved at different times and with different methods of treatment is not an easy task.

1. Local circumstances differ. Some receive their patients directly from delivery rooms, others later. The important age at which therapy was started may thus vary even in the same paper.
2. No general agreement upon homogeneous classification of the primary status has existed, even if suggestions have been made (17,214). Perhaps the most useful has been the division into rigid (true) and flexible (postural) clubfeet (17).
3. There is no uniform model and no criteria for the review of materials. Feet have been evaluated on a subjective, clinical, functional and radiological basis as well as on the basis of various combinations of them. Even classifications differ: excellent- good- fair- poor, satisfactory-unsatisfactory, good- fair-poor. The limits of classes also show variation.

Nichols (92) considered factors associated with recurrence and noted that recurrence was probable after operations without reposition in Chopart's joint or correction of the talar and calcaneal deviation. Stein (215), supported by Somppi and Sulamaa (36), concludes —1. that the number of recurrences was higher if the TEV was combined with another orthopedic fault such as a dislocated hip, —2. that it was lower in cases treated in the first days of life and, —3. that neglect of treatment increased the number of recurrences. Scheel (148) was of the opinion that poor end-rusults were due to —1. delayed start of treatment, —2. poor technique, —3. insufficiency in maintaining the position, —4. an at-

tempt to correct the equinus by action on the forefoot, —5. forceful corrective plaster casting. He agreed in principle with Müller (216) who, additionally, recommended operation in 80 per cent of cases.

Several authors (121,131,192,217) have disagreed with the term recurrence or relapse, thinking that it was a matter of a residue, i.e. defective therapy.

Results, divided into two, three and four classes as well as results reached by different methods and the proportion of operatively to conservatively treated cases are presented in Tables 5,6,7,8, and 9 on the following pages.

Table 5. Results, classified into two groups, as collected from 5 papers.

Author	Year	Excellent + good*	Fair+ poor*	Number of feet	Note
Kuhlman & Bell (218)	1956	73	27	30	Posteromedial release + achilles elongation
"	1956	50	50	12	Achilles elongation only
"	1956	31	69	16	Medial release only
"	1956	86	14	29	Tibialis anterior tendon transfer
Nemechek (219)	1968	70	30		Therapy started at the age of less than 1 month
"	1968	56	44	359	Therapy started at the age of more than 1 month
"	1968	12—32	68—88	—	Therapy started at the age of more than 15 years
Bleck (99)	1977	85	15	—	—
Main, Crider, Polk, Lloyd-Roberts, Swann & Kamdar (128)	1977	83	17	6	Operated at the age of less than 6 months
"	1977	35	65	23	Operated at 7—12 weeks of age
"	1977	57	43	35	Operated at 13—18 weeks of age

* Per cent

continues

Table 5. continued

Author	Year	Excellent + good*	Fair+ poor*	Number of feet	Note
"	1977	46	54	13	Operated at 19—24 weeks of age
"	1977	51	49	77	Whole material
Petri (182)	1979	35	65	63	Primary results
"	1979	70	30		After additional corrective operation

* Per cent

Table 6. Results, classified mainly into three groups as collected from 29 papers.

Author	Year	Good*	Fair*	Poor*	Over-corrected*	Number of feet	Note
Lindeman (220)	1934	54	30	16	—	44	Achilles tenotomy, conservative manipulation
Critchley & Taylor (55)	1952	73	9	18	—	22	Tendon transfers
Bösch (179)	1953	18	32	50	—	102	—
" (179)	1953	24	38	38	—	69	P-m release
Bachmann (207)	1953	33	33	33	—	—	Achilles lengthening
Fredenhagen (43)	1955	53	30	17	—	163	Sherb's method
Becker (221)	1955	40	36	11	13	445	—
Debrunner (76)	1956	60	33	7	—	15	Under 1 month of age
" (76)	1956	46	36	18	—	11	Over 11 months of age, whole mat. 83 ff
Bertelsen (222)	1957	44	28	28	—	114	Conservative therapy
Jansen (223)	1957	50	38	12	—	150	40.7 per cent operated
Hervig & Schiemann (213)	1958	42	44	14	—	70	—
" (213)	1958	62	24	14	—	70	Functionally
Solonen & Parkkulainen (27)	1958	51	30	19	—	108	82 per cent operated
Pasila & Sulamaa (176)	1961	76	24	—	—	38	Operated at the age of 3—7 days
Seyfarth (4)	1962	85	11	4	—	48	—

* Per cent

continues

Table 6. continued

Author		Year	Good*	Fair*	Poor*	Over-corrected*	Number of feet	Note
Dwyer	(170)	1963	48	52	—	—	56	All operated
Ponseti & Smoley	(29)	1963	71	28	1	—	94	78.8 per cent subcutaneous achilles lengthening
Tönnis & Bikadorov	(96)	1968	12	55	27	6	263	—
Somppi & Sulamaa	(36)	1971	35	41	24	—	87	All operated at the age of less than 2 weeks
	(36)	1971	8	42	50	—	11	" " with an associated anomaly
Manes, Costa Innao	(224)	1973	40	60	—	—	5	Primary class I
"	(224)	1973	62	38	—	—	13	Primary class II
"	(224)	1973	46	37	17	—	41	Primary class III
"	(224)	1973	49	39	12	—	59	Whole material
Preston	(182)	1976	46	27	27	—	33	All methods
"	(182)	1976	43	24	33	—	21	Operated
"	(182)	1976	42	42	16	—	12	Conservative therapy
"	(182)	1976	55	28	17	—	18	Treated at the age of less than 1 month
"	(182)	1976	33	27	40	—	15	Treated over 1 month of age
Herring	(195)	1977	54	33	13	—	72	The Turco method
Swann	(225)	1977	76	24	0	—	17	Operated at the age of 0—6 weeks
"	(225)	1977	56	11	33	—	18	Operated at the age of 7—12 weeks
"	(225)	1977	33	—	67	—	—	Operated at the age of 13—18 weeks
"	(225)	1977	11	22	67	—	—	Operated at the age of more than 19 weeks
Price	(226)	1978	64	18	18	—	121	Conservative therapy
Bethem	(194)	1978	80	9	11	—	54	All operated
Stein	(215)	1979	44	37	19	—	104	—
"	(215)	1979	17	67	16	—	—	Cases with associated orthopaedic anomaly

* Per cent

continues

Table 6. continued

Author		Year	Good*	Fair*	Poor*	Over-corrected*	Number of feet	Note
Tayton & Thompson	(127)	1979	36	53	11	—	91	Boys
"	(127)	1979	11	59	30	—	27	Girls
"	(127)	1979	31	54	15	—	118	Boys and girls
Nyga	(199)	1979	58	24	12	6	34	Tendon transfers
Tripathi & Chatuwerdi	(227)	1979	62	22	16	—	32	—
"	(227)	1979	100	0	0	0	20	Treated at the age of 8 mths—3 yrs
"	(227)	1979	0	100	0	0	7	Treated at the age of 3—5 yrs
"	(227)	1979	0	0	100	0	5	Treated over 5 yrs of age
Kumar	(214)	1979	87	7	6	—	32	Whole material
"	(214)	1979	100	—	—	—	12	Primary class I
"	(214)	1979	100	—	—	—	91	Primary class II
"	(214)	1979	60	20	20	—	10	Primary class III (The author's classification

* Per cent

Table 7. Classification of results into four groups as collected from in four papers.

Author		Year	Excellent*	Good*	Fair*	Poor*	Number of feet	Note
MacEven Scott, & Shands	(28)	1961	40	32	4	24	96	Clinical
MacEven Scott, & Shands	(28)	1961	49	9	16	26	96	Radiologic
Morita	(193)	1962	26	37	17	20	35	—
Turco	(112)	1971	48	39	10	3	58	—
Imhäuser	(156)	1980	35	33	23	9	393	Whole material
"	(165)	1980	42	30	21	7	204	Operated within 2 first years of life

* Per cent

continues

Table 7. continued

Author		Year	Excel-lent*	Good*	Fair*	Poor*	Number of feet	Note
"	(165)	1980	31	34	25	10	153	Operated at the age of 2—6 years
"	(165)	1980	14	42	28	16	36	Operated at ages more than 7 years

* Per cent

Table 8. Results, classified into four groups with comparison of different methods**

Method	Good*	Fair*	Poor*	Over-corrected	Total number of feet
— Conservative therapy	11 (6)	58(32)	106(58)	7(4)	182
— Soft tissue operation	14(13)	59(56)	29(27)	4(4)	106
— Lengthening of tendo achillei + partial posterior release	4 (8)	20(42)	21(44)	3(6)	48
— Lengthening of tendo achillei + medial release	6(22)	19(70)	1 (4)	1(4)	27
— Lengthening of tendo achillei + tibialis anterior tendon transfer	2(15)	7(54)	4(31)	0	13
— Lengthening of tendo achillei + medial release + tibialis anterior tendon transfer	1(17)	5(83)	0	0	6

*Percentages are given in brackets
**(96)

Table 9. The division into operative versus conservative treatment in 18 papers and 3657 feet.

Author		Year	Conservative*	Operative*	Number of feet	Notes
Bachmann	(207)	1953	37	63	24	—
Fredenhagen	(43)	1955	69	31	532	—
Debrunner	(76)	1956	50	50	87	—
Jansen	(223)	1957	59	41	150	—
Solonen & Parkkulainen	(27)	1958	38	62	108	—
McEven, Scott & Shands	(28)	1961	67	33	237	—
Seyfarth	(4)	1961	30	70	74	—
Ponseti & Smoley	(29)	1963	21	79	94	—
Kite	(30)	1964	92	8	922	—
Wynne-Davis	(113)	1964	30	70	121	—
Hersch	(15)	1967	56	44	159	—
"		1967	51	49	43	Treated at the age of less than 1 year
"		1967	58	42	116	Treated at the age of more than 1 year
Denham	(177)	1967	79	21	223	In 100 per cent of the mild, and 60 per cent of the severe cases the results of conservative therapy were good
Tönnis & Bikadorov	(96)	1968	65	35	263	—
Preston & Fell	(183)	1976	36	64	33	—
Richardson & Westin	(228)	1978	50	50	362	—
Tripathi & Chatuwerdi	(227)	1979	80	20	32	—
Kumar	(214)	1979	66	34	32	—
Laaveg & Ponseti	(123)	1980	12	88	104	—
Summary			52	48	3657	

* Per cent

There are various papers which could not be included in the above tables. Kite (30) was satisfied with the results in 2/3 of his mainly conservatively treated cases. Shaw (156) regards results as the worse the later the patients are operated on. He mentions, additionally, three conservative methods, the order of which, as far the success is concerned, is: 1. Stretching and taping (75 per cent good), 2. Denis Browne's splinting (25 per cent good), and 3. Sole manipulation (no success at all). Various other authors shared his opinion concerning early operation (27,36,76,128,164,183,225,227). Wynne-Davies (113) did not find any difference in the disparity between unilateral clubfeet which were treated either conservatively or operatively. She considered that the main residual trouble was the equinus, the share of forefoot varus and adductus being of little consequence. According to her the clinical and the radiological status were fairly analogous. On this point, several others disagreed (127,128,195,207). Tayton and Thompson (127) observed considerably better results in boys compared with those in girls and mentioned as well that the incidence of satisfactory results was unrelated to age at operation. Yamamoto (32) on the contrary established no connection between sex and heredity on the one hand and results on the other. In his material bilateral cases were operated upon more often. In Imhäuser's (165) cases results in respect of the form were throughout almost twice as good as those in function.