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Outcome After Achilles Tendon Lengthening with a Posterior Capsulolysis According to Imhäuser in Idiopathic Congenital Clubfoot

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SUMMARY

Background. The Ponseti method has radically reduced the need for extensive surgical treatment in idiopathic clubfoot. At present there are no universally accepted criteria for the use of the various surgical techniques.

Material and methods. 77 patients with idiopathic congenital clubfoot (111 affected feet) were treated according to Imhäuser. The operative release included z-shaped Achilles tendon lengthening and a posterior capsulolysis of the talocrural and talocalcaneal joint. In case of relapse in infancy and school age, a transfer of the tendon of the anterior tibial muscle (n=26) and a release of the talonavicular, navicular cuneiform I and cuneiform metatarsal I joints (n=15) were carried out. 49 patients with 70 clubfeet were followed up at a mean age of 9.8 years (± 7 years) and the length of follow-up averaged 8.6 years (± 6.2 years).

Results. In 71.4% (50 feet) a "very good" or "good" correction of shape and in 64.2% (45 feet) "very good" or "good" function was achieved. A statistically significant correlation was found between delayed onset of walking and the risk of revision surgery due to a relapse of the deformity.

Conclusions. 1. Important problems in the treatment of clubfoot according to Imhäuser in our study were residual partial forefoot adduction and restriction of mobility in the upper ankle joint. 2. Our analysis of radiographs showed that despite unsatisfactory X-ray findings, clinical correction and mobility were good. 3. Rigid congenital clubfeet, however, require peritalar releases.

Key words: idiopathic clubfoot, operative treatment, Achilles tendon lengthening, Imhäuser technique, onset of walking

BACKGROUND

Various methods of treatment of the idiopathic congenital clubfoot are in use with general agreement that primary manipulation and redressing treatment should start immediately after birth. The objective of redressing treatment is to correct all components of the deformity except in cases with a therapy-resistant equinus component. The irreducible equinus deformity has to be corrected surgically between the 3rd and 6th months of life with various recommended surgical procedures [1,2,3,4,5,6,7,8,9,10].

The Ponseti method with manipulation, long-leg casting and a simple percutaneous achillotenotomy for the remaining equinus has considerably decreased the need for extensive surgical treatment in recent years [11,12, 13,14,15].

The use of physiotherapy, ankle motion exercises and continuous use of the passive motion machine seem to have a positive effect in pre- and early post-operative management of congenital clubfoot [16,17,18,19].

The treatment of idiopathic clubfoot according to Imhäuser was very popular in Germany in the 1980s and 1990s. The basic idea of the Imhäuser protocol was to complete the therapy of clubfoot within the first year of life. The subsequent long-term aftercare mainly serves to maintain the correction in terms of "normal" shape and function and to ensure a timely detection of any relapse [3, 4].

MATERIAL AND METHODS

77 patients with only idiopathic clubfoot (111 affected feet) were treated by the Imhäuser procedure [3, 4]. All teratogenic clubfeet were excluded.

49 of 77 patients were followed up for an average of 8.6 years (± 6.2 years). The mean age at follow-up was 9.8 years (± 7 years). The male/female ratio was 4.5:1. 34 patients (44%) were affected bilaterally and 43 patients (56%) unilaterally. The right foot was affected 2.3 times more than the left. The family history was positive in 8 patients (10.4%). Various malformations were additionally found in 12 patients (Tab. 1).

The age of onset of walking was documented only in 40 (81.6%) of the 49 patients. Due to the retrospective nature of the investigation, in 9 cases the parents were not able to give precise information about the onset of walking. The average follow-up of these 40 patients was 8.21 years (± 4.01 years).

Clinical examination included a description of the foot's shape and function, an assessment of gait as well as the patients' and parents' subjective feeling and degree of satisfaction. Our findings were interpreted according to Imhäuser's evaluation scheme (Tab. 2).

Tab. 1. Additional malformations in 12 patients with idiopathic clubfoot

1.	Crus varum of the same side
2.	Digitus quintus hypoplasia on one side and bilateral clubfoot
3.	Dysplasia of the 5th metatarsal bone on one side and bilateral clubfoot
4.	Mental retardation
5.	Hallux varus and digitus quintus subductus of the collateral foot
6.	Hypoplasia of the 1st metatarsal bone and of the 1st toe, shortening of the foot on one side and bilateral clubfoot
7.	Inguinal hernia
8.	Hyposomia (treated with STH)
9.	Umbilical hernia, genu recurvatum on one side and bilateral clubfoot
10.	Pyloric stenosis, congenital hip dysplasia bilateral and bilateral clubfoot
11.	Pyloric stenosis
12.	Supinatory malposition of the contralateral foot

Tab. 2. Evaluation scheme for foot shape and function according to Imhäuser

	Shape of the foot	Function of the foot
very good	no equinus	passive dorsiflexion≥15-20
	regular heel position, no varus	active dorsiflexion≥10°
	supination up to 10°, actively readjustable	plantar flexion≥20°
	forefoot adduction up to 20°	pro- and supination≥½
	forefoot abduction up to 10°	no rigid forefoot
	physiologically-shaped foot arches	toes freely mobile
		normal gait
		no pain
good	no equinus	passive dorsiflexion≥5-10°
	heel varus up to 5°	active dorsiflexion≥0°
	heel valgus up to 10°	plantar flexion≥10°
	supination up to 20°, actively readjustable	pro- and supination≥½
	forefoot adduction up to 30°	normal gait
	forefoot abduction up to 20°	no pain
	deeply-situated head of the fourth metatarsal bone	
satisfactory	no equinus	dorsiflexion and plantar flexion up to neutral position
	heel varus up to 10°	pro- and supination up to neutral position
	heel valgus up to 15°	no pain
	supination up to 30° or only passively readjustable	
	no physiologically-shaped foot arches	
poor	physiologically-shaped foot cannot be achieved passively	physiological position of the foot cannot be achieved actively or pain in the foot

4 at the time of the investigation in the 1980s and 1990s no standardised clubfeet classification according to degrees of severity was used in our hospital.

66 preoperative X-rays of 47 patients and 73 postoperative X-rays of 50 patients were analyzed. The patients' mean age at postoperative X-ray imaging was 6.7 years (± 4.75 years).

We evaluated standardized antero-posterior views (with the central ray aimed at the area directly distal to the upper ankle joint at 30° to the perpendicular) and lateral views (in maximum dorsal extension). The sagittal and dorsoplantar talocalcaneal angle and the talometatarsal-I-angle were evaluated.

In the first week of life the treatment started with redressement of the clubfoot and long leg casting with 90° flexed knee joint. Manual redressment of the feet was done according to the Imhäuser method, which was widely used in Germany at that time [3,4]. Up to the second week the casts were changed every 3 to 5 days, and after that once a week, in order to maintain the best fit of the plaster casts (rapid weight loss in the baby's first week of life, increase in weight in the second week).

In the fourth to sixth months Achilles tendon lengthening and dorsal capsule release of the upper and lower ankle joint were carried out. The indication for surgery was made after clinical and radiological demonstration of pes equinus and residual deformity. The radiological criterion was the finding, on standardised radiographs, of a pathological sagittal and dorsoplantar talocalcaneal angle and tibiocalcaneal angle.

After surgery there was a 6-week period of long leg casting with the knee joint flexed at 90°. To preserve the correction according to the Imhäuser protocol, a lower leg orthosis (until the child started walking) and long leg night splints (up to the end of the 2nd year of life) were fitted [3,4]. The parents started daily physiotherapy after removal of the casts and once the children started walking, they were provided with pronation insoles with a hollow position for metatarsal I and a pronating wedge. The patients were followed up every 6-12 weeks up to school age and twice a year afterwards.

Any relapse of clubfoot before school age was treated once again with an Achilles tendon lengthening procedure and dorsal capsular release of the upper

and lower ankle joints, often combined with the transfer of the tibial anterior muscle tendon to the base of the fifth metatarsal bone and release of the talonavicular, navicular-cuneiform I and cuneiform-metatarsal I joint.

The data were statistically analyzed using the Wilcoxon's rank test (SAS program).

RESULTS

77 patients with 111 clubfeet were treated according to Imhäuser. In 70 patients (91%) readjusting manipulation and redressing cast treatment started during the first week of life. The delay in starting treatment for the remaining 7 patients (9%) was generally caused by late referral to our centre. After a plaster cast redressement of 24.3 weeks on average (± 8.6 weeks), an axially readjusted pes equinus was obtained in 88 of the 111 feet (79%). Preoperatively 23 feet had mild to moderate forefoot adduction and supination. 61 children (79%) were operated on (Achilles tendon lengthening, dorsal capsular release of the ankle joints) for the first time before the 41st week of life followed by immobilisation in long leg casts for 8 weeks (± 3.5 weeks). Subsequently, they were provided with ankle-foot orthoses and night splints for an average of 10.4 months (± 5.9 months). 10.3 months (± 6.8 months) after the operation, with ambulant children being provided with the above-mentioned correcting insoles. The treatment with night splints lasted 24.3 months on average (± 25.1 months). The mean duration of insole application amounted to 4.3 years on average (± 5.8 years). In cases of adequate correction, insole treatment was no longer continued.

The average age at which the children started to walk was 13.56 months (± 3.01 months). Patients with bilateral clubfoot showed on average a delayed onset of walking. Statistical significance compared to unilaterally affected patients could not be demonstrated (Tab. 3).

Twelve (30%) of the 40 patients who were monitored when they started walking developed a relapse requiring revision surgery. The mean age at which they started to walk was 16 months (± 3.61 months) in this group (Tab. 4). The revision operation was carried out at 3.92 years on average (± 1.75; 2 to 7 years). The average age at the final follow-up was similar to that in the whole group, amounting to 8.36 years (± 3.91 years).

Twenty-eight of the children (70%) did not need any further operation for relapse of clubfoot till a follow-up age of 7.96 (± 4.23). The mean age at beginning of ambulation in this group was 12.52 months (± 1.93 months), i.e. 3 months earlier than those children who needed revision surgery (Tab. 4). The time of onset of walking was significantly different (p-value = 0.0018) in patients with and without revision surgery.

Thirty-four patients (44%) had to be operated on several times due to relapses (Tab. 5). All of them underwent lengthening of the Achilles tendon at least once, 26 patients (76.5%) underwent a transfer of the anterior tibial muscle, and 15 patients (44.1%) had a release of the talonavicular, navicular cuneiform I and cuneiform metatarsal I joints.

The follow-up of 49 patients with 70 clubfeet revealed "very good" or "good" results for the correction of shape in 71.4% (50 feet) and "very good" or "good" function in 64.2% (45 feet) according to the Imhäuser criteria (Tab. 2). We found distinctly better results in the correction of shape than in function (Tab. 6, Fig. 1, 2, 3).

24 feet (34.3%) showed a persisting forefoot adduction. In 17 feet we observed a slight, spontaneous forefoot adduction which could be entirely compensated actively and passively. Severe cases of forefoot adduction were found in 7 feet.

In 41 feet (58%), the dorsiflexion was not larger than 5° and in 21 feet (30%) the plantar flexion did not exceed 15°. This restriction, however, does not appear to be the decisive parameter of foot function since in most patients – despite an ankle dorsiflexion

Tab. 3. Onset of walking in patients (with and without relapse) with bilateral and unilateral clubfoot

Clubfoot		bilateral clubfoot	right clubfoot	left clubfoot
N=40 patients		n=17	n=15	n=8
Onset of walking (months)	mean	14.53	12.97	12.62
	s_D	3.62	2.58	2.13
	min	10	10	10
	max	24	21	16
		no statistically significant difference		

of 5° – normal physiological gait and unrestricted level of activity were found.

A pes equinus was found in only 6 feet (two feet each of 10°, 5° and 3° respectively).

Five feet (7.1%) showed a malposition in supination of about 5°, of which 3 were entirely actively readjustable.

Fifty-eight feet (83%) had an eversion/inversion of >= 1/2, and 59 feet (84%) a pronation/supination of >= 1/2. All toe joints had a normal range of motion.

Most of our patients had a regular heel position and a physiologically-shaped plantar arch. In one case we found a valgus heel of 9° and in 7 cases a varus heel of 8° to 10°. Four feet had flattened lon-

Tab. 4. Onset of walking and age at follow-up in patients with and without relapse

Onset of walking / age at follow-up		all patients N=40	without relapse N=28	with relapse N=12
Onset of walking (months)	mean	13.56	12.52	16.00
	s_D	3.01	1.93	3.61
	min	10	10	12
	max	24	18	24
			significantly different p=0.0018	
age at follow-up (years)	mean	8.21	7.96	8.36
	s_D	4.01	4.23	3.91
	min	2	2	2
	max	16	16	16

Tab. 5. Age of patients at surgery due to relapse

Revision surgery	Patients N=34	average age at surgery	s_D	the youngest patient	the oldest patient
1. Revision surgery	23	4.6 years	3.7 years	1 year	21 years
2. Revision surgery	7	6 years	3.5 years	2 years	15 years
3. Revision surgery	3	14 years	7.6 years	2.5 years	23 years
4. Revision surgery	one patient at the age of 4				

Tab. 6. Shape and function of foot – Summary of follow-up results of 49 patients with 70 clubfeet

Rating	Shape of foot		Function of foot		Shape and function (Total result)	
(N=70 feet)	feet (n)	%	feet (n)	%	feet (n)	%
very good	49	70.0%	8	11.4%	6	08.6%
good	1	1.4%	37	52.8%	32	45.7%
satisfactory	11	15.7%	15	21.4%	22	31.4%
poor	9	12.9%	10	14.3%	10	14.3%

gitudinal arches, 8 a hollow foot component and 6 a splayfoot. Altogether 62 feet (88.6%) had a physiological heel position, 58 feet (82.9%) a physiological longitudinal arch, and 64 feet (91.4%) a physiological transverse arch.

Twelve feet had toe malpositions: 8 digitus-V-varus, 2 hallux varus and 2 hallux valgus, but without contractures.

Fifty-five feet (78.6%) showed physiological muscular strength according to MRC (Medical Research Council) criteria, whereas in 11 feet (16%) the pronators were substantially reduced (3 feet with MRC "grade 4" and 8 feet with "grade 3"). There was a weakness of the extensors (MRC "grade 4") in 3 feet and of the supinators (MRC "grade 4") in one foot and no flexor weakness was found.

Ten of the patients (20.4%) had difficulties with heel walking. This refers to patients being unable to perform a dorsiflexion in the upper ankle joint. Two patients were unable to walk on tiptoe due to stiffness of the ankle joint.

Thirty-nine patients (79.6%) showed normal physiological gait with footwear as well as barefooted, at most with slight supination or forefoot adduction which could be corrected actively. In 10 patients (20.4%) a fluent gait with shoes was observed, but they had difficulties walking barefooted due to forefoot adduction or supination or restricted mobility in the upper ankle joint which were not actively reducible.

The evaluation of radiological findings revealed that restoration of normal anatomical-morphological axis conditions between the talus, calcaneus and

Tab. 7. Radiographic evaluation

Radiological	Preoperative (N=66 feet)				Postoperative (N=73 feet)			
findings	mean	s_D	min	max	mean	s_D	min	max
Sagittal talocalcaneal angle	12.05°	10.28°	0°	42°	22.73°	06.51°	10°	42°
Dorsoplantar talocalcaneal angle	15.08°	06.84°	2°	23°	21.32°	14.15°	2°	70°
Talometatarsal-I-angle	37.29°	23.30°	2°	87°	21.66°	12.91°	0°	50°

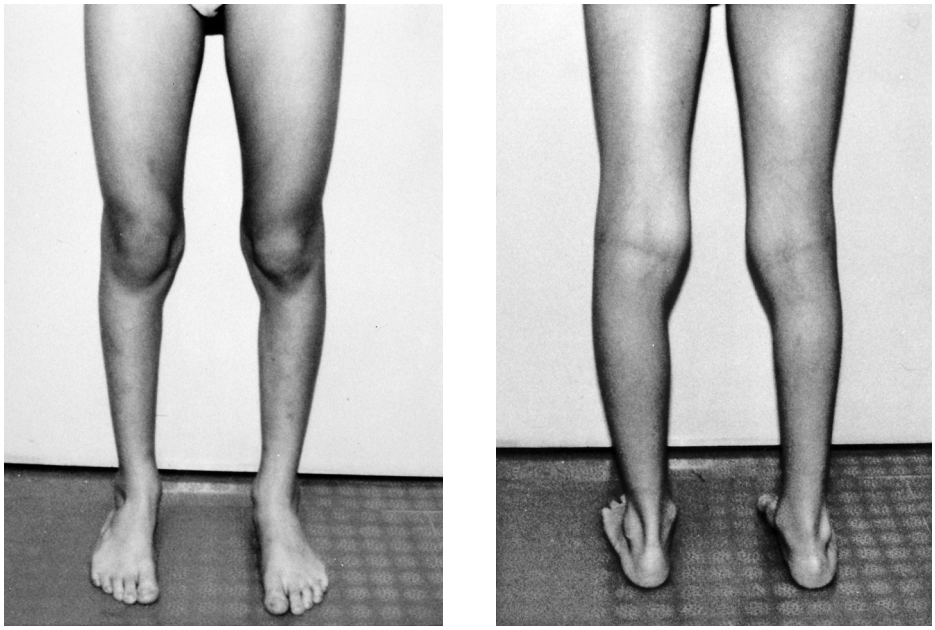

Fig. 1. Male patient, age 9.5 years, right-sided idiopathic clubfoot. Very good shape and function of foot – very good result

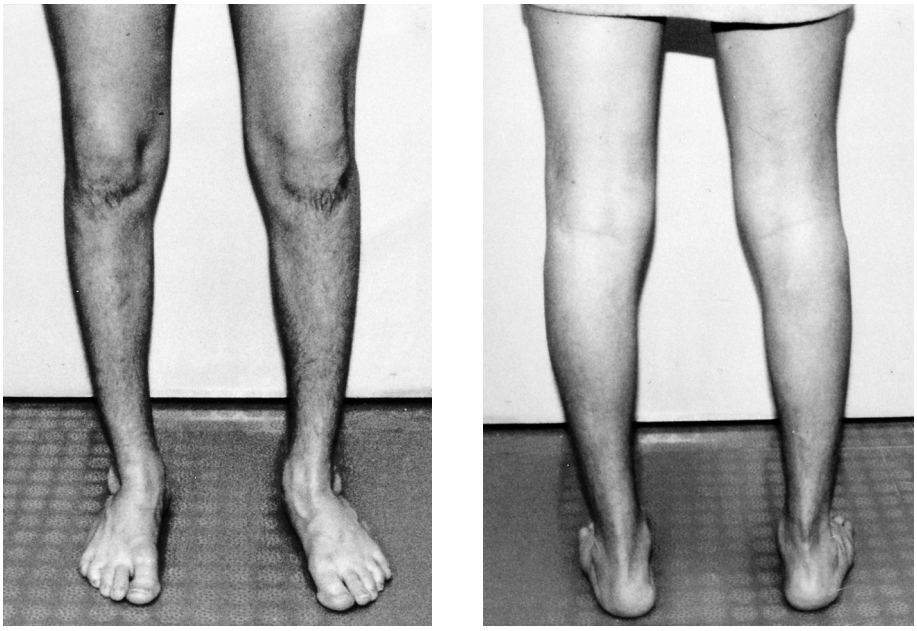

Fig. 2. Male patient, age 16 years, bilateral idiopathic clubfoot. Very good shape and good function of right foot, satisfactory shape and good function of left foot – satisfactory result

Fig. 3. Female patient, age 23 years, bilateral idiopathic clubfoot. Not satisfactory shape or function of both feet – poor result

metatarsal I was usually not achieved (Tab. 7). Postoperative findings showed some correction of the conditions but still deviations from the physiological situation. Observed deviations of the radiological axis conditions between the talus, calcaneus and metatarsal I did not clearly correlate with the clinical findings. There could be good shape and function despite incomplete radiological correction.

Thirty-five patients (71.4%) were still provided with Imhäuser's pronating insoles, which could be conveniently worn inside normal shoes. Three patients needed a shoe adaptation (rolling sole, raised heel).

During the follow-up, 47 patients (95.9%) wore normal ready-made shoes, one patient needed ready-made shoes of different sizes and one patient needed custom-made orthopaedic shoes.

Forty-three (87.8%) of our patients (or of their parents) found their own (or their children's) performance unrestricted or only slightly restricted with regard to special activities. Children who excelled in sports and thereby stressed their feet more than usual (skiing, soccer, badminton, ballet) suffered from slight complaints. In particular, jumping was affected by occasional restrictions when practised for a longer time. Twenty-eight patients (57.1%) regularly practised various kinds of sport.

Forty-five patients (91.8%) had no pain or slight pain after intense strain of their feet. Four patients felt slight pain after walking or standing for a longer time.

Forty-five patients (91.8%) and their parents declared they were satisfied with the treatment and its outcome.

DISCUSSION

One of the most frequently applied surgical techniques in clubfoot treatment was a posteromedial release with Kirschner wire fixation as carried out by Turco [1,2]. By applying Turco's modified arthrolysis1, Bohne achieved "best results" in 18% of the patients and "good results" in 50% [20]. Using a modified Turco method, Singh and Vaishnavi described "good and excellent results" in 82% (27 of 33 feet) after a mean follow-up of 13.8 years (10-16 years) [21].

A complete subtalar release was often performed. Simons saw the highest percentage of successful corrections, above all in the hind foot area, as the main benefit of this method [5,6]. The greatest disadvantage in his opinion is the tendency towards over-correction. Simons' clinical investigation showed "satisfying results" in 72% (19 cases) of patients with complete subtalar release [5,6]. A comparison of pre- and postoperative radiographs showed that complete subtalar release allowed a significantly better reduction of the equinus and varus position as well as talonavicular subluxation.

Hudson and Catterall postulated that not all patients require a radical release-operation [9]. They achieved "satisfactory results" with a single posterolateral release in 46% of their patients.

Reichel et al achieved "good and excellent results" in 79.9% of surgically treated clubfeet using posteroplantar release in 93 patients with a mean follow-up of 7 years. [22]. The main problem was residual forefoot adduction in 17 feet of 15 patients.

With various procedures depending on the patients' age and the state of the deformity after the primary treatment, Grill achieved "normal" results in 8%, "good" in 76%, and "not satisfactory" in 16% of the patients [7]. The operative techniques used by Grill included complete subtalar medial and lateral release, dorsal release, lengthening of the Achilles tendon with dorsal capsulotomy and other combined approaches [7]. He regarded the foot's rigidity and the lack of strength during repulsion in tiptoe walking as the main causes of the unsatisfactory results.

In long-term follow-up, 30 years on average, Dobbs et al.23 found a significant functional impairment of patients with extensive soft-tissue release. They postulate that extensive surgery with repeated soft-tissue release leads to increased ankle stiffness and painful foot, increased osteoarthritis in the foot and ankle and increased gastrocnemius weakness. Dobbs et al.23 concluded that the results obtained with extensive soft-tissue release deteriorate with time.

As a rule the various release steps have to be adapted to the severity of the deformity [8,10,16,24, 25]. The extensive release operations have increasingly led to over-correction and ankle stiffness whereas less extensive operation methods, among them the Imhäuser method, often achieved too little readjustment [7,17,27].

Cooper and Dietz achieved 78% "good and excellent results" with the Ponseti method in long-term follow-up (25-42 years) [28]. Morcuende et al. reported a 95% rate of good correction with the Ponseti method without the need for extensive surgery [14]. The average age at the final follow-up was 26 months (6 months to 8 years). In some studies long-term results are missing [13,29,30,31,32]. Nowadays it is not predictable how far secondary operations become necessary when using the Ponseti method. The most common factors related to the risk of recurrence are non-compliance with the use of the orthoses and the educational level of the parents (high-school or less) [33,34].

Some of the most important problems in the treatment of clubfoot according to Imhäuser in our study were residual forefoot adduction and restriction of mobility in the upper ankle joint (especially in dorsiflexion). Residual forefoot adduction is a frequent problem in posterior release, caused mostly by residual talonavicular subluxation [22]. The correction of the talocalcaneonavicular malposition is decisive in surgical treatment of idiopathic clubfoot [35].

The range of motion of the lower ankle joint was much better than the mobility of the upper ankle joint.

The relatively small postoperative correction of the sagittal and dorsoplantar talocalcaneal angle indicates incomplete subtalar correction, which might possibly favour later development of a relapse.

Our analysis of antero-posterior and lateral radiographs showed that, despite unsatisfactory X-ray findings, clinical correction and mobility were good. A normal-looking, painless, plantigrade foot with good function could be compatible with a medial dislocation of the navicular and a pathological talocalcaneal angle. Singh and Vaishnavi found the best clinical and radiological correlation with the dorsoplantar talometatarsal I angle and the poorest with the dorsoplantar talocalcaneal angle [21]. Vitale et al showed that the radiographic measures did not reflect patient-based outcomes after clubfoot surgery [36].

One has to assume that the structural pathological alterations and malpositions of the tarsal skeleton are not completely reducible with lengthening of the Achilles tendon and posterior capsulolysis according to Imhäuser in many cases. Thus a "normal" foot cannot be expected.

Friedman and de Almeida Fialho found a significant correlation between the talometatarsal I, the cal-

caneal-metatarsal II and calcaneal-metatarsal V angles in a dorsoplantar X-ray view and the clinical outcome after surgery in congenital clubfoot [37]. The sagittal and dorsoplantar talocalcaneal angles, the talocalcaneal index and the sagittal calcaneal-metatarsal I angle did not show significant association with the functional results [37].

The treatment results in idiopathic clubfoot seem to be dependent predominantly on the severity of the deformity and not on the therapeutic procedure. A comparison of different procedures and their results shows that even a uniform treatment scheme can lead to different outcomes. The success rate of all practised methods, from gentle or tough manual redressement to plaster cast treatment, medial, posterior or lateral release, to diverse osteotomies and arthrodeses, is always more or less limited and none is able to guarantee a complete anatomical correction [10,38].

A connection between the beginning of treatment and the emergence of relapses necessitating surgery could not be observed in our study. Furthermore obtaining an axially aligned pes equinus did not play a decisive role as regards the occurrence of relapses. In most patients operated on several times, an axially adapted pes equinus was documented after the initial redressing plaster cast treatment. Likewise the first clubfoot operation of most patients took place before the 41st week of life. Although beginning treatment immediately after birth is one of the most important principles of clubfoot treatment and one unanimously postulated by all authors, it is obviously not only the only factor influencing the clinical course. Even though we strictly followed the therapeutic scheme, we did not succeed in preventing relapses. Thirty-four patients (44%) had to be operated on again due to a relapse.

However, our investigation shows that there is a correlation between a late onset of walking and the risk of a relapse necessitating an operation.

Rigid congenital clubfeet, however, require additional extended peritalar releases. The operative approach in clubfoot should be individually adapted to the severity of the deformity, to the anatomical structures which contribute to each component of the deformity and to the clinical course [10]. At present there are no universally accepted criteria for the use of the various surgical techniques. The objective of clubfoot treatment should generally be successful correction through minimal surgical release, if possible, by one single operation.

CONCLUSIONS

1. Important problems in the treatment of clubfoot according to Imhäuser in our study were residual forefoot adduction and restriction of mobility in the upper ankle joint (especially in dorsiflexion).
2. Our analysis of radiographs showed that good clinical correction and function and normal-looking, painless, plantigrade foot could be compatible with unsatisfactory X-ray findings.
3. The structural pathological alterations and malpositions of the tarsal skeleton are not completely reducible with lengthening of the Achilles tendon and posterior capsulolysis according to Imhäuser in many cases.
4. Obtaining an axially aligned pes equinus after the initial redressing plaster cast treatment does not appear to be decisive as regards the occurrence of relapses.
5. A statistically significant correlation was found between a delayed onset of walking and the risk of revision surgery due to a relapse of the deformity.
6. A comparison of different procedures and their results showed that the treatment results in idiopathic clubfoot seem to be dependent predominantly on the severity of the deformity rather than the therapeutic procedure.
7. The treatment in clubfoot should be individually adapted to the severity of the deformity.

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