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Long-term follow-up of patients with clubfeet treated with extensive soft-tissue release

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Long-Term Follow-up of Patients with Clubfeet Treated with Extensive Soft-Tissue Release

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Background: Although long-term follow-up studies have shown favorable results, in terms of foot function, after treatment of idiopathic clubfoot with serial manipulations and casts, we know of no long-term follow-up studies of patients in whom clubfoot was treated with an extensive surgical soft-tissue release.

Methods: Forty-five patients (seventy-three feet) in whom idiopathic clubfoot was treated with either a posterior release and plantar fasciotomy (eight patients) or an extensive combined posterior, medial, and lateral release (thirty-seven patients) were followed for a mean of thirty years. Patients were evaluated with detailed examination of the lower extremities, a radiographic evaluation that included grading of osteoarthritis, and three independent quality-of-life questionnaires, including the Short Form-36 Medical Outcomes Study.

Results: At the time of follow-up, the majority of patients in both treatment groups had significant limitation of foot function, which was consistent across the three independent quality-of-life questionnaires. No significant difference between groups was noted with regard to the results of the quality-of-life measures, the range of motion of the ankle or the position of the heel, or the radiographic findings. Six patients who had been treated with only one surgical procedure had better ranges of motion of the ankle and subtalar joints ($p < 0.004$) than those who had had multiple surgical procedures.

Conclusions: Many patients with clubfoot treated with an extensive soft-tissue release have poor long-term foot function. We found a correlation between the extent of the soft-tissue release and the degree of functional impairment. Repeated soft-tissue releases can result in a stiff, painful, and arthritic foot and significantly impaired quality of life.

Level of Evidence: Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.

Idiopathic congenital talipes equinovarus (clubfoot) is a common complex deformity that occurs in approximately one or two per 1000 newborns[1]. Treatment of clubfoot has been controversial because initial correction of the deformity can be attained with both primarily nonsurgical and surgical methods[2-15]. The long-term goal of treatment is a functional, pain-free, plantigrade foot with good mobility, without calluses, and without the need for shoe-wear modification[12,14].

Many investigators have reported short-term success, in terms of correction of clubfoot, with use of the Ponseti method of treatment with serial manipulations and casts[15-17]. In addition, good foot function was reported more than twenty-five years after the treatment of clubfeet by Ponseti[12,14]. As a result of these reports, the number of children undergoing extensive surgical soft-tissue releases has decreased. However, extensive soft-tissue releases are often performed when the results of the Ponseti method are inadequate, in children with resistant clubfoot, or because of recurrence secondary to poor compliance with bracing[16].

Extensive soft-tissue releases frequently provide definitive correction[8,18-24], but they may have short-term complications and up to 47% of patients need additional surgery[16,25-30]. Reported long-term complications include stiffness of the ankle and subtalar joints[13,31,32], arthritis[13], muscle weakness[13,31], pain[13], and residual deformity[13,31,32]. However, in most long-term follow-up studies of clubfeet treated with an extensive soft-tissue release, patients were followed into their teens[12-14,31-34], which may be inadequate to assess foot function into adulthood[14]. The purpose of this study was to determine the long-term results, at a minimum of twenty-five years, in a group of patients in whom idiopathic clubfoot had been treated with an extensive soft-tissue release in infancy.

Materials and Methods

The present study was performed with the approval of our institution's human subjects review board, and all participants signed an approved informed-consent form.

A computer-generated search identified eighty-two pa-

tients who had been treated for a clubfoot deformity at St. Louis Shriners Hospital for Children between 1972 and 1979. Seventy-five patients had an extensive soft-tissue release, with thirteen of them having an extensive posterior release and sixty-two having an extensive combined posterior, medial, and lateral release. The remaining seven patients had initially been treated elsewhere and were managed at our institution with salvage procedures; they were not included in this study. Of the seventy-five patients who had a complete soft-tissue release at our institution, sixty-two met the inclusion criteria for this study. The others were excluded because the clubfoot was associated with a syndrome or a neuromuscular condition or because they were older than two years of age at the time of the initial surgery. All patients underwent surgical treatment only after the treating surgeon had determined that application of serial casts had not adequately corrected the clubfoot deformity.

The patients identified with the computer-generated search were located with use of information in their medical records, with use of the state Department of Motor Vehicles registry, and by means of a contract with a private search service (ChoicePoint, McLean, Virginia). Of the sixty-two patients who met the inclusion criteria, fifty-three were located. Of these fifty-three patients, three refused to participate in the study and five were willing to participate but were not evaluated because of time or financial constraints. The remaining forty-five patients (with a total of seventy-three clubfeet) made up the study group, a 73% rate of follow-up. Thirty-one patients were male, and fourteen were female. The clubfoot was bilateral in twenty-eight patients and unilateral in seventeen. The patients were divided into two groups on the basis of the extent of the initial clubfoot release. Eight patients had an extensive posterior release and plantar fasciotomy (group 1), and thirty-seven patients had an extensive subtalar, posterior, medial, and lateral release (group 2).

Information gathered from the medical records included demographic data (including the sex of the patient), laterality of the clubfoot, age at initiation of treatment, duration of cast treatment before the surgery, age at the time of surgery, duration of cast treatment after the surgery, and details of the initial and subsequent surgical procedures. In addition, we obtained information from the charts of the seventeen patients who were lost to follow-up or would or could not return for the final evaluation in this study so that we could determine whether their postoperative course differed from that of the patients who did participate in this study.

Treatment Method

The first group of eight patients (thirteen clubfeet), treated in the early part of this series (between 1972 and 1974), underwent an extensive posterior release and plantar fasciotomy after four to six months of cast treatment with the Kite method[35] had failed to achieve a complete correction. Postoperatively, these patients were treated with three to four months of immobilization in a long leg plaster cast followed by the use of a hinged ankle-foot orthosis with a plantar flexion stop at neutral for several years. Recurrent deformities were treated with repeat manipulations and application of long leg plaster casts followed by a repeat posterior release when necessary to correct the equinus. Residual deformities were managed with a variety of surgical procedures, including a calcaneal slide osteotomy, distal tibial physeal stapling, tendon transfers, and fusion procedures.

The second group of thirty-seven patients (sixty clubfeet) were treated with an extensive combined subtalar, posterior, medial, and lateral release[5,36] after three to four months of manipulations and applications of casts as described by Kite[35] failed to achieve complete correction. The complete soft-tissue release, based on the procedure described by Turco[36], involved extensive dissection of the posterior, medial, and lateral portions of the foot. The posterior release included (1) Achilles tendon lengthening; (2) release of the posterior ankle and subtalar joints, including the posterior talofibular ligament; (3) release of the thickened peroneal retinaculum and tendon sheaths; and (4) lengthening of the tendons of the flexor digitorum longus and flexor hallucis longus. The medial release included (1) lengthening of the tibialis posterior tendon, (2) talonavicular joint capsulotomy, (3) recession of the abductor hallucis tendon, (4) release of the medial and plantar surfaces of the calcaneocuboid joint (in twenty-nine feet), (5) release of the medial aspect of the subtalar joint, and (6) release of the interosseous ligament. The lateral release involved the release of the lateral aspect of the subtalar joint and the calcaneofibular ligament. A plantar release, if performed, was done through a separate skin incision. In addition, the talocalcaneal interosseous ligament was released completely in all but four feet. A single smooth Kirschner wire was used to transfix the talonavicular joint and was removed at an average of six weeks. Postoperatively, the limb was immobilized for four months in a long leg plaster cast, which was changed every two to four weeks. The patient then wore a hinged ankle-foot orthosis for two to four years. The ankle-foot orthosis had a plantar flexion stop at neutral but allowed free ankle dorsiflexion. Recurrent deformities were treated with a second medial or posteromedial release as indicated. Again, residual deformities were treated with a variety of surgical procedures, including a calcaneal slide osteotomy, distal tibial physeal stapling, tendon transfers, and fusion procedures.

Three patients (four clubfeet) in group 1 and three patients (five clubfeet) in group 2 had had only one surgical procedure on the feet at the time of the latest follow-up. These patients were analyzed as a separate group and then were compared with the rest of the patients in the series, who had had more than one major surgical procedure on the feet.

Self-Reported Questionnaires

The results of treatment were evaluated with use of the 100-point system of Laaveg and Ponseti[12]. A score of 90 to 100 points was rated as excellent; 80 to 89 points, as good; 70 to 79 points, as fair; and <70 points, as poor. All patients also completed the Foot Function Index, which is a validated and reliable visual analog scale for measuring limitation of activity,

pain, and disability[37,38]. In addition, the Short Form-36 Medical Outcomes Study (SF-36 MOS, version 2.0)[39] was administered to all patients at the time of final follow-up. This thirty-six-question generic health outcomes measure is useful for comparing the relative burdens of disease in populations and the health benefits of different treatments. The physical component summary score is based on twenty-one questions, and the mental component summary score is based on fifteen questions. In version 2.0 of the SF-36, the scoring system was normalized to a mean of 50 points with a standard deviation of 10 points in the general population of the United States. Norm-based scoring facilitates comparisons between populations[40]. The reliability, internal consistency, responsiveness, construct validity, discriminant validity, and convergent validity of this test have all been supported[41].

Clinical Evaluation

At the time of the latest follow-up (at a minimum of twenty-five years after the index procedure), all subjects were interviewed about pain in, and overall function of, the lower extremities and all had a physical examination of both lower extremities. The clinical examination included assessment of the patient's height and weight, limb lengths (measured from the anterior superior iliac spine to the medial malleolus), circumference of the calves (in centimeters), and length and width of the feet (in centimeters). The feet were inspected for evidence of calluses and were palpated for areas of tenderness. Gait was observed for limping. A handheld goniometer was used to measure passive dorsiflexion and plantar flexion of the ankle with the knee straight as well as supination and pronation of the forefoot and varus-valgus movement of the heel. The motor strength of the anterior tibialis, posterior tibialis, gastrocnemius-soleus, peroneals, extensor hallucis longus, extensor digitorum communis, flexor hallucis longus, and flexor digitorum longus was evaluated according to the Jones classification as reported by Tachdjian[42]. The patient stood on one foot and performed rapid toe-ups, stopping when he or she had done forty of them or when there was moderate pain or fatigue in the gastrocnemius-soleus. All patients were examined by one of us (M.B.D.).

Radiographic Examination

Radiographs made just prior to the complete soft-tissue release were available for all but two patients. At the time of the latest follow-up (at a minimum of twenty-five years after the index procedure), anteroposterior and lateral radiographs of the affected foot, as well as the contralateral, normal foot when applicable, were made with the patient standing. The anteroposterior talocalcaneal angle, the navicular-first cuneiform angle, the angle between the calcaneus and the fifth metatarsal, and the angle between the long axis of the talus and the first metatarsal were measured on the anteroposterior radiographs[43]. The lateral talocalcaneal angle, the angle between the long axis of the talus and the first metatarsal, the angle between the first and fifth metatarsals, and the distance between the tip of the medial malleolus and the navicular were measured on the lateral radiographs[43,44]. All radiographic angles were measured by one of us (M.B.D.). Osteoarthritic changes of the tarsal joints were graded, according to the system of Kellgren[45,46], by two musculoskeletal radiologists, who performed the measurements simultaneously and reached a consensus regarding each one. All of the radiographic measurements were compared between the seventy-three clubfeet and the seventeen unaffected feet.

Statistical Methods

Continuous data are expressed as the mean and standard deviation. Differences between the treatment groups with regard to the radiographic data and the responses to the functional questionnaires were analyzed with use of a paired t test. Unpaired t tests were used to compare the SF-36 scores in our cohort with published normative values in the United States[47] and to compare the functional scores in our cohort with those in two other groups of patients with clubfoot reported on in the literature[12,14]. Spearman coefficients were used to determine significant relationships between variables. For all statistical analyses, a p value of <0.05 was considered to be significant.

Results

The mean duration of follow-up was thirty-one years (range, thirty to thirty-two years) in the first group of eight patients (thirteen feet) and twenty-eight years (range, twenty-five to twenty-nine years) in the second group of thirty-seven patients (sixty feet). The mean age at the time of the initial surgical procedure was thirteen months (range, twelve to fifteen months) in the first group and seven months (range, six to nine months) in the second group. The mean duration of cast treatment before the surgery was four months (range, one to six months) in both groups.

Of the forty-five patients, thirty-nine (five of the eight patients in group 1 and thirty-four of the thirty-seven patients in group 2) had additional surgical procedures on the clubfeet by the time of the latest follow-up. Most of the additional surgical procedures were performed in adolescence or early adulthood, which indicates that the initial correction of the clubfoot deformities was satisfactory. The additional surgical procedures in group 1 included a medial soft-tissue release (one foot) and a second posterior release (five feet). In group 2, the additional surgical procedures included a second extensive posterior, medial, and lateral soft-tissue release (thirteen feet); a third extensive posterior, medial, and lateral soft-tissue release (four feet); a second medial soft-tissue release (eight feet); a second posterior release (four feet); distal tibial stapling and/or a calcaneal slide osteotomy (seventeen feet); transfer of the tibialis anterior tendon to the dorsum of the foot (three feet); and irrigation and débridement because of wound infection (two feet). In addition, one foot in group 1 and four feet in group 2 had fusion procedures because of painful arthritis in the tarsal joints; these procedures included two talonavicular fusions, two triple arthrodeses, and one subtalar arthrodesis (Figs. 1-A and 1-B).

There was no significant difference between groups 1 and 2 with regard to the results of the questionnaires ($p >$

TABLE I Laaveg-Ponseti Functional Scores for Patients Treated with Extensive Soft-Tissue Release in Current Study Compared with Scores for Patients Treated with Ponseti Method in Study by Laaveg and Ponseti[12]

	Study by Laaveg and Ponseti (104 Clubfeet)	Current Study (73 Clubfeet)	P Value
Mean score and standard deviation	87.5 ± 11.7 points	65.3 ± 10.6 points	<0.001
Excellent result (90-100 points)	56 feet (54%)	0 feet (0%)	<0.001
Good result (80-89 points)	21 feet (20%)	24 feet (33%)	<0.001
Fair result (70-79 points)	15 feet (14%)	15 feet (20%)	<0.125
Poor result (<70 points)	12 feet (12%)	34 feet (47%)	<0.001

0.68), ankle range of motion or heel position ($p > 0.73$), or radiographic findings ($p > 0.45$). For that reason, the treatment groups were combined for the statistical analyses of the remainder of the reported results.

A review of the charts at the time of the last clinical evaluation of the seventeen patients who met the inclusion criteria but did not participate in the study revealed no difference, with the numbers available, between those patients and the patients who were included in this study in terms of age at the time of the initial surgery ($p > 0.67$), duration of cast treatment before the surgery ($p > 0.72$), or number of subsequent operations ($p > 0.94$).

Questionnaires

According to the Laaveg-Ponseti scale, the mean functional score for the seventy-three clubfeet in the series was 65.3 ± 10.6 points (range, 30 to 82 points). No foot had an excellent result, twenty-four feet had a good result, fifteen had a fair result, and thirty-four had a poor result. Fifty feet were occasionally painful during daily activities, sixty-two feet were painful after strenuous activities, and thirty-six were painful during walking. The patients in this study had significantly lower functional scores than did similar cohorts of patients with clubfoot who had been treated with the Ponseti method and followed for similar durations[12,14] ($p < 0.001$) (Tables I and II). The six patients in our study who had had only one surgical procedure by the time of the latest follow-up had a mean functional score of 78.4 ± 3.5 points (range, 65 to 82 points). This score was significantly better ($p < 0.005$) than the score (64.8 ± 2.4 points) for the patients who had had more than one surgical procedure.

As measured with the Foot Function Index, overall activity limitation was more severe on the clubfoot side than on the contralateral, normal side (mean, 21 compared with 8 points; $p < 0.0001$). There was also more overall foot pain (mean, 30 compared with 12 points; $p < 0.0001$) and more overall foot disability (mean, 34 compared with 13 points; $p < 0.0001$) on the clubfoot side. The patients' responses to direct queries from the examiner about pain in the ankle, subtalar, and midfoot regions revealed significantly more pain on the clubfoot side than on the contralateral, normal side ($p < 0.0001$). The mean scores for activity limitation, overall foot pain, and overall foot disability did not differ significantly between the patients with bilateral clubfoot and those with unilateral clubfoot.

The mean SF-36 scores for each of the eight domains tested as well as the physical and mental component summary scores for the forty-five patients at the time of the latest follow-up are shown in Table III. The mean physical component summary score was nearly two standard deviations below the

Fig. 1-A

Fig. 1-B

Figs. 1-A and 1-B Clinical photographs of a thirty-year-old patient who underwent an extensive soft-tissue release for the treatment of a right-sided clubfoot deformity at one year of age. At the age of fifteen years, the patient had a subtalar arthrodesis because of a painful residual hindfoot deformity.

TABLE II Results, According to Modified Laaveg-Ponseti Functional Scale, for Patients Treated with Extensive Soft-Tissue Release in Current Study Compared with Results for Patients Treated with Ponseti Method in Study by Cooper and Dietz[14]

	Study by Cooper and Dietz (45 Patients)	Current Study (45 Patients)	P Value
Excellent result	28 patients (62%)	2 patients (4%)	0.001
Good result	7 patients (16%)	10 patients (22%)	0.145
Fair/poor result	10 patients (22%)	33 patients (73%)	0.005

average normal population value, but the mean mental component summary score was similar to the value for the normal population. The physical component summary score for our cohort was similar to that reported for patients with several other major medical conditions[47-56] (Table IV). The physical component summary scores for the six patients in our study who had had only one surgical procedure were consistently higher ($p < 0.003$) than the scores for the patients who had had more than one surgical procedure, but they were still lower than the age-based norms. The mental component summary scores did not differ between the patients treated with one surgical procedure and those treated with multiple procedures. The findings on the SF-36 were similar to those on the Foot Function Index. As patients became more limited with regard to their participation in vigorous activities, their scores for overall activity limitation ($r = 0.59$, $p = 0.002$) and foot disability ($r = 0.60$, $p = 0.005$) increased. Similarly, as patients became more limited with regard to their ability to walk >1 mi (1.6 km), their scores for overall activity limitation ($r = 0.58$, $p = 0.004$) and foot disability ($r = 0.56$, $p = 0.005$) increased.

Findings on Clinical Examination

On the average, there was no difference in the length of the lower extremity with the clubfoot and the length of the normal, contralateral extremity in the seventeen patients who had a unilateral clubfoot. The circumference of the calf was on the average 3 cm smaller on the involved side, and the clubfoot was on the average 1 cm shorter and 0.7 cm narrower than the uninvolved foot.

Forty-nine clubfeet were associated with tenderness to palpation around the ankle joint, in the sinus tarsi, or under the metatarsal heads. Nineteen (42%) of the forty-five patients walked with a limp. Ankle dorsiflexion and plantar flexion averaged 4.2° ± 5.0° and 15.9° ± 12.3°, respectively, in association with the clubfeet treated with more than one surgical procedure; 8.3° ± 5.4° and 20.4° ± 5.2° in association with the clubfeet treated with one surgical procedure; and 16.2° ± 4.5° and 40.3° ± 6.1° in association with the normal feet. The mean varus-valgus movement of the heel and supination-pronation of the forefoot measured 8.1° ± 3.9° and 24.3° ± 7.7°, respectively, in the clubfeet treated with more than one surgical procedure; 15.4° ± 4.9° and 41.4° ± 4.7° in the clubfeet treated with one surgical procedure; and 37.9° ± 8.1° and 65.3° ± 10.5° in the normal feet. Each of the above angular measurements differed significantly between the limbs with the clubfeet and the normal limbs ($p < 0.0001$ for all) as well as between the clubfeet treated with one surgical procedure and those treated with more than one surgical procedure ($p < 0.004$ for all). Nineteen patients were unable to walk on their toes, and twenty-one were unable to walk on their heels. The muscles were weaker than normal in sixty-two of the seventy-three limbs. Most significant was gastrocnemius-soleus weakness, which was noted in fifty-nine limbs. The patients treated with only one surgical procedure had significantly less gastrocnemius-soleus weakness (mean grade of 5) than did those treated with more than one posterior release (mean grade of 3, $p < 0.005$). Thirty-one of the forty-five patients were unable to do forty rapid toe-ups on the affected side. In contrast, all were able to do forty toe-ups on the normal side.

Radiographic Results

The radiographs made at the time of the last follow-up showed several differences between the clubfeet and the contralateral, normal feet (Table V). The mean distance between the tip of the medial malleolus and the navicular tuberosity was smaller in

TABLE III SF-36 Scores for Patients with Clubfoot in Current Study (N = 45) Compared with Norm-Based Scores

SF-36 Scale	Score for Patients with Clubfoot* *(points)*	P Value†
Physical functioning	32.95 ± 10.05	<0.001
Role physical	33.86 ± 8.75	<0.001
Bodily pain	34.91 ± 9.23	<0.001
General health	38.23 ± 10.56	<0.005
Vitality	37.59 ± 9.92	<0.001
Social functioning	40.57 ± 8.44	<0.005
Role emotional	47.39 ± 21.54	0.8
Mental health	47.27 ± 21.82	0.9
Physical component summary	33.65 ± 8.45	<0.001
Mental component summary	47.34 ± 7.43	0.8

*The values are given as the mean and standard deviation. †The p values, calculated with unpaired t tests, are for the difference between the scores for the patients with clubfoot and the published norms in the general United States population. The mean score for each category in the general United States population is 50 ± 10 points.

Fig. 2-A

Figs. 2-A, 2-B, and 2-C Radiographs of a twenty-nine-year-old man who underwent extensive soft-tissue releases for the treatment of bilateral clubfoot when he was an infant. This patient had one of the best radiographic results in the series. **Fig. 2-A** Standing anteroposterior radiograph of both feet, revealing bilateral forefoot adduction, a moderate lateral shift of the cuneiforms, and residual hindfoot varus deformities.

the clubfeet than it was in the normal feet. Compared with the normal feet, the clubfeet had decreased anteroposterior and lateral talocalcaneal angles, indicating residual heel varus; an increased lateral talus-first metatarsal angle and first-fifth metatarsal angle, indicating residual cavus deformity (Figs. 2-A, 2-B, and 2-C); and a decreased navicular-first cuneiform angle, indicating that the cuneiforms were shifted more laterally. The anteroposterior talus-first metatarsal angle and the calcaneus-fifth

Fig. 2-B

Fig. 2-C

Figs. 2-B and 2-C Lateral radiographs of both feet, revealing moderate navicular wedging and dorsal navicular subluxation.

Fig. 3-A

Figs. 3-A and 3-B Standing lateral radiographs of the right foot of the patient shown in Figure 1.
Fig. 3-A Radiograph made when the patient was eleven years of age, demonstrating moderate osteoarthritic changes in the subtalar and talonavicular joints.

metatarsal angle in the clubfeet reflected residual forefoot adduction. There were no significant differences in any of the measured radiographic angles between the clubfeet that had been treated with one surgical procedure and those treated with more than one surgical procedure.

The radiographic grade of osteoarthritis, according to the system of Kellgren[46], was consistently higher for each joint of the clubfoot in which it was measured than it was for the same joint of the uninvolved foot (Table VI). The joints that were significantly more degenerated in the surgically treated clubfeet than in the normal feet included, in rank order from the most involved to the least involved, the talonavicular ($p < 0.0001$), calcaneocuboid ($p < 0.0001$), subtalar ($p < 0.0004$), naviculocuneiform ($p < 0.0003$), and tibiotalar ($p < 0.0002$) joints (Figs 3-A and 3-B). In the seventy-three clubfeet, forty-one talonavicular, thirty-two calcaneocuboid, thirty subtalar, twenty-four naviculocuneiform, and eighteen tibiotalar joints had moderate or severe osteoarthritis (Table VI).

There was no significant difference with respect to the level of osteoarthritis (mean Kellgren grade) in any of the joints

Fig. 3-B

Radiograph made when the patient was thirty years of age, fifteen years after a subtalar arthrodesis was performed to treat continued pain in the hindfoot.

TABLE IV Mean SF-36 Physical and Mental Component Summary Scores for Selected Chronic Health Conditions

Disease/Condition	No. of Subjects	Physical Component Summary Score*	Mental Component Summary Score*
Surgically treated clubfoot (current study)	45	33.7	47.3
Cervical spine pain and radiculopathy[56]	1809	33.6	44.8
Parkinson disease[55]	14530	30.1	39.4
Hemodialysis[49]	14815	31.6 ± 9.8	46.0 ± 11.3
Preop. coronary artery bypass graft surgery[51]	1744	32.9 ± 9.1	44.2 ± 11.8
Chronic heart failure[54]	30	32.8 ± 8.8	46.6 ± 12

*The values are given as the mean and standard deviation.

measured between the clubfeet treated with one surgical procedure and those treated with more than one surgical procedure. However, patients treated with an extensive posterior soft-tissue release alone had significantly less osteoarthritis in all of the joints in which it was measured than did the patients treated with an extensive subtalar, posterior, medial, and lateral soft-tissue release ($p < 0.003$ for all comparisons) with the exception of the ankle joint, in which the grade of osteoarthritis was the same in the two groups.

Correlations Between Foot Function Index and Kellgren and Moore Radiographic Scores

Separate subsections of the Foot Function Index were used to determine whether each domain was associated with the radiographic findings. Activity limitation correlated significantly with the Kellgren and Moore grades of osteoarthritis of the talonavicular ($r = 0.64$, $p = 0.0006$), calcaneocuboid ($r = 0.54$, $p = 0.0001$), and subtalar ($r = 0.51$, $p = 0.0004$) joints in the clubfeet. Foot disability correlated significantly with the Kellgren and Moore grade of osteoarthritis of the talonavicular joint ($r = 0.53$, $p = 0.003$) in the clubfeet. Foot pain correlated significantly with the Kellgren and Moore grades of osteoarthritis of the talonavicular ($r = 0.62$, $p = 0.0002$) and subtalar ($r = 0.57$, $p = 0.003$) joints in the clubfeet.

Discussion

Using three independent quality-of-life scales, we found significant impairment of physical function at the time of long-term follow-up of patients in whom clubfoot had been treated with an extensive soft-tissue release. In fact, although the patients were evaluated at an average of thirty years after the corrective surgery, the impact of these changes over a patient's lifetime may be underestimated. This may be particularly the case for patients who have radiographic evidence of arthritis in the foot and ankle but are not currently symptomatic.

Many previous studies of clubfeet treated with an extensive soft-tissue release showed good early results, but the follow-up in those studies was limited and in no series were the patients followed into adulthood[4,5,7,8,13,19,31,32,57-60]. The few studies in which patients were followed to skeletal maturity showed that the early results obtained with an extensive soft-tissue release deteriorate with time[13,31,32], indicating that longer follow-up is necessary to evaluate the lifelong function of a surgically treated clubfoot. Ippolito et al.[13] found that patients in whom

TABLE V Comparison of Radiographic Scores Between Affected and Normal Sides in Patients with Clubfoot in Current Series*

	Clubfeet† (N = 73)	Normal Feet† (N = 17)	P Value‡
Anteroposterior talocalcaneal angle	12.77 ± 7.24	14.00 ± 2.32	0.54
Anteroposterior calcaneus-fifth metatarsal angle	10.32 ± 7.70	–1.43 ± 1.55	<0.0001
Anteroposterior talus-first metatarsal angle	15.95 ± 11.83	0.07 ± 1.21	<0.0001
Anteroposterior navicular-first cuneiform angle	–13.5 ± 9.96	1.14 ± 0.86	<0.0001
Angle between tip of medial malleolus and navicular on lateral radiograph	12.77 ± 6.60	2.64 ± 0.93	<0.0001
Lateral talocalcaneal angle	23.32 ± 6.59	41.57 ± 1.91	<0.0001
Lateral talus-first metatarsal angle	7.68 ± 15.80	1.21 ± 1.19	0.14
Lateral first-fifth metatarsal angle	18.09 ± 11.67	14.07 ± 1.69	0.21

*When the clubfoot was bilateral, one side was randomly selected. †The values are given, in degrees, as the mean and standard deviation. ‡P values were calculated with paired t tests.

TABLE VI Grades of Osteoarthritis, According to System of Kellgren[45,46], in Current Series

Joint	No. of Feet with Moderate or Severe Osteoarthritis (Grade 4 or 5)	No. of Feet with No, Doubtful, or Minimal Osteoarthritis (Grade 1, 2, or 3)
Clubfeet (n = 73)		
Subtalar	30 (41%)	43 (59%)
Talonavicular	41 (56%)	32 (44%)
Calcaneocuboid	32 (44%)	41 (56%)
Naviculocuneiform	24 (33%)	49 (67%)
Tibiotalar	18 (25%)	55 (75%)
First metatarsophalangeal	3 (4%)	70 (96%)
Lesser metatarsophalangeal joints	1 (1%)	72 (99%)
Normal feet (n = 17)		
Subtalar	0 (0%)	17 (100%)
Talonavicular	1 (6%)	16 (94%)
Calcaneocuboid	0 (0%)	17 (100%)
Naviculocuneiform	0 (0%)	17 (100%)
Tibiotalar	0 (0%)	17 (100%)
First metatarsophalangeal	1 (6%)	16 (94%)
Lesser metatarsophalangeal joints	0 (0%)	17 (100%)

clubfoot had been treated with a more extensive soft-tissue release surgery functioned less well at skeletal maturity than did those treated with the Ponseti method of manipulation and casts. Unsatisfactory results were attributed to increased osteoarthritis in the foot and ankle, increased ankle stiffness, and increased gastrocnemius weakness in the patients treated with the more extensive surgery.

Direct comparisons of our surgically treated patients with patients treated by Ponseti, as reported in previous studies[12,14], demonstrated significantly fewer excellent or good outcomes in our surgically treated group (Tables I and II). In 1980, Laaveg and Ponseti[12] reviewed the cases of patients who had been followed for an average of nineteen years after treatment by Ponseti. In 1995, Cooper and Dietz[14] reported, after an average duration of follow-up of thirty-four years, the results in the same cohort of patients treated by Ponseti. Using a modification of the functional scale described by Laaveg and Ponseti, they found that thirty-five (78%) of forty-five patients had an excellent or good outcome. According to the same functional scale, only twelve (27%) of our forty-five surgically treated patients had an excellent or good outcome at an average of thirty years postoperatively.

Radiographic evidence of degenerative changes in the foot and ankle have been noted in patients with clubfoot who were followed to skeletal maturity after having been treated with either primary cast immobilization or an extensive soft-tissue release[13,14,61]. We found moderate-to-severe osteoarthritic changes in 56% of our surgically treated patients, whereas Cooper and Dietz[14] noted only mild degenerative changes in 35% of clubfeet treated with the Ponseti method and followed for an average of thirty-four years. Ippolito et al.[13] noted degenerative changes in 40% of patients treated with an extensive soft-tissue release and followed for an average of twenty-five years, although the degree of degenerative changes was not noted.

The long-term physical impact of an extensive soft-tissue release in a clubfoot was borne out by the results of the SF-36 questionnaire. To our knowledge, we were the first to use a well-recognized health outcomes measurement tool to evaluate the overall quality of life of patients who had undergone an extensive soft-tissue release for the treatment of clubfoot. In our cohort, the physical component summary score was, on the average, almost two standard deviations below that of the normal population of the United States. Perhaps even more surprising, the mean physical component summary score for our patients in whom clubfoot was treated with extensive soft-tissue release was equivalent to or worse than those of patients with end-stage kidney disease[49], congestive heart failure[54], or cervical spine pain and radiculopathy[56]. Changes in the mental component summary score were negligible in our study, as they were for patients with the other conditions, suggesting that the main effect of the clubfoot procedure is a profound impact on the patient's sense of physical well-being.

We also found that patients who had been treated with only one major surgical procedure on the clubfoot had, by the time of the latest follow-up, a better range of motion of the ankle and subtalar joints, a better functional result, less arthritis in the treated feet, and a better quality of life when compared with the patients who had undergone multiple surgical procedures. The amount and degree of foot and ankle osteoarthritis were more severe in the patients who had had more extensive surgery. These findings suggest a correlation between the extent of the soft-tissue release and the degree of functional impairment, although the number of patients with only one surgical procedure in our study was small.

One limitation of this study is that our surgical technique utilized in the beginning of the study period (i.e., almost thirty-

five years ago) differed significantly from our current standard treatment. In our early surgical experience, we typically released the entire subtalar joint in the manner described by Turco in 1971[36]. We also routinely performed z-plasty lengthening of both the flexor digitorum communis and the flexor hallucis longus tendons. In the patients treated with repeat surgical releases, extensive scarring of those previously lengthened tendons to each other and to the surrounding soft tissues was often noted. This represents our initial experience with this operation for the correction of clubfoot. A reported problem with this operation, which we also noted, was a high rate of excessive internal rotation of the foot and valgus deformity of the hindfoot[5]. In 1979, Turco recommended several modifications to his originally described clubfoot release[5]. Specifically, he recommended a less aggressive release of the talocalcaneal interosseous ligament with transfixion of the subtalar joint to prevent lateral translation of the calcaneus and resultant hindfoot valgus deformity. Other investigators have also emphasized the importance of preserving the talocalcaneal interosseous ligament in preventing hindfoot valgus deformity[9,21]. Using this modified approach, several investigators have reported good short-term results with low early recurrence rates[58,62]. With experience and better understanding of the appropriate surgical techniques, we also have observed similar good short-term results. These early results may translate into improved long-term outcomes if the initial clubfoot correction is maintained and the patients require fewer surgical procedures. Recently, there has been a move by many authors toward an "a la carte" approach to clubfoot surgery, rather than the all-or-nothing approach[8,63,64], in the hopes of minimizing the extent of surgery necessary to achieve correction.

Because the Ponseti technique has become the standard for the treatment of clubfoot, it will be difficult to perform a randomized, controlled trial comparing clubfeet treated with the Ponseti method with those treated with an extensive soft-tissue release. Our patients were treated during a period (1972 to 1979) in which all patients with clubfoot underwent extensive soft-tissue release and no patients were treated with casts alone. The Ponseti method of manipulation and cast immobilization results in initial correction rates of >90%, with very few patients (2.5%) needing an extensive soft-tissue release[15-17]. However, reports on the long-term success of the Ponseti method are limited thus far to those from only a few treatment centers[12-14]. Although short-term success has now been reported at several centers[15,16], longer follow-up will be required to assess whether the Ponseti method can have equivalent results over the long term. Institutions currently vary greatly in terms of the numbers of patients who eventually require soft-tissue release to treat severe and resistant clubfoot deformity or for salvage following recurrence related to poor compliance with bracing[16]. It will also be important to study the long-term results of clubfeet treated with extensive soft-tissue release surgery with modern surgical techniques. To our knowledge, systematic studies have not yet been performed to identify clubfoot deformities that will ultimately require, and benefit from, extensive or selective soft-tissue releases. Because there will probably always be patients with clubfoot deformity who are treated surgically, our data suggest that an operative plan that minimizes frequent or invasive surgical intervention may result in greater long-term success. ■

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