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Background: Long-term follow-up studies of adults who had been treated for congenital clubfoot as infants are rare. The purpose of this study was to review and compare the long-term results in two groups of patients with congenital clubfoot treated with two different techniques. In both groups, treatment was started within the first three weeks of life by manipulation and application of toe-to-groin plaster casts, with a different technique in each group. At the end of the manipulative treatment, a posteromedial release was performed when the patient was between eight and twelve months of age in the first group and a limited posterior release was performed when the patient was between two and four months of age in the second group.

Methods: At the follow-up evaluations, all patients were interviewed and examined, and standing anteroposterior and lateral radiographs and computed tomography scans of the foot were made. The results of treatment were graded according to the system of Laaveg and Ponseti. Numerous angular measurements were made on the radiographs, and the measurements in the two groups were compared.

Results: The first group, which included thirty-two patients (forty-seven clubfeet), was followed until an average age of twenty-five years. The second group, with thirty-two patients (forty-nine clubfeet), was followed until an average age of nineteen years. In the first group, there were two excellent, eighteen good, eleven fair, and sixteen poor results. In the second group, there were eighteen excellent, twenty good, six fair, and five poor results. According to the system of Laaveg and Ponseti, the mean rating in the first group was 74.7 points and that in the second group was 85.4 points.

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

Level of Evidence: Therapeutic study, Level III-2 (retrospective cohort study). See Instructions to Authors for a complete description of levels of evidence.

The treatment of congenital clubfoot continues to be controversial[1-16]. The aim of such treatment has been to obtain a straight, painless, plantigrade, and mobile foot with a normal radiographic appearance. In the past, greater emphasis was placed on operative[1,5,10,16-18] than on manipulative techniques[2,4,6,8,9]. Moreover, the functional long-term outcome of the treatment of clubfoot has not been adequately investigated[19-24].

For many years, treatment of congenital clubfoot at the Department of Orthopaedic Surgery of the University of Rome "La Sapienza" consisted of manipulation with use of a traditional technique adopted in 1934. In cases resistant to manipulation and cast application, either a posterior release or a posteromedial release was performed, depending on the extent of the residual deformity. The results of this treatment were often unsatisfactory, and many feet treated with only a posterior release still had some residual cavovarus and adduction deformity at the time of follow-up. Therefore, a more extensive posteromedial release was performed on all feet that did not respond to several months of manipulation and cast

immobilization. In 1979, the senior author (E.I.) started treating clubfeet with the manipulative technique described by Ponseti and Smoley[6]. In the present study, we report the long-term results of both treatment methods.

Materials and Methods

The patients included in this study had no other congenital anomaly, had had no previous treatment, were less than three weeks old at the onset of treatment, and were examined when their feet were fully mature. All of the clubfeet included in the study were in group III of the classification described by Manes et al.[25,26].

One hundred and nine patients were treated between 1973 and 1977. Of these patients, fifty-six who initially had been treated elsewhere and twelve who had had mild deformities corrected with manipulation and plaster casts alone were excluded from the study. Of the remaining patients who met the inclusion criteria, six were lost to follow-up and three were unable to return for follow-up, leaving thirty-two patients (forty-seven clubfeet) who returned for evaluation. These patients constituted the first group. Twenty-four patients were male, and eight were female. The clubfoot was bilateral in fifteen patients and unilateral in seventeen.

Eighty-four patients were treated between 1979 and 1984. Of these patients, thirty-three who initially had been treated elsewhere and thirteen who had had mild deformities corrected with manipulation and plaster casts alone were excluded from the study. Of the remaining patients who met the inclusion criteria, three were lost to follow-up and three were unable to return for follow-up, leaving thirty-two patients (forty-nine clubfeet) who returned for evaluation. These patients constituted the second group. Twenty-two patients were male, and ten were female. The clubfoot was bilateral in seventeen patients and unilateral in fifteen.

The clubfoot deformity in the first group of patients was manipulated with the technique described by Marino-Zuco[4], and then casts were applied starting around the tenth day of life. The forefoot was abducted and pronated, with counterpressure on the anterior tuberosity of the calcaneus, which was grasped with the other hand. After three months, a gentle correction of the equinus as well as of the varus of the heel was started by exerting a counterpressure on the posterolateral aspect of the lateral malleolus. Feet showing resistance to correction were treated with a posteromedial release, after the application of an average of sixteen toe-to-groin plaster casts with the knee flexed 90°. The operation was performed according to the technique described by Codivilla[1], and later slightly modified by Turco[11], but to avoid scar retraction two incisions were made instead of the one originally described. An aluminum brace extending proximal to the knee was applied at night until the child was three years of age. High-top reverse-last shoes were worn until the age of five years. Feet that relapsed were treated with a second posteromedial release if they were stiff and with a transfer of the anterior tibial tendon to the third cuneiform if they were passively correctable. Plantar fasciotomy was never performed.

In the second group of patients, the foot was manipulated weekly, starting in the first week of life, according to the method described by Ponseti and Smoley[6]. After the application of an average of six toe-to-groin plaster casts, an open heel-cord z-lengthening and a posterior capsulectomy of the ankle joint was performed, instead of the percutaneous heel-cord lengthening recommended by Ponseti and Smoley. An aluminum brace with the knee flexed 90° was worn until the age of four years. Deformities that recurred were treated either with manipulation and plaster cast application for two to three months or with a transfer of the anterior tibial tendon to the third cuneiform and Achilles tendon lengthening when it was necessary to correct the equinus.

The results of treatment were rated with use of the 100-point system of Laaveg and Ponseti[19]. A score of 90 to 100 points was rated excellent; 80 to 89 points, good; 70 to 79 points, fair; and <70 points, poor. Motor strength of the leg muscles was evaluated according to the Jones classification as reported by Tachdjian[27]. The ability to walk on tiptoe and/or on the heels was recorded as well. A handheld goniometer was used to measure passive dorsiflexion of the ankle with the knee straight as well as eversion and inversion of the forefoot and varus-valgus movement of the heel.

Anteroposterior and lateral radiographs of the feet 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 talus and the first metatarsal were measured on the anteroposterior radiographs[28]. The lateral talocalcaneal angle, the lateral angle between 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[28]. Computed tomography of the hindfoot was performed with the technique described by Seltzer et al.[29], in order to evaluate the subtalar, talonavicular, and calcaneocuboid joints. Any osteoarthritic changes of the tarsal joints, as demonstrated by irregularity of the joint space, osteophytes, and subchondral bone sclerosis, were also recorded. The normal feet of the patients with unilateral clubfoot served as controls. We obtained authorization to perform the radiographic and computed tomography examinations from the ethics committee of our university hospital, and informed consent was provided by all of the patients who were examined.

Results were expressed as the mean and standard deviation. An unpaired Student t test and the Pearson correlation coefficient were used for the statistical analysis. When the p value was <0.05, the difference or correlation was considered to be significant. The Bonferroni test[30] was applied in a multisample hypothesis testing between the normal feet and the treated clubfeet in each group, and between the treated clubfeet of the two groups.

Results

At the time of follow-up, the average age was twenty-five years (range, twenty-four to twenty-eight years) in the first group and nineteen years (range, seventeen to twenty-two

years) in the second group. Twenty-two of the forty-seven clubfeet in the first group relapsed at an average age of three years, and twenty of the forty-nine clubfeet in the second group relapsed at an average age of four years. Of nine relapsed feet in the first group that had a second posteromedial release, six had a second relapse.

In the first group, two feet had an excellent result; eighteen, a good result; eleven, a fair result; and sixteen, a poor result (Figs. 1-A, 1-B, and 1-C). Eighteen feet in the second group had an excellent result; twenty, a good result; six, a fair result; and five, a poor result (Figs. 2-A, 2-B, and 2-C). The mean score for the clubfeet was 74.7 ± 11.37 points in the first group and 85.4 ± 5.29 points in the second group. The difference was significant ($p < 0.0001$). Ten feet in the first group and two in the second group were occasionally painful during daily activities, twenty feet in the first group and sixteen in the second group were painful after strenuous activities, and six feet in the first group and one foot in the second group were painful during walking. The painful feet were painful and tender around the ankle, in the sinus tarsi, or on the sole under the metatarsal heads. A significant association was found between the scores of the treated clubfeet in the two groups and pain ($p < 0.0001$).

The mean ankle dorsiflexion, varus-valgus movement of the heel, and inversion-eversion of the forefoot measured 4.26° ± 7.62°, 12.68° ± 7.95°, and 35.45° ± 10.72°, respectively, in the first group; 8.55° ± 5.29°, 17.59° ± 6.47°, and 42.78° ± 10.10° in the second group; and 14.66° ± 5.60°, 38.41° ± 7.66°, and 67.78° ± 10.29° in the normal limbs. The difference between both groups and the normal limbs was significant ($p < 0.0001$), as was the difference in inversion-eversion motion of the forefoot between the two groups ($p < 0.0424$). Eleven patients in the first group and seven patients in the second group were unable to walk on the toes of the clubfeet. The leg muscles were weaker than normal in twenty-seven involved limbs in the first group and in thirteen in the second group. In particular, the gastrocnemius-soleus was weaker than normal in fourteen involved limbs in the first group and in eight in the second group. Four feet in the first group had a planovalgus deformity. None of the patients limped.

The radiographic studies showed a difference between the clubfeet in the two groups and between them and the normal feet (Figs. 3-A through 4-C). The distance between the tip of the medial malleolus and the navicular tuberosity in the first group (1.54 ± 0.60 cm) was greater than that in the second (1.29 ± 0.53 cm) but still smaller than that in the normal limbs (2.36 ± 0.39 cm). The difference between both groups and the normal limbs was significant ($p < 0.0001$). The anteroposterior and lateral talocalcaneal angles (14.09° ± 6.69° and 33.19° ± 8.62° in the first group, 16.10° ± 5.39° and 38.78° ± 5.86° in the second group, and 21.59° ± 3.76° and 42.81° ± 5.28° in the normal limbs) were smaller than normal in both groups, indicating residual heel varus. The anteroposterior talocalcaneal angle in the two groups was significantly different from that in the normal limbs ($p < 0.0001$), whereas the lateral talocalcaneal angle in the first group was significantly different from both that in the normal limbs ($p < 0.0001$) and that in the second group ($p < 0.0068$). The lateral talus-first metatarsal angle and the first-fifth metatarsal angle (9.40° ± 9.49° and 22.13° ± 6.32° in the first group, 6.39° ± 7.10° and 15.45° ± 4.34° in the second group, and 2.47° ± 5.45° and 15.72° ± 4.10° in the normal limbs) indicated a residual midfoot cavus deformity in both groups, whereas a residual forefoot cavus deformity was present only in the first group. The lateral talus-first metatarsal angle differed significantly only between the first group and the normal limbs ($p < 0.0085$), whereas the first-fifth metatarsal angle differed significantly between the first group and both

Fig. 1-A

Figs. 1-A, 1-B, and 1-C A patient in the first group. **Fig. 1-A** Severe bilateral clubfoot deformity in a two-week-old girl. The left foot relapsed and was treated with an anterior tibial tendon transfer to the third cuneiform.

the second group and the normal limbs ($p < 0.0001$). The navicular-first cuneiform angle (–7.85° ± 11.75° in the first group, –19.78° ± 10.20° in the second group, and 0.63° ± 8.86° in the normal limbs)—an index of the amount of lateral shift of the cuneiforms—showed that the cuneiforms were shifted more laterally in the second group than in the first group. There was a significant difference in this angle between the two groups ($p < 0.0001$), between the first group and the normal limbs ($p < 0.0353$), and between the second group and the normal limbs ($p < 0.0001$). The anteroposterior talus-first metatarsal angle and calcaneus-fifth metatarsal angle (8.28° ± 8.09° and –0.62° ± 8.48° in the first group, 0.94° ± 6.95° and –6.80° ± 8.57° in the second group, and –0.06° ± 7.40° and –2.19° ± 4.88° in the normal limbs) reflected the persistence of a certain amount of forefoot adduction in the clubfeet in the first group but in none in the second group. The anteroposterior talus-first metatarsal angle differed significantly between the first group and both the second group and the normal limbs ($p < 0.0002$), whereas the calcaneus-fifth metatarsal angle differed significantly only between the first and second groups ($p < 0.0093$).

Computed tomography showed abnormalities in the shape of the posterior articulation of the subtalar joint in forty-two feet in the first group and in forty-three feet in the second group. In these feet, the curvature of the articular facets of both the talus and the calcaneus ranged from a lesser curvature to a flat articular surface. The posterior articulation was normal in appearance in only five feet in the first group and six in the second group. The talonavicular joint was normal in twelve feet and medially subluxated in thirty-five feet in the first group, whereas it was normal in four feet and medially subluxated in forty-five feet in the second group. The calcaneocuboid joint was medially subluxated in nine feet in the first group, and its articular facets had an abnormal shape in thirty-seven feet in the first group and in forty-six feet in the second group. The joint was shaped normally in

Fig. 1-B

Fig. 1-C

Figs. 1-B and 1-C When the patient was seen at twenty-five years of age, bilateral cavus deformity and forefoot adduction as well as some varus angulation of the right heel were present. The patient had bilateral metatarsalgia and pain in the right ankle. The right foot scored 72 points and the left, 78 points.

Fig. 2-A

the remaining feet in both groups. Degenerative changes of the tarsal joints were present in twenty-six feet in the first group and in twelve in the second group. These changes were either mild or moderate.

Discussion

Long-term follow-up studies of adults with treated congenital clubfoot are rare[19,22,23], and reports on series treated

Figs. 2-A, 2-B, and 2-C A patient in the second group. **Fig. 2-A** Severe bilateral clubfoot deformity in a one-week-old boy. Both feet relapsed, and both were treated with an anterior tibial tendon transfer to the third cuneiform.

Fig. 2-B

Fig. 2-C

Figs. 2-B and 2-C When the patient was seen at twenty years of age, the feet were very well aligned, although slight varus of the left heel was evident. The left foot was painful after strenuous activities. The right foot scored 94 points and the left, 83 points.

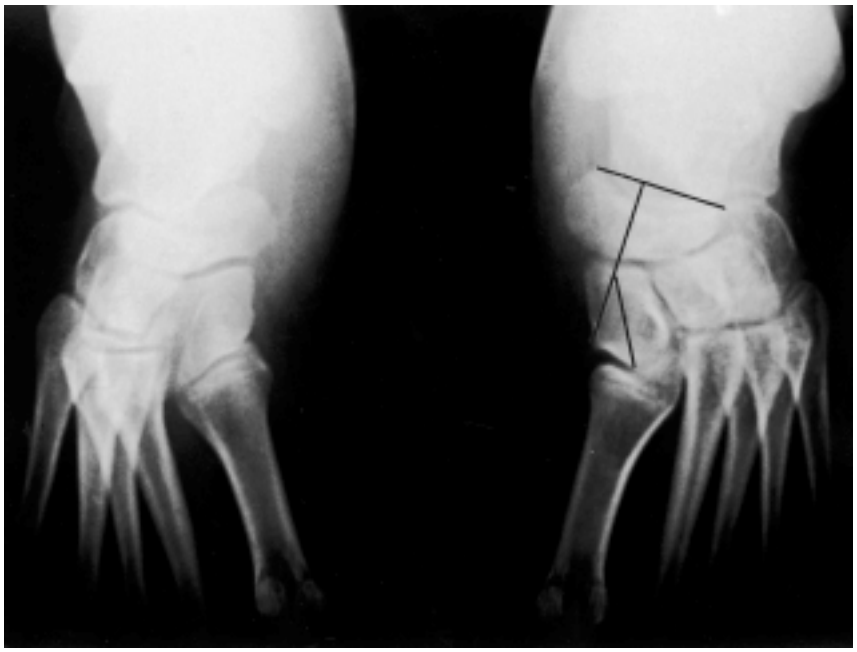

Fig. 3-A

Fig. 3-B

Fig. 3-C

Standing anteroposterior radiograph (Fig. 3-A) and lateral radiographs of the right (Fig. 3-B) and left (Fig. 3-C) treated clubfeet shown in Fig. 1. Bilateral forefoot adduction, bilateral cavus deformity, and varus of the right foot were evident. A moderate lateral shift of the cuneiforms was indicated by a negative navicular-first cuneiform angle (Fig. 3-A). The distance between the medial malleolus and the navicular (Fig. 3-B) was shorter on the right than on the left.

since birth by the same author are even rarer[19,23]. Moreover, the results of treatment in different series are very difficult to compare because of different degrees of severity at birth, differences in treatment, and use of different rating systems to assess the results. The two groups reported on in this study, although containing only limited numbers of patients, were very uniform because all of the patients had been treated by the same surgeon or under his supervision and only treatment of severe deformities was evaluated, as mild cases had been excluded from the study.

The first group of patients was treated with a manipulation technique that abducted the forefoot in pronation and lowered the first metatarsal to the level of the fifth in order to place the foot in a plantigrade position. We believe that this maneuver might have caused metatarsal adduction and cavus deformity, which were the most common sequelae observed in our first group. In the late 1940s, Ponseti started to apply a new manipulative technique in which all of the components of the clubfoot are corrected simultaneously by abducting the foot under the talus while a counterpressure is applied to the head of the talus. Using this technique, we obtained a much faster and better clinical correction. In our second group of clubfeet, which was treated in this manner, adduction was never observed and the prevalence of mild midfoot cavus was very low.

Surgery was a mandatory step in the treatment of our first patient group because of the residual deformities present

after the manipulation. We used a posteromedial release[1] that is similar to other extensive soft-tissue releases[5,11,17]. Our early results appeared to be very satisfactory, as reported in a short-term follow-up study[31]. However, several patients who were found to have a very good result in that study had a fair or poor result when they were reevaluated for the present study, almost twenty years later. Good results have been reported in other short-term studies of patients treated with extensive soft-tissue releases, but the results at the end of skeletal growth are unknown[10-15,17,18,32,33]. In the second group in the present study, all patients had only resistant equinus at the end of manipulation. We thought that open Achilles tendon lengthening together with a posterior capsulectomy of the ankle joint would provide greater foot dorsiflexion than the percutaneous tenotomy indicated by Ponseti's protocol. In fact, our patients had a wide range of ankle dorsiflexion during childhood[31], but at the time of the last follow-up the mean ankle dorsiflexion was similar to that reported by Laaveg and Ponseti[19], although the mean lateral talocalcaneal angle was larger than that in Ponseti's groups. A lack of correlation between functional results and radiographic angles was reported by Herbsthofer et al.[34].

The result was excellent or good in 43% of the feet in our first group and in 78% of those in our second group. Hutchins et al.[20], who employed the same rating scale that we used, reported an excellent or good result in 57% of the

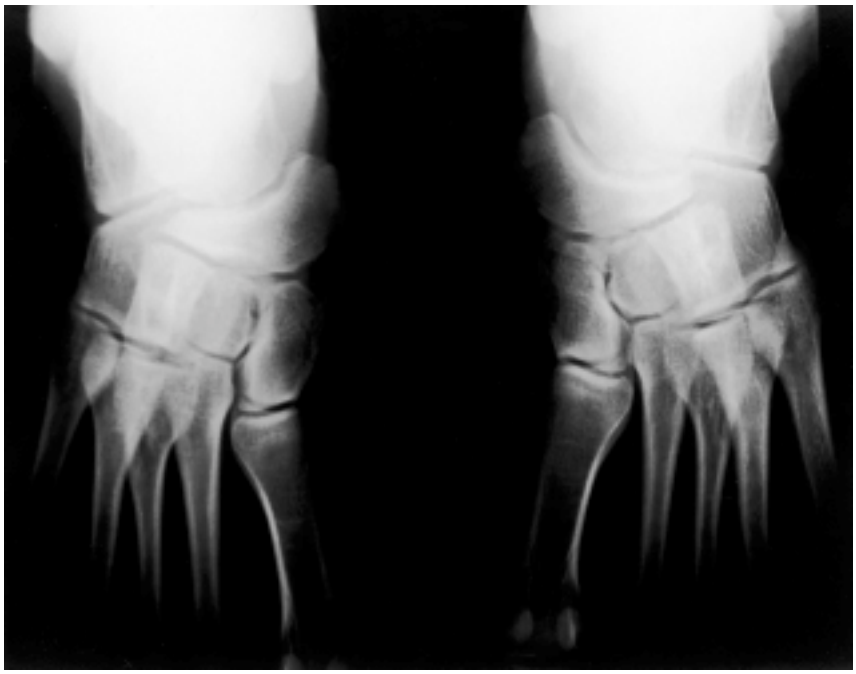

Fig. 4-A

Fig. 4-B

Fig. 4-C

Standing anteroposterior radiograph (Fig. 4-A) and lateral radiographs of the right (Fig. 4-B) and left (Fig. 4-C) treated clubfeet shown in Fig. 2. The forefoot was well aligned with the hindfoot on both sides, and no cavus deformity was present. The distance between the medial malleolus and the navicular was short in both feet, and a marked lateral shift of the cuneiforms was indicated by a very low navicular-first cuneiform angle.

feet treated with early surgical release. However, since those authors included patients who were still growing, it is likely that some of their results will deteriorate with time. In our second group, both the mean score and the number of excellent and good results were similar to those reported by Laaveg and Ponseti[19], whereas patients treated with manipulation and posterior release in the study by Haasbeek and Wright[22] had a lower score; however, those authors did not report the number of excellent and good results. Pain was present in 76% of the feet in our first group and in 38% of the feet in our second group, and in both groups we found a significant correlation between the quality of the result and pain, as was also observed by Laaveg and Ponseti[19]. Radiographic signs of osteoarthritis were present in 40% of the feet in our first group and in 20% of those in our second group. In both groups, pain had started by the end of the adolescent growth spurt. Since pain has never been reported in short-term follow-up studies on congenital clubfoot, to our knowledge, such studies are not reliable for evaluating the lifelong function of the foot[10-15,17,18,32,33].

A flatfoot deformity was present in about 9% of the feet in the first group and in none in the second group. It is possible that, after the posteromedial release, the scar tissue that replaced the excised ligaments of the medial and plantar aspect of the foot was mechanically weak and unable to support the medial arch of the foot, as happens more frequently when posteromedial releases are performed after the first year of life[11]. Ankle dorsiflexion, varus-valgus movement of the heel, and inversion-eversion of the forefoot were more limited in the first group than in the second, and the foot movements of both groups were more limited than those of the normal feet. In both of our groups, a significant association ($p < 0.0001$) was found between the quality of the result and the range of motion of the foot and ankle. Several patients in both groups were unable to walk on their toes. This functional limitation, which can be crippling[21,35,36], might be caused by excessive lengthening of the Achilles tendon and worsened by forced dorsiflexion of the foot in the brace.

Ponseti[37] showed that foot abduction corrects heel varus because the calcaneus, when abducted, everts at the subtalar joint. However, in several cases in the second group, we observed perfect alignment of the forefoot with the hindfoot but heel varus was still present. In those cases, the subtalar joint was very abnormal and the navicular-first cuneiform angle had a high negative value. Therefore, when the subtalar joint was severely abnormal, the calcaneus could only partially evert, and the cuneiforms, the cuboid, and the metatarsals shifted laterally in order to obtain foot abduction. This compensatory correction took place in front of a navicular that remained medially subluxated. The misshapen subtalar joint is another basic pathologic abnormality in fetuses with congenital clubfoot[38] and, together with the stiff ligaments and tendons, it may strongly influence the quality of correction of the deformity. The navicular was medially subluxated in 74% of the feet in the first group and in 92% of the feet in the second group. Posteromedial release restored the normal relationships between the head of the talus and the navicular in 26% of the feet in the first group. However, the reduction of the talonavicular subluxation did not influence the mean functional score in the first group, which remained lower than that in the second group, in which only 8% of the feet showed reduction of the medial subluxation of the navicular. Medial subluxation of the cuboid on the calcaneus was present in only 19% of the feet in the first group. Surgical reduction of the calcaneocuboid subluxation has been advocated[39-41], but this was never necessary in the clubfeet in the second group, in which manipulation alone was sufficient to obtain a good reduction.

The relapse rate was similar between the two groups (47% in the first group and 41% in the second group), and the anterior tibial tendon transfer to the third cuneiform was effective in controlling relapse and preventing additional relapses in all of the feet that were treated with that operation, a finding that has been previously reported[19,23,41-44]. On the other hand, posteromedial release performed in nine relapsed feet in the first group was followed by another relapse in six. Apparently, the scar tissue that replaces the ligaments, muscles, and tendons after posteromedial release retains a tendency to retract[38,45,46], as was postulated by Goldner and Fitch[47].

In conclusion, our long-term results of posteromedial release were disappointing. Thirty years ago, we thought that extensive surgery was the right approach to the management of congenital clubfoot, but the present study indicates that a proper manipulation technique is the most important for treatment of clubfoot. Open Achilles tendon lengthening and posterior capsulectomy of the ankle failed to improve the range of ankle dorsiflexion compared with that obtained by stretching the capsule and performing a subcutaneous tenotomy of the Achilles tendon. In addition, open surgery weakened ankle plantar flexion and prevented some patients from being able to walk on their toes. ■

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