The influence of treatment on the pathology of club foot

CT STUDY AT MATURITY

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We performed CT to investigate how treatment may modify the basic skeletal pathology of congenital club foot. Two homogenous groups of patients treated by one of the authors (EI) or under his supervision were studied. The first included 32 patients with 47 club feet reviewed at a mean age of 25 years and treated by manipulation, application of toe-to-groin plaster casts and an extensive posteromedial release. The second included 32 patients with 49 club feet reviewed at a mean age of 19 years and treated by the Ponseti manipulation technique, application of toe-to-groin plaster casts and a limited posterior release.

At follow-up the shape of the subtalar, talonavicular and calcaneocuboid joints was found to be altered in many feet in both groups. This did not appear to be influenced significantly by the type of treatment performed. Correction of the heel varus and the increased declination angle of the neck of the talus was better in the club feet of the second group, whereas reduction of the medial subluxation of the navicular was better in the first. There was a marked increase in the external ankle torsion angle in the first group and a moderate increase of this angle in the second group, in which medial subluxation of the cuboid on the anterior apophysis of the calcaneum was always corrected. Equinus was corrected in both groups but three-dimensional CT reconstruction of the whole foot showed that cavus, supination and adduction deformities were corrected much better in the second group.

Pathological studies of aborted fetuses and stillborn infants with idiopathic congenital club foot have shown abnormalities in both the size and shape of the tarsal bones as well as changes in their relationships. The severity of the deformity varies according to the severity of the pathological anomalies which in turn may have a major influence on the outcome of treatment.1-6

Radiological studies performed on treated congenital club feet either at or close to skeletal maturity have shown residual skeletal changes which resemble the original abnormalities, some of which appear to be modified by treatment, whereas others remain largely unchanged.7-11 However, plain radiography allows an assessment of the anatomy of the foot in only two planes. As a result the morphology of some important joints of the hindfoot as well as the spatial arrangement of the bones of the foot cannot be fully investigated, as pointed out by Johnston et al.12

Our aim therefore was to investigate using CT how treatment may modify the basic skeletal pathology of club foot by evaluating at maturity two homogeneous groups of patients treated by different protocols.

Patients and Methods

Two groups of patients with idiopathic congenital club foot were treated by one of the authors (EI) or under his supervision. The first included patients treated between 1973 and 1977 according to the traditional protocol of our hospital13 which began with manipulation followed by application of serial toe-to-groin plaster casts, with the knee flexed to 90°. Manipulation consisted of abduction and pronation of the forefoot, while a counterpressure was exerted by the other hand on the anterior tuberosity of the calcaneum. Feet resisting correction after the application of 14 to 20 plaster casts were treated at an age ranging from eight to 12 months by postero-medial release as described by Codivilla14 and later modified by Turco.15 An aluminium brace extending to above the knee was worn all the time until the infant began to walk, and then only at night until the age of three years. Relapsed stiff feet were treated by a second postero-medial release. Transfer of the tendon of anterior tibialis to the third cuneiform was performed when the relapsing feet were passively correctable. Of the original 109 patients treated 32...
with 47 club feet returned for follow-up examination. Of the 77 excluded from the study, 56 had started treatment elsewhere, 12 had a mild deformity corrected only by manipulation and plaster casts, six were lost to follow-up, and three were unable to return for follow-up. There were 24 men and eight women with a mean age of 25 years (24 to 28). The club foot was bilateral in 15 and unilateral in 17 patients.

The results obtained with the traditional method of treatment adopted in our institution were sometimes unsatisfactory. Therefore, it was decided to change the method of manipulation to that described by Ponseti and Smoley. The second group included patients treated between 1979 and 1984 by weekly, or two-weekly manipulation and application of toe-to-groin plaster casts. The Ponseti technique consists of abduction of the whole foot in supination under the talus, while counterpressure is applied with the other hand to the lateral aspect of the head of the talus. After the application of a mean of six plaster casts, only the equinus deformity resisted correction. At a mean age of 2.5 months a Z-lengthening of tendo Achillis and posterior capsulectomy of the ankle were performed. This limited open posterior release was a personal modification of the traditional Ponseti technique which advocates subcutaneous tendo Achillis lengthening at the beginning of the second month of life. A brace extending to above the knee was worn all the time until the infant began to walk and then only at night until the age of four years. Patients who relapsed were treated by tendon transfer of anterior tibialis to the third cuneiform and lengthening of tendo Achillis when necessary to correct recurrent equinus. Of the 84 patients treated 32 with 49 club feet returned for follow-up examination. Of the 52 patients excluded from the study, 33 had been initially treated elsewhere, 13 had a mild deformity which was corrected by manipulation and application of plaster casts alone, three were lost to follow-up, and three were unable to return for follow-up. There were 22 men and ten women with a mean age of 19 years (17 to 22) at CT evaluation. The club foot was bilateral in 17 and unilateral in 15.

Technique of CT. The CT study was approved by the Ethical Committee and informed consent was obtained from all patients. CT was performed using a Siemens Somaton AR-HP system (Siemens, Erlangen, Germany). The patient was positioned supine on the machine platform, with the lower limbs parallel and the knees extended. The feet were held parallel in a neutral position by a radiolucent support. The longitudinal axis of the feet coincided with the longitudinal axis of the support. Scans 1.5 mm thick were taken in the three spatial planes. The relationships and the shape of the hindfoot joint were assessed. The angle formed by the longitudinal axis of the support and of the ankle mortice. The angle was obtained at the levels of the proximal juxta-articular epiphysis of the tibia and of the ankle mortice. The angle was measured according to Jakob, Haertel and Stussi by considering the angle formed between the lines coincident with the axis of the proximal tibial epiphysis and the bimalleolar axis. Three-dimensional reconstructions were also made of

Table I. Mean (SD) ankle and hindfoot angles in normal feet and treated club feet

<table>
<thead>
<tr>
<th>Angle</th>
<th>Normal feet</th>
<th>First group</th>
<th>Second group</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsion angle of the ankle mortice (˚)</td>
<td>21.44 (7.56)</td>
<td>29.91 (7.55)</td>
<td>24.18 (7.5)</td>
<td>Normal versus first group &lt;0.0001</td>
</tr>
<tr>
<td>Declination angle of the neck of the talus (˚)</td>
<td>17.81 (5.54)</td>
<td>30.28 (7.34)</td>
<td>23.20 (8.63)</td>
<td>Normal versus first group &lt;0.0001</td>
</tr>
<tr>
<td>Calcaneocuboid angle (˚)</td>
<td>13.84 (7.68)</td>
<td>7.74 (16.86)</td>
<td>1.82 (16.71)</td>
<td>Normal versus first group &lt;0.0001</td>
</tr>
</tbody>
</table>

* not significant
ten unilateral and five bilateral club feet in each group as well as the normal feet of seven volunteers whose age was similar to that of our patients, in order to obtain a better understanding of the shape and the relationships of the bones of the feet.

Statistical analysis. The results were expressed as the mean ± SD. Bonferroni’s test was applied in a multisample hypothesis testing between the normal feet and treated club feet of both groups, and between the treated club feet of both groups. A p value of <0.05 was considered to be significant.

Results

Tables I and II give details of the CT findings for both groups and the normal feet.

In the first group the torsion angle of the ankle mortice was greater than that in the second group, and in both groups it was greater than normal (Fig. 1). The difference between the first group and normal was statistically significant, as was the difference between the first and the second groups. No statistically significant difference was found between the second group and the normal feet (Table I).

The declination angle of the neck of the talus was greater in the first group than that in the second, and in both groups this angle was greater than that in the normal feet (Fig. 2). The difference between the second group and the normal feet was not statistically significant, but that between the first group and both the second group and the normal feet was significant (Table I).

In the coronal scans of the normal feet, the subtalar joint appeared to be formed by three distinct articulations: a large posterior articulation made by a convex calcaneal surface and a concave talar surface, a narrow middle articulation and a very narrow anterior one. In the first group, all except five of the club feet had only two articulations since the middle and the anterior ones formed the whole joint. In five feet, only the posterior articulation was present. Both the talar and the calcaneal surfaces of the posterior joint were flat in 18 feet, and flat and slanted laterally downwards in seven. In 17 feet, the curvature of the two articular surfaces was less than that in the normal feet, and in the
remaining five the posterior articulation was normal. In five feet of the second group, both the middle and the anterior articulations were absent. The posterior articulation had flat articular surfaces in 17 feet, was flat and slanted laterally downwards in six with a curvature which was less than normal in 20 feet and normal in six (Fig. 3, Table II).

In the normal feet, the articular surface of the calcaneum was convex and that of the cuboid was concave. Both articular surfaces were flat in 11 feet of the first group and in 18 feet of the second group; they were both wave-shaped in 16 feet of the first group and 15 of the second group, and normal in ten feet of the first group and in four of the second. The articular surface of the calcaneum was concave and that of the cuboid convex, in ten feet of the first group and in 12 of the second. In nine feet of the first group, the cuboid was medially subluxated (Fig. 4, Table II).

The calcaneocuboid angle was less than normal in the first group but the difference was not statistically significant. However, in the second group it was decreased more than sevenfold in comparison with the normal (Fig. 4, Table I).

In the first group, the talus and navicular had normal articular relationships in 12 feet, but in 35 the navicular was medially subluxed to some extent. In the second group the talonavicular joint was normally congruent in four feet but the navicular was medially subluxed in 45 feet. The navicular was either flat or wedge-shaped or both in 39 feet of the first group and in 46 of the second. The head of the talus was spherical in 29 club feet of the first group and in 32 of the second. It was dome-shaped in six feet of the first group and in seven of the second, and moderately flat in the remaining feet of both groups (Fig. 5, Table II).

Three-dimensional CT reconstruction of the whole foot showed that in those club feet in the first group in which the declination angle of the neck of the talus was high, the malleolar mortice was externally rotated to keep the foot straight. In these feet, the navicular, the first cuneiform and the first metatarsal were aligned with the neck of the talus and the calcaneum was positioned in varus under the body of the talus and curved medially. The calcaneocuboid angle had a high value, and in some cases the cuboid was medially subluxed, whereas the navicular was superomedially subluxed and close to the medial malleolus. The forefoot was adducted and cavus, and the midfoot was cavus and supinated (Fig. 6). In the second group, the torsion angle of
the ankle mortice was moderately increased even in cases with a high declination angle of the neck of the talus. The navicular remained subluxed, but the cuneiforms and the cuboid were shifted markedly laterally to re-establish the correct alignment of the forefoot with the hindfoot. No forefoot adduction or cavus deformity or supination was present, and the calcaneum was never in a marked varus position underneath the talus (Fig. 7).
Discussion
The most important and recurrent skeletal abnormalities shown by pathological studies of fetuses and stillborn infants with congenital club feet are as follows: the small size of the calcaneum, the navicular and the talus, the neck and head of which are markedly deviated medially in severe cases; medial subluxation of both the talonavicular and the calcaneocuboid joints with wedging of both the head of the talus and the articular part of the anterior tuberosity of the calcaneum; inversion and adduction of both the navicular and the cuboid; inversion and adduction of the calcaneum the anterior tuberosity of which is located beneath the head of the talus; a misshapen subtalar joint; and increased plantar flexion of the first metatarsal in comparison with the lateral metatarsals (forefoot cavus). As far as we know, no previous CT study has been performed in skeletally mature club feet to investigate how these congenital skeletal abnormalities may be modified by different protocols of treatment.

The protocols adopted in our two groups of patients differed in both the technique of manipulation and the complementary soft-tissue surgery. The traditional manipulation technique of our hospital, used in the first group, attempted correction of club foot by pronation and abduction of the forefoot with counterpressure applied by the contralateral thumb against the cuboid. Ponseti’s manipulation technique, adopted in the second group, is based on abduction of the whole foot in supination under the talus, while counterpressure is applied with the contralateral thumb against the head of the talus. After manipulation and casting, an extensive postero-medial release was performed in the club feet of the first group, which were immobilised after surgery with the forefoot in pronation and abduction. Z-lengthening of tendo Achillis and posterior capsulectomy of the ankle were the only open surgical procedures adopted in the second group.

In a previous radiological investigation of the same series of patients, the height of the talar trochlea and the length of both the talus and calcaneum were smaller than normal and very similar to each other in both groups. These parameters were not influenced by treatment. Both the medial subluxation of the navicular and the abnormal varus position of the calcaneum beneath the talus were only partially modified by the two different methods of treatment. The former was better reduced in the first group but the latter was superior in the second. Some of the other basic club-foot deformities such as cavus, supination and adduction seemed to be better corrected in the second group. However, plain radiography cannot analyse certain morphological aspects of the skeletal components of the foot, which can only be assessed by three-dimensional diagnostic imaging such as CT or MRI. Johnston et al studied 24 club feet and three normal feet in children aged from three to ten years, and made three-dimensional reconstructions of their plain images. However, details of treatment were only given in two examples and the authors made clear the disadvantages of imaging skeletally immature feet in this way.

Using CT, we studied 96 club feet and 46 normal feet at skeletal maturity. The strict treatment protocols applied in the two groups of patients make each group reasonably homogeneous. The external torsion of the ankle mortice was higher than normal in both groups, although the difference was not statistically significant in the second group. As a result, the Ponseti manipulative technique, in comparison with the extensive medial release associated with the traditional manipulative technique which we previously used, achieved better alignment of the forefoot on the hindfoot, without externally rotating the ankle mortice too much. The ankle torsion angle has been reported to be normal in stillborn infants with congenital club foot. In both of our series treatment increased the external torsion of the ankle mortice, which appears to compensate for both the lack of eversion of the calcaneum and the persistence of a high value of the declination angle of the neck of the talus. In such cases, mainly seen in the first group, three-dimensional reconstruction showed that the navicular and the cuneiforms remained aligned with the head of the talus, the cuboid was medially angulated and the forefoot aligned with the tarsal bones. In these cases, the increased external torsion of the ankle mortice allowed the forefoot to point straight forwards while the calcaneum remained in varus. This false correction gave the foot a typical ‘bean shape’. Ankle torsion has been evaluated by CT in children with congenital club foot aged from two to 12 years. In one study, the mean external ankle torsion was 1˚ greater in congenital club foot than in the normal, whereas in the other study it was 11˚ less than in the normal. The discrepancy between these results and our findings may be related to the different treatment as well as to the age of the patients. Cuevas De Alba et al showed a gradual increase with age of external ankle torsion in children with congenital club foot.

In fetuses and stillborn infants with congenital club foot the talar neck is more or less medially angulated, depending on the severity of the deformity. An increase in the declination angle of the neck of the talus depending on the severity of the deformity was observed by Kamegaya et al in an MRI study of club feet in 36 patients whose age ranged from four to 12 months. Using MRI, Pirani, Zenznik and Hodges showed an improvement in the declination angle of the neck of the talus in children treated by the Ponseti method. Our CT study showed that the declination angle of the neck of the talus was better corrected in the second group than in the first.

The misshapen subtalar joint is another basic pathological abnormality which is present in fetuses with congenital club foot and which is not improved by treatment. This joint was still misshapen in more than 85% of treated club feet in both of our groups. Ponseti showed that abduction of the foot corrected heel varus because the calcaneum, when abducted, everted in the subtalar joint. However, in several cases in our second series with a very abnormal subtalar joint, the forefoot showed perfect alignment with the

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hindfoot, but heel varus was still present. In these cases, three-dimensional reconstructions of the foot showed that forefoot abduction took place in front of both the navicular and the anterior tuberosity of the calcaneum by a lateral shift of the cuneiforms and the cuboid. We believe that the misshapen subtalar joint is an important limiting factor in the correction of the varus deformity of the heel and that it may strongly influence the result of any form of treatment, including extensive soft-tissue release operations.

The calcaneocuboid joint was misshapen in 77% of cases in the first group and 94% in the second. However, in most in both groups the medial subluxation of the cuboid on the anterior tuberosity of the calcaneum was reduced. The lateral shift of the cuboid played an important role in the realignment of the forefoot with the hindfoot, as shown by the decrease of the calcaneocuboid angle in the feet in both groups compared with the normal. Medial subluxation of the cuboid on the calcaneum has been considered to be a deformity which is difficult to correct,26-28 and surgical reduction has also been advocated.26 However, in club feet in both of our groups manipulation was sufficient to obtain satisfactory reduction or even an over-reduction of the calcaneocuboid joint, especially in the second group in which over-reduction probably caused a higher incidence of flattening of the joint.

The navicular was still medially subluxed in 75% of the feet in the first group and in 92% in the second. The talonavicular joint was misshapen in almost 40% of the cases in both groups. Posteromedial release restored the normal relationships between the talus and navicular in about 25% of cases of the first group. However, reduction of the talonavicular joint did not influence the correction of the adduction and cavus deformities which were present more often in the first group than in the second, in which only 8% of the cases showed reduction of the medial subluxation of the navicular.

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References