CLUB FOOT

OBSERVATIONS ON THE SURGICAL ANATOMY OF DORSIFLEXION

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Dorsiflexion has been studied in three normal feet and in three feet with talipes equinovarus to determine the anatomical features which might contribute to the failure of operative treatment to correct the deformity. In the normal feet the movement of dorsiflexion was found to be essentially rotatory in nature and not simply hinging; as dorsiflexion proceeds the fibula moves forwards relative to the os calcis and the calcaneal tendon. In the club feet a posterolateral tether was found; this prevented fibular movement and blocked dorsiflexion. As a result of this study a posterior and lateral release is advocated for the operative correction of the hindfoot in a child with a club foot deformity, particularly under the age of a year.

At first sight the operative correction of fixed equinus seems a straightforward procedure. But when equinus is associated with other fixed deformities, as it is in club foot, correction is hard to achieve despite the present trend towards an increasingly radical operation at an early age (Clark 1968; Turco 1979; Smith, Campbell and Bonnett 1976). Some authors even advise division of the interosseous tibiofibular ligament (De Langh *et al.* 1975; Smith *et al.* 1976) to allow the wider anterior half of the talus to slide back into the mortice and so permit full dorsiflexion.

It seems to us that certain anatomical features of club foot have hitherto not been appreciated and that this has prevented primary correction from being achieved.

MATERIAL AND METHODS

Three normal feet and three feet with talipes equinovarus were available for study. All came from children who were stillborn and whose feet had been preserved in formalin. By crown-pubis measurements their gestational age was estimated to be between seven and nine months. Amputation through the lower tibia was performed; then the skin and subcutaneous tissues of the foot were excised and the main muscle mass removed from the associated tendons in order to reduce the bulk of the preparation.

In the normal feet, the tibia was fixed in a clamp leaving the fibula free to move. Dorsiflexion was studied

in two separate experiments. In the first (*intact preparation*) dorsiflexion in the intact foot was produced by a force applied to the forefoot. In the second (*hindfoot preparation*) the forefoot was amputated through the talonavicular and calcaneocuboid joints so that dorsiflexion of the hindfoot could be studied separately.

After movement had been studied in the intact preparation, two tethers were applied by inserting black silk sutures: the first tether extended from the lateral malleolus to the os calcis in the line of the posterior calcaneofibular ligament; the second from the fifth

Fig. 1

The anterior surface of the dome of the normal right talus viewed from above. The lines show the different curvatures of the medial and lateral articular surfaces; they subtend to a point medially, suggesting that there must be an element of rotation on dorsiflexion. Note the extension of the articular surface on the medial side of the neck of the talus.

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Fig. 2

Fig. 3

Figure 2—Anterior view of the normal right foot in plantarflexion; the antero-lateral articular surface has moved forwards and medially and become uncovered (arrow). Figure 3—Posterior view of the normal foot in dorsiflexion; the posterolateral articular surface has moved backwards and medially and is uncovered (arrow).

Fig. 4

Fig. 5

Figure 4—A dissected preparation of a normal right hindfoot in plantarflexion viewed from in front. This shows that the lateral articular surface has moved forwards and medially more than the medial surface. The pointer indicates the axis of the neck of the talus. Figure 5—The same foot viewed from in front, but in dorsiflexion. The dome of the talus has now slid backwards out of view. Note the degree of lateral rotation as indicated by the pointer in the talus. There has also been rotation of the os calcis under the talus (arrow).

Fig. 6

Fig. 7

Figure 6—Lateral view of the normal foot in full dorsiflexion: the lateral surface of the talus has slid backwards behind the fibula. The os calcis has moved away from the fibula. Figure 7—A black silk suture (arrow) has been inserted between the fibula and the insertion of the calcaneal tendon into the os calcis. This posterolateral tether prevents the lateral surface of the talus (front arrow) from sliding backwards, and keeps it subluxated anteriorly. Note that the angle of dorsiflexion is reduced: the foot only just reaches a right angle.

metatarsal to the navicular in the line of the distal attachment of tibialis posterior. The effect of these tethers on dorsiflexion could then be studied. The study of the hindfoot preparation is discussed later.

In the light of the observations made in the normal feet the three club feet were then dissected to determine whether the fixed deformities were the consequence of simple tethers and to study the effect of soft-tissue release.

FINDINGS

Normal feet. Shape of the talus. On the superior aspect of the talus, the articular surface of the medial side of the body extended well forward onto the neck and was almost straight, whereas the lateral border of this surface was shorter and more curved (Fig. 1). The ratio of the area of the articular surface of the talus to the corresponding surface of the lower tibia was 1:1.3. When viewed from the side the vertical height of the talus was greatest at the anterior margin of the articular surface and least at its

the tibialis posterior needed to be relaxed. As it proceeded from the position of full equinovarus, every 10 degrees of dorsiflexion was accompanied by approximately 10 degrees of lateral rotation of the foot on the tibia. As a result the anterior and lateral aspects of the articular surface of the talus became uncovered in plantarflexion and the posterior one-third of this surface in dorsiflexion (Figs 2 and 3). Moreover, as dorsiflexion proceeded pronation increased at the expense of supination.

Hindfoot preparation. In full plantarflexion the anterior and lateral aspects of the body and neck of the talus came forward out of the mortise and the long axis of the neck pointed downwards and medially. On dorsiflexion from this position, there was a posterior and rotatory movement of the talus within the mortise; the posterior and lateral aspect of the body came backwards out of the mortise posteriorly (Figs 4 and 5). Simultaneously there was a rotatory movement of the os calcis under the talus; as dorsiflexion continued the os calcis moved posteriorly on the talus.

Fig. 8

Fig. 9

Figure 8—Lateral air arthrogram of a normal foot. In dorsiflexion the talus normally remains congruent within the mortise (arrow). Figure 9—Lateral air arthrogram with a posterolateral tether in position. The talus now hinges on the anterior lip of the tibia—the arrow shows the posterior joint opening up.

posterior aspect. The curvature of the medial border of the articular surface (facing the medial malleolus) differed from that of the lateral side (Fig. 1). This difference confirms the observations of Inman (1976) in the adult foot and suggests that talar movement within the ankle mortise is a combination of anteroposterior gliding with rotation and not a simple hinge movement.

Dorsiflexion. Dorsiflexion of the normal intact foot from the position of equinovarus enabled us to confirm the observations made by Swann, Lloyd-Roberts and Catterall (1969); two phases were noted. In the first, dorsiflexion took place at the ankle: for this only the calcaneal tendon needed to be relaxed. In the second phase the foot rotated beneath the talus: for this both the calcaneal tendon and

The effect of the tethers. The effect on dorsiflexion of a suture tethering the fibula to the os calcis was marked. Firstly full dorsiflexion could not be achieved even when all the tendons were completely relaxed and considerable force was used; the anterolateral aspect of the articular surface remained uncovered anteriorly (Figs 6 and 7). The normal rotation of the os calcis under the talus was also completely prevented. A lateral radiograph showed the talus hinging on a line of contact between the lower tibia and the anterior margin of the articular surface (Figs 8 and 9). Attempted pronation of the forefoot caused subluxation of the talonavicular joint (Figs 10 to 12).

The effect of the second suture tethering the

Fig. 10

Fig. 11

Fig. 12

A dissected normal left foot viewed from above. The os calcis is held rigidly but the talus and forefoot are able to move freely. The pointers inserted into the talus and forefoot show the changes in orientation on manipulation of the forefoot. The directions of rotation are indicated by the black arrows. Figure 10—When the forefoot is supinated the talus rotates laterally in order to maintain talonavicular congruity. Figure 11—The forefoot is pronated but talar movement is prevented. Note the subluxation at the talonavicular joint (white arrow). Figure 12—The forefoot remains pronated, but medial talar movement has now occurred and talonavicular congruity is restored.

Fig. 13

Fig. 14

Lateral view of a normal foot. A black silk suture inserted on the medial side represents a distal contracture of tibialis posterior and a tether of the tendon proximal to the medial malleolus. The nail is in the fibula, and the black line shows the position of the forefoot. Figure 13—In plantarflexion the distal tether has caused supination and adduction of the forefoot. Figure 14—On dorsiflexion both supination and adduction of the forefoot persist. Note also that dorsiflexion is partially blocked and that the talus remains subluxated anterolaterally.

Fig. 15

Posterolateral view of a partially dissected club foot. A pointer is inserted into the calcaneal tendon. The stirrup applied to the forefoot is being used to attempt to dorsiflex the foot. A thick fibrous band (arrow) is seen running between the peroneal tendon sheath and the insertion of the calcaneal tendon. This band extended deeply into the posterior talofibular ligament and tethered the fibula to the posterior aspect of the os calcis.

navicular to the base of the fifth metatarsal is shown in Figures 13 and 14. With this tether the foot adopted a position of fixed adduction and supination; it could not be dorsiflexed above a right angle even when all the tendons were free to move.

Club feet. Dissection of the club feet revealed a number of abnormalities in all three specimens. First, the lateral malleolus was displaced posteriorly, bringing it relatively closer to the calcaneal tendon (Fig. 15). In part this was produced by shortening of the calcaneofibular ligament and in part by thickening of the fascia enclosing the peroneal tendons; this combination resulted in a thick strap of tissue tethering the fibula to the lower margins of the calcaneal tendon and the os calcis. Secondly, in the uncorrected position of equinovarus the talus was displaced anteriorly out of the mortice with the antero-lateral part of the body uncovered, as noted by Swann *et al.* (1969). Thirdly, the dissections confirmed the finding by Waisbrod (1973) of abnormalities and contractures in the tibialis posterior distal to its attachment to the navicular.

DISCUSSION

This study has underlined two important concepts in the movement of dorsiflexion of the foot. The first is the essentially rotatory nature of the process usually considered to be a hinging movement. Secondly, dorsiflexion can only proceed normally if the lateral malleolus is free to move. In other words, adequate mobility of the fibula is an essential requirement for normal dorsiflexion.

Shortening of the structures attached to the posterior and lateral aspect of the fibula restrict its normal excursion; in particular the rotatory movement of the os calcis under the talus in the second phase of dorsiflexion is restricted.

The thickened tissue preventing normal fibular movement has been previously reported by Ippolito and Ponseti (1980). Attenborough (1966) also stressed the lateral movement of the talus which takes place during dorsiflexion and Swann *et al.* (1969) noted that with an uncorrected or relapsed club foot the lateral malleolus was unduly posterior. Similar observations were made by Carroll, McMurtry and Leete (1978), and Inman and Mann (1978) reported that pronation and supination were accompanied by rotation of the os calcis under the talus.

Until now, however, descriptions of the conventional posterior release operation for correction of equinus refer to posterior capsulotomy of the ankle and subtalar joints, but do not mention release of the fibula. De Langh *et al.* (1975) and Smith *et al.* (1976) advocated splitting the interosseous tibiofibular ligament to allow the mortice to accommodate the wider anterior third of the talus if equinus could not be corrected at operation. This procedure assumes that dorsiflexion is a simple posterior movement of the talus in the mortice, the wedge-shaped dome of the talus being too wide anteriorly to enter the mortice. Even if such a release achieved dorsiflexion the ankle would not be congruent and stiffness would inevitably follow. Attenborough is the only author to dissect the peroneal sheath for the purpose of tendon transfer and he reported a much higher degree of correction when this was done (Attenborough 1972).

The importance of fibular mobility has not been discussed in previous reports nor has the difference in height of the talus in its anterior and posterior parts been noted. During dorsiflexion of the normal foot the fibula moves forward relative to the os calcis. Interference with this movement caused profound impairment of the normal mechanics. With the foot in full equinus the os calcis moves posteriorly relative to the talus. In this position the ligaments between the fibula and the os calcis are at their slackest and the thickest part of the talus outside the anterior aspect of the mortice. If adaptive shortening of these ligaments occurs either by growth or scarring the talus may displace forward as an orange pip into the position of fixed subluxation. This ligamentous shortening may also explain the observations made by Main *et al.* (1977) that a conventional posterior release is most effective when undertaken in the first six weeks of life, before adaptive shortening has occurred.

The implications for the treatment of club foot, where there is both hindfoot and forefoot deformity, are clear. Clinical examination should establish first whether there is mobility of the fibula; and secondly, whether the midtarsal joint also is mobile with the tibialis posterior and long flexors relaxed in equinovarus. If, in this position, the midtarsal joint is mobile it would seem

reasonable only to divide the tethers described and the tibialis posterior—a posterolateral release; in addition, of course, to lengthening the calcaneal tendon. This should be sufficient to restore full mobility to the hindfoot, though serial manipulations and plaster will still need to be continued to correct the forefoot deformity.

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