Role of calcaneal osteotomy in the management of symptomatic flexible flatfoot.

Essay

Submitted for fulfillment of master degree in orthopedic surgery

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<td>Flexible flat foot with short tendo achilis</td>
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<td>PTTD</td>
<td>Posterior tibial tendon dysfunction</td>
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<td>AAFF</td>
<td>Acquired adult flat foot</td>
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<td>MDCO</td>
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Introduction

Flatfoot deformity also known as pes planovalgus deformity, has multiple etiology ranging from idiopathic, posterior tibial tendon dysfunction (PTTD), inflammatory arthritis ,neuropathy ,trauma ,and neuromuscular conditions of foot(1).In adult population PTTD is by far the most common cause of acquired pathological flat foot deformity(2).

The conservative management of pes planus when patient demonstrates clinical deformity with the highest likelihood of responding to conservative management, If patient is evaluated in acute state, he or she can be treated with a short term trial of immobilization.Casting can be supplemented with a trial of non steroidal antiinflammatory drugs.

Often, the casting trial must be for as long as one month before a significant clinical effect is noted. Followed by physiotherapy after diminishing of the symptoms. custom made orthotics are recommended with inclusion of forefoot posts as well as heel cups and support for the arch .Medial fore foot posting should be used for a flexible planovalgus deformity, lateral forefoot posting with a flexible cavo varus deformity.

Surgical treatment of pes planus may be considered if appropriate conservative treatment fails . Surgical management typically involves both a soft tissue (flexor digitorum longus transfer or tendo achiles lengthening) and a bony ( calcaneal osteotomy ,subtalar arthroereisis or arthrodesis) (3,4). Calcaneal osteotomy has yielded good result with minimal complications and high satisfaction rate (5).

Evans described a lengthening opening wedge osteotomy of calcaneal neck (6). It provides an effective restoration of the arch of foot by the lengthening of the lateral column and, thereby, rotating forefoot and hind foot medially. The restoration of foot tripod is through a 3
dimentional modification of foot alignment. It can be performed in combination with medial translational osteotomy of calcaneal tuberosity in patient with severe flatfoot deformity.

The indication for corrective osteotomy of the calcaneus is a cavovarus or planovalgus foot deformity that is driven, at least in part, by a malaligned calcaneus with a supple subtalar joint.

Contraindications to calcaneal osteotomy include preexisting subtalar arthritis. In the presence of subtalar arthritis, subtalar arthrodesis alleviates pain and extra articular osteotomy is required. Attempted realignment at the site of fusion may lead to non union and failure of fusion. Relative contraindications include smoking and patient medical comorbidity such as obesity, diabetes, peripheral vascular disease, peripheral edema and skin conditions. Many patients find that the incidence and severity of these complication unacceptable risks for elective surgery in addition to the prolonged period period of immobilization required.

Complications with calcaneal osteotomy include over and under correction, the lack of appreciation of heel cord tightness, and those of all osteotomies non union and local complications to the sural nerve and skin. Nerve injury from lateral surgical approaches to the calcaneus has been well studied in the anatomy and trauma literature, and can result in temporary and permanent irritation along the course of sural nerve at the heel with neuroma formation and distal dysesthesia (7) A painful scar, with or without identifiable nerve injury, may also be associated with a surgical approach to the calcaneus.

Tarsal tunnel syndrome has been associated with lateralizing calcaneal osteotomy. Higher risk of tarsal tunnel syndrome is associated with greater translation of the osteotomy and osteotomies performed
more anteriorly on the tuberosity(8). This is presumably because of irritation of the nerve passing through the tarsal tunnel and sinus tarsi.

Overcorrection is uncommon complication that demonstrate the power of calcaneal osteotomy, and has been reported in a single case for a planovalgus foot overcorrected into varus by medial slide osteotomy.

Painful hardware is relatively common for calcaneal osteotomy. Screw heads that are placed in the posteroinferior tuberosity or a lateral plate for a translational or evans osteotomy are potential sources of hardware related pain. Patients should be counseled for this and potential requirement for hardware removal in the future(4).
Aim of the work

The aim of this essay is to review the role of calcaneal osteotomy as a line of management of symptomatic flexible flatfoot.
Chapter 1

Flexible FlatFoot
Introduction of flexible flatfoot

Flatfoot deformity means loss of the normal arch of the foot. There are very few foot conditions that remain as poorly understood as the congenital flexible flatfoot, primarily because of the large volume of conflicting and poorly conducted research studies that have been carried out over many decades. This foot shape is common, often familial, rarely painful, and even more rarely disabling, yet the flexible flatfoot generates interest, investigation, and controversy. There is, in fact, no consensus among health care providers as to whether flatfoot represents a deformity or a variation of normal foot shape.

Harris and Beath [9], in their 1947 study of foot problems in 3,600 recruits in the Royal Canadian Army, stated that the flexibility of the subtalar joint and the longitudinal arch, along with the ability of both to reverse their alignments, was more important than the static shape of the foot. The flexible, or hypermobile, flatfoot accounted for most of the flatfeet that they identified in their study population. This type was determined to be the normal contour of a strong and stable foot, and not the cause of pain and disability.

Pathomechanics

The functions of the foot include the provision of a stable, but supple, platform that adapts to the ground during the early stance phase of gait, followed by conversion to a rigid lever during push-off. Several authors have represented the complex interrelationships between the bones of the mid- and hindfoot as a mitered hinge, though that analogy is clearly too simplistic. Using that as a first approximation or basic foundation, one must add a thorough understanding of the shape,
structure, relationships, and motions of the subtalar joint complex to truly understand the biomechanics of the foot.

The subtalar joint complex is comprised of three bones (calcaneus, talus and navicular) possibly four, if one includes the cuboid), several important ligaments (including the spring, or calcaneo-navicular ligament), and multiple joint capsules that all function together as a unit. Almost 200 years ago, Scarpa [10] noted similarities between the subtalar joint complex and the hip joint. He compared the femoral head to the talar head, and the pelvic acetabulum to the so-called “acetabulum pedis”, a cup-like structure made up of the navicular, spring ligament, and anterior end of the calcaneus and its facets. It is not a perfect comparison, but the two anatomic areas share certain features that seem to make the comparison both valid and worthwhile. The hip, a pure ball-and-socket joint with a central rotation point, is comprised of two bones, one intra-articular ligament, and a joint capsule. The subtalar joint is not an independent ball-and-socket joint, though the combined motions of the subtalar joint and the immediately adjacent ankle joint give that impression. Its axis of motion is in an oblique plane that is neither frontal, sagittal, nor coronal. This creates motions that are best described with the unique terms “inversion” and “eversion”. The stable structure in the hip joint is the acetabulum (the socket), while the stable structure in the subtalar joint complex is the talus (the ball). Inversion is comprised of plantar flexion, supination, and internal rotation of the acetabulum pedis around the head of the talus [11]. The static position of inversion of the subtalar joint is called hindfoot varus and is found in cavovarus feet and clubfeet. Eversion is a combination of dorsiflexion, pronation, and external rotation of the acetabulum pedis around the talar head. Hindfoot
valgus is the static position of the everted subtalar joint and is seen in flatfeet and skewfeet.

The tibia and talus internally rotate during the first half of the stance phase of the gait cycle while the subtalar joint complex everts. The talar head plantar flexes because of the lost support from the acetabulum pedis. The foot becomes quite supple, or unlocked, and flattens. During the latter part of the stance phase, the tibia and talus externally rotate, while the subtalar joint complex inverts, so that the acetabulum pedis once again supports the head of the talus. The talus dorsiflexes and the entire foot becomes more rigid, or locked. This diminishes stress on the muscles and ligaments during push-off.

The flexible flatfoot begins stance in an unlocked, everted position, and does not completely convert to a rigid, inverted lever during the latter portion of stance. Based on the work by Mann and Inman [12], who found that greater intrinsic muscle activity is required to stabilize the transverse tarsal and subtalar joints in a flatfooted individual than in one with an average height arch, this might be expected to lead to foot fatigue and pain. Fortunately, foot fatigue and pain seem to occur only in some flatfooted individuals.

The orthopedist is urged to avoid the use of the term ‘pronated’ as a substitute for the term ‘flatfoot.’ While it is true that pronation is a component of the hindfoot deformity in this condition, the subtalar joint is dorsiflexed and externally rotated, the midfoot is abducted, and the forefoot is supinated in relation to the hindfoot.
Epidemiology

The true incidence of flatfoot is unknown, primarily because there is no consensual agreement on the strict clinical or radiographic criteria for defining a flatfoot. At the root of this dilemma is the lack of a universally accepted definition of a “normal,” in contrast to an ‘average height,’ longitudinal arch. Traditionally, a flat-foot has been defined subjectively as a weight-bearing foot with an abnormally low or absent longitudinal arch. This definition is based solely upon the static anatomic comparison of the height of the arch within a population. It fails to take into consideration the etiology of the flatfoot, the functional relationships between the bones, and the presence or evidence-based expectation of future pain or disability. It also ignores normal anatomic variations in arch height among adults, between children and adults, and between racial groups. It is well recognized that there is a higher incidence of flatfeet in blacks [13] than Caucasians, and that these flatfeet, like those in Caucasians rarely cause disability.

Morley [14] evaluated the heel-to-arch width ratio on the footprints of children in the first decade of life and found that nearly 100% of 2-year-olds were flatfooted, while the same pattern was seen in only 4% of 10-year-old children.

Though he and other authors [15] believed that many of these flatfeet actually had an arch that was obscured by a fat pad, Gould et al. [16] and others refuted the fat pad theory with radiographic evidence of actual flattening of the medial longitudinal arch. Staheli et al. [17] used the footprint technique to evaluate the shape of the plantar surface in 882 asymptomatic feet in normal people aged 1 – 80 years. He demonstrated that most infants are flatfooted, that the arch develops spontaneously during the first decade of life in most children, and that flatfeet are within
the normal confidence limits for arch height in adults as well as children. Vanderwilde et al. [18] confirmed these findings with the first comprehensive study on normative radiographic measurements of the foot in children. They found that there is a large spectrum of normal values for children of different ages, that these normal values are different from adult normal values, and that these normal values change spontaneously with age into the adult norms.

Comprehensive, normative radiographic values have recently become available for the adult foot. Wide variations were found in all measurements. Since all feet of the study subjects, despite anatomic variations, were painless and therefore “normal,” the conclusions were that radiographs should not direct treatment, even if the values are beyond the normal range. Radiographs can define the static relationships between bones, but they cannot provide clinical information on pain, flexibility, or function.

Despite the lack of a strict definition, it is believed that most children and at least 20% of adults (19) have flatfeet, most of which are flexible. Harris and Beath using their own anatomic criteria, identified flatfeet in approximately 23% of their adult study subjects. They subdivided flatfeet into three types: flexible flatfoot (FFF) flexible flatfoot with short tendo-Achilles (FFF-STA), and peroneal spastic or rigid flatfoot. They found that flexible flatfoot accounted for approximately two-thirds of all flat feet and, in contrast to the latter two types, rarely caused disability. They emphasized that the flatness of the arch in weight-bearing was of less importance than the mobility of the joints and tendons. They identified contracture of the Achilles tendon in association with flexible flatfoot in 25% of the total number of subjects with FFF and noted that this type was often accompanied by pain and functional...
disability. Rigid flatfoot, characterized by restricted motion of the subtalar joint, accounted for approximately 9% of all the flatfeet that they studied.

These were most commonly associated with tarsal coalitions and were occasionally symptomatic. Tarsal coalitions and other conditions that cause rigid flatfoot are not the focus of this review and will not be discussed in detail.

Certain features of the rigid flatfoot will, however, be mentioned to aid with differentiation from the flexible flatfoot.

While it is possible to document the number of individuals with painful FFF (with or without short tendo Achilles) that seek medical attention, it is not possible to accurately document the much larger number of individuals with asymptomatic FFF who do not seek medical attention and, therefore, go uncounted. It is, thus, impossible to accurately estimate the risk of pain or disability from this very common foot shape. Nevertheless, the risk has been estimated to be small, even according to proponents of most surgical procedures for painful flatfeet.

Pathogenesis

There are two main theories explaining the pathogenesis of FFF: a type of flatfoot that is present from birth and is accompanied by good joint mobility and apparently normal muscle function. Duchenne [20] and others believed that coordinated and normal function of the muscles of the foot and ankle was responsible for the maintenance of the longitudinal arch and that sub-clinical muscle weakness was responsible for the flexible flatfoot.

This theory was refuted by Basmajian (21) whose electromyographic studies of the muscles of the foot and ankle showed that the height of the longitudinal arch is determined by features of the
bone–ligament complex, and that the muscles maintain balance, accommodate the foot to uneven terrain, protect the ligaments from unusual stresses, and propel the body forward. Proponents of this bone–ligament theory believe that the shape of the longitudinal arch under static loads is determined by the shape and interrelationship of the bones, coupled with the strength and flexibility of the ligaments.

It is unproven whether the abnormal shape of individual bones and joints represents a primary or secondary reflection of a long-standing flatfoot, though most current authors conclude that excessive ligamentous laxity is the primary abnormality. Muscles are necessary for function and balance, but not for structural integrity. Mann and Inman [12] confirmed that muscle activity is not required to support the arch in static weight-bearing. They also found that the intrinsic muscles are the principal stabilizers of the foot during propulsion, and that greater intrinsic muscle activity is required to stabilize the transverse tarsal and subtalar joints in a flatfooted individual than in one with an average height arch.

There are no long-term prospective studies on the natural history of untreated FFF in regard to the development of pain, only the cross-sectional study of Harris and Beath (9). They found that, whereas FFF is rarely a cause for concern, FFF-STA often causes pain and disability. It is unknown whether the short tendo-Achilles in these feet is a primary pathologic feature or a secondary developmental deformity. Harris and Beath [19] believed that FFF and FFF-STA are separate entities, although the documentation of early clinical differentiation has not been reported.
Types of pediatric flatfoot

Various terms are used to describe the different types of flatfoot. For example, flatfoot is either asymptomatic or symptomatic. As mentioned earlier, the majority of children with flatfoot have an asymptomatic condition. Symptomatic flatfoot is further described as being either flexible or rigid. “Flexible” means that the foot is flat when standing (weight-bearing), but the arch returns when not standing. “Rigid” means the arch is always stiff and flat, whether standing on the foot or not. Several types of flatfoot are categorized as rigid (22). The most common are:

**Tarsal coalition**

This is a congenital (existing at birth) condition. It involves an abnormal joining of two or more bones in the foot. Tarsal coalition may or may not produce pain. When pain does occur, it usually starts in preadolescence or adolescence.

**Congenital vertical talus**

Because of the foot’s rigid “rocker bottom” appearance that occurs with congenital vertical talus, this condition is apparent in the newborn. Symptoms begin at walking age, since it is difficult for the child to bear weight and wear shoes. There are other types of pediatric flatfoot, such as those caused by injury or some diseases (22).
Types of adult flat foot

*Posterior Tibial Tendon Dysfunction (PTTD)*

Damage to the posterior tibial tendon is the most common cause of acquired adult flat foot (AAFD). The posterior tibial tendon is one of the most important tendons of the leg. It starts at a muscle in the calf, travels down the inside of the lower leg and attaches to the bones on the inside of the foot. The main function of this tendon is to hold up the arch and support the foot while walking. If the tendon becomes inflamed or torn, the arch will slowly collapse.

Women and people over 40 are more likely to develop problems with the posterior tibial tendon. Other risk factors include obesity, diabetes, and hypertension. Having flat feet since childhood increases the risk of developing a tear in the posterior tibial tendon. In addition, people who are involved in high impact sports, such as basketball, tennis, or soccer, may have tears of the tendon from repetitive use.\(^{(5)}\)

**CLASSIFICATION BASED ON MRI** \(^{(5)}\)

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<th>Type</th>
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<td>One or two fine longitudinal splits, without evidence of transubstance degeneration.</td>
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<td>Type II</td>
<td>The tendon is narrowed with longitudinal splits and evidence of intramural degeneration.</td>
</tr>
<tr>
<td>Type III</td>
<td>Diffuse swelling of the tendon with uniform degeneration. A few strands can be intact of the tendon is completely replaced by scar tissue.</td>
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### CLASSIFICATION ACCORDING TO THE CLINICAL SIGNS

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<tr>
<td>Stage II</td>
<td>A flexible planovalgus foot. Medial or lateral pain or both. The &quot;too many toes sign&quot; and single limb heel rise are present. The tendon is elongated and functionally incompetent.</td>
</tr>
<tr>
<td>Stage III</td>
<td>All the signs of stage II are present, the pes planovalgus deformity is fixed. Lateral Pain at the calcaneal -fibular contact.</td>
</tr>
<tr>
<td>Stage IV</td>
<td>End stage, valgus tilt of the talus in the ankle mortise leads to lateral tibiotala degeneration, osteoarthritis of the ankle, with Limited ability to walk.</td>
</tr>
</tbody>
</table>

### Arthritis

Inflammatory arthritis, such as rheumatoid arthritis, can cause a painful flatfoot. This type of arthritis attacks not only the cartilage in the joints, but also the ligaments that support the foot. Inflammatory arthritis not only causes pain, but also causes the foot to change shape and become flat. The arthritis can affect hindfoot or midfoot, both of which can result in a fallen arch.

### Trauma

An injury to the ligaments in the foot can cause the joints to fall out of alignment. The ligaments support the bones and prevent them from moving. If the ligaments are torn, the foot will become flat and painful. This more commonly occurs in the middle of the foot (Lisfranc injury), but can also occur in the back of the foot.

In addition to ligament injuries, fractures and dislocations of the bones in the midfoot can also lead to a flatfoot deformity.
Diabetic Collapse (Charcot Foot)

People with diabetes or with a nerve problem that limits normal feeling in the feet, can have arch collapse. This type of arch collapse is typically more severe than that seen in patients with normal feeling in their feet. This is because patients do not feel pain as the arch collapses. In addition to the ligaments not holding the bones in place, the bones themselves can sometimes fracture and disintegrate - without the patient feeling any pain. This may result in a severely deformed foot that is very challenging to correct with surgery. Special shoes or braces are the best method for dealing with this problem.

Clinical assessment

Flexible flatfeet rarely cause pain or disability in infancy and childhood. Children in this age group usually present for evaluation because of their parents’ concern about the appearance of the feet or because of the history of special shoe wearing during childhood.

The clinical assessment of a child with a flatfoot should consist of a general examination of the musculoskeletal system, in addition to the specific foot and ankle examination. The general examination is aimed at assessing torsional and angular variations of the lower extremities and the walking pattern. The patient should be examined for evidence of generalized ligamentous laxity, which can include touching the thumb to the volar forearm, hyperextension of the metacarpo-phalangeal joints of the fingers to 90°, hyperextension of the elbows and/or knees into recurvatum, and touching the palms to the ground with the knees extended. It is often rewarding to inquire about familial flatfeet and to examine the feet of other family members who are present in the examination room. Flexible flatfeet may cause rapid and uneven shoe
wear in older children and adolescents, so the child’s shoes should be examined.

Assessment of the foot and ankle begins with the recognition, as first clearly stated by Mosca [23], that “the foot is not a joint.” This simplistic and seemingly apparent fact is the foundation for the appropriate assessment and management of foot deformities in children. There are at least two segmental deformities, often in opposite directions from each other, in all congenital and developmental deformities of the child’s foot [23]. For example, a flatfoot is a combination of deformities that includes valgus deformity of the hindfoot and supination deformity of the forefoot. These are rotationally opposite direction deformities that, according to Mosca [23], give the impression that the foot has been “wrung out like a towel.” In a symptomatic flatfoot, there is also a contracture of the gastrocnemius alone or the entire triceps surae (Achilles tendon).

The clinical appearance of a flatfoot is more complicated than the simple depression or absence of a longitudinal arch. There is a straight or convex plantar-medial border of the foot. The lateral border is straight or concave. The midfoot sags and touches the ground in weight-bearing (Fig. 1a). The foot appears externally rotated in relation to the leg and the weight-bearing axis of the lower extremity passes medial to the mid-axis of the hindfoot. The hindfoot is in valgus alignment (Fig. 1b).

The flexibility of flatfoot is a more important feature than the static shape. Flexibility refers to the motion of the subtalar joint complex and requires careful assessment. The subtalar joint will invert from valgus to neutral and a longitudinal arch will be observed in a flexible flatfoot that is dangling in the air while the individual is seated. A longitudinal arch can also be created by dorsiflexing the great toe (Fig. 2). This so-called
toe-raising test, initially described by Jack and explained by Hicks, is due to the “windlass action” of the plantar fascia. A windlass is an apparatus for moving heavy weights. It consists of a horizontal cylinder which is rotated by the turn of a cran. The plantar fascia simulates a cable attached to the metatarso-phalangeal joints at one end and the calcaneus at the opposite end. Dorsiflexion of the toes winds the plantar fascia around the heads of the metatarsals. This winding of the plantar fascia shortens the distance between the calcaneus and metatarsals and elevates the medial longitudinal arch. The windlass effect is also demonstrated when toe-standing, by means of the same biomechanics (Fig. 3).

Fig 1. Flexible flat foot

a. convex medial border with midfoot sag.

b. valgus hindfoot

Supination deformity of the forefoot on the hindfoot is revealed when the valgus hindfoot is passively inverted to neutral (Fig. 4). It should be apparent that this separate, rotationally opposite, segmental deformity exists in a flat foot. If not, a flatfooted individual would stand
on the plantar-medial aspect of the everted/pronated hindfoot and the plantar-medial aspect of the first metatarsal, with the lateral forefoot elevated off the ground. Instead, compensatory forefoot supination places all metatarsal heads on the ground for shared weight-bearing when the hindfoot is everted.

A flexible flatfoot with short tendo-Achilles (FFF-STA) has the same subtalar joint mobility of an FFF, but is differentiated from it by a limitation of ankle dorsiflexion.

Short tendo-Achilles should be considered as a proxy for contracture of either the gastrocnemius alone or the entire triceps surae (tendo-Achilles), as both prevent the talus from dorsiflexing in the ankle joint during the stance phase of gait. With an STA, the dorsiflexion force is shifted to the subtalar joint which, as a component of eversion, enables dorsiflexion of the calcaneus (acetabulum pedis) in relation to the talus. This false dorsiflexion often results in foot and ankle pain either under the head of the talus or in the sinus tarsi area.

Fig 2. Jacks toe raising test. An arch is created in flexible flatfoot by the windlass action of the great toe and plantar fascia. (24)
Fig 3 a. weight bearing left FFF. b, in toe standing, heel valgus converts to varus and the longitudinal arch can be seen. (24)

Fig 4. Forefoot supination can be appreciated when the hindfoot is inverted to neutral. (24)

Assessment of true ankle dorsiflexion and Achilles tendon excursion are important, yet difficult, to evaluate accurately. The subtalar joint complex must be inverted to neutral and held locked in that position in order to isolate and assess the motion of the talus in the ankle joint. The knee is flexed and the ankle is dorsiflexed while maintaining neutral alignment of the subtalar joint. Dorsiflexion is measured as the angle
between the plantar-lateral border of the foot and the anterior tibial shaft. Less than 10 of dorsiflexion indicates contracture of the soleus muscle, which equates to contracture of the entire tendo-Achilles.

The knee is then extended while maintaining neutral alignment of the subtalar joint and trying to maintain dorsiflexion of the ankle joint. Dorsiflexion is remeasured.

If more than 10 of dorsiflexion was possible with the knee flexed, but less than 10 of dorsiflexion is possible with the knee extended, the gastrocnemius alone is contracted (Fig. 5). One should differentiate contracture of the gastrocnemius from contracture of the entire triceps surae (tendo-Achilles), because both can cause pain that justifies surgical management, but the surgical technique obviously varies between them.

In contrast to these two types of flexible flatfoot is the rigid flatfoot, which was defined by Harris and Beath [9] as being characterized by the restriction of subtalar joint motion. The arch remains flat when the foot is dangling in the air while the individual is seated, as well as during toe-standing and the toe-raising test. This type of flat foot can occasionally cause pain and disability.

**Fig 5.** The subtalar joint must be held in neutral position and the knee extended in order to accurately assess ankle dorsiflexion. (24)
Most flexible and rigid flatfeet do not hurt. Acquired and environmental causes of pain may occur in a foot with any foot shape, including flatfoot. Therefore, one must not automatically assume that pain is related to shape. If pain is the presenting complaint, it is critically important to inquire about its exact location and precipitating causes. Those characteristics of pain in a flatfoot can often indicate the Harris and Beath type of flatfoot that exists in the patient. Pain from FFF-STA is usually located on the plantar-medial aspect of the midfoot and occasionally in the sinus tarsi area. Pain from a rigid flatfoot may be experienced at several sites, including the medial hindfoot, the sinus tarsi area, and, occasionally, the plantar-medial midfoot. In both of these conditions, the pain is exacerbated by activities and relieved by rest. Night pain is extremely unusual. Redness, swelling, and warmth are not characteristic findings.

**Radiographic evaluation**

Radiographs of the flexible flatfoot are not necessary for diagnosis, but they may be indicated to help with the assessment of uncharacteristic pain, decreased flexibility, and for surgical planning. Weight-bearing anteroposterior (AP) and lateral views of the foot are generally sufficient to evaluate the flexible flatfoot. Without weight-bearing, or at least simulated weight-bearing, the radiographic relationships between the bones will not represent the true clinical deformities. The addition of the oblique and the axial, or Harris, views is necessary to evaluate the rigid and/or painful flatfoot. A calcaneo-navicular tarsal coalition is best seen on the oblique view, and a talo-calcaneal tarsal coalition can often be seen on the axial view (though a computed tomography [CT] scan is preferable for complete evaluation of that condition). An AP view of the ankle is also necessary, in most cases, to assess varus or valgus deformity
at that adjacent joint. The lateral appearance of the ankle can be appreciated on the lateral image of the foot.

The lateral radiograph of a flatfoot reveals plantar flexion of the calcaneus, measured by the calcaneal pitch and an even greater degree of plantar flexion of the talus, measured by the talo-horizontal angle (Fig. 6). Meary defined a normal longitudinal arch as having a continuous straight line formed by the lines drawn through the mid-axis of the talus and the mid-axis of the first metatarsal on a standing lateral radiograph. He defined a flatfoot as one with a plantar sag where those two lines intersect, but there is, in fact, a range of normal values that includes a few degrees of plantar sag.

The lateral view can also be used to identify the site of the midfoot sag, i.e., the site of the angular deformity. Although the foot is not a single bone, Paley’s [25] concept of the center of rotation of angulation (CORA) can be applied to the foot in a modified version. The site of intersection of the axis of the talus and that of the first metatarsal in a flatfoot is most often located in the head of the talus or at the talo-navicular joint, which indicates that the midfoot sag is at the talo-navicular joint (Fig. 7b). But the CORA can alternatively be located at the naviculo-cuneiform joint, or within the body of one of the mid-tarsal bones. A CORA located in the body of the talus or higher indicates a skewfoot deformity (Fig. 8b).

It is more difficult to interpret the AP radiograph than the lateral one. The navicular is laterally positioned on the head of the talus in a flatfoot. Since the navicular does not normally ossify until the age of 3–4 years, and since its early ossification is asymmetric toward the lateral aspect of the cartilaginous anlage, assessment of the talo-navicular joint alignment must be accomplished indirectly.
Fig. 6 Standing lateral radiograph showing three fairly reliable angular measurements: the calcaneal pitch (CP), talo-horizontal (T-H), and Meary’s talus–first metatarsal angle (T-1MT) (26).

Fig 7. Standing radiographs of a flatfoot showing talus and first metatarsal axis lines crossing at the center of rotation of angulation (CORA) in the
center of the head of the talus, indicating a single deformity at the talonavicular joint. a Anteroposterior view. b Lateral view. (24).

Fig. 8 Standing radiographs of a skewfoot showing two opposite direction angular deformities between the talus and the first metatarsal, making the CORA for those bones meaningless. A Anteroposterior view. B Lateral view. (Reference 26).
There are many angles to determine deformities in flatfoot (forfoot abduction, collapse of longitudinal arch and hindfoot valgus). As in table

<table>
<thead>
<tr>
<th>Value</th>
<th>Radiographic parameter</th>
<th>View</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>To assess forfoot abduction</td>
<td>Talo navicular coverage angle</td>
<td>AP foot</td>
<td>&lt;7</td>
</tr>
<tr>
<td>To assess forfoot abduction</td>
<td>1st metatarsal talar angle</td>
<td>AP foot</td>
<td>0</td>
</tr>
<tr>
<td>To assess longitudinal arch</td>
<td>Talo 1st metatarsal angle</td>
<td>Lat foot</td>
<td>&lt;4</td>
</tr>
<tr>
<td>To assess longitudinal arch</td>
<td>Calcaneal pitch angle</td>
<td>Lat foot</td>
<td>20</td>
</tr>
<tr>
<td>To assess hindfoot valgus</td>
<td>Talo calcaneal angle</td>
<td>AP foot</td>
<td>15 - 30</td>
</tr>
<tr>
<td>To assess hindfoot valgus</td>
<td>Talo calcaneal angle</td>
<td>Lat foot</td>
<td>25 - 45</td>
</tr>
</tbody>
</table>

Table 3 of common radiographic parameters with average normal values (82).
Treatment

There are no controlled prospective studies documenting the avoidance of long-term pain or disability by prophylactic non-operative or operative treatment of asymptomatic FFF. Therefore, the treatment of people with asymptomatic FFF does not seem reasonable, though there are health care providers who ignore the evidence and treat these feet non-operatively and operatively.

The typical FFF has a normal, but not average, longitudinal arch height. There is no reason to treat that which is normal. Some FFF have arches that are clinically and radiographically beyond 2 standard deviations from average. These are technically abnormal, but there is no evidence that they will necessarily cause disability, so there is no rational indication for treatment. There may, in fact, be some specific advantages to having flatfeet. Giladi et al. [27] found that military recruits with flatfeet had significantly less risk of stress fractures than those with average or high arches.

Despite the absence of scientific evidence for derived benefit, the treatment of asymptomatic flexible flatfoot has been advocated for years. Although several authors believed that muscle weakness was responsible for flatfootedness, muscle strengthening exercises with the goal of developing an arch in a child’s foot are unfounded.

Several uncontrolled studies in the US have reported that definite permanent increases in arch height can be achieved both clinically and radiographically by the use of “corrective shoes,” over-the-counter and custom-molded arch supports, custom orthoses, and heel wedges [28]. However, the effect of any intervention cannot be determined without
appropriate untreated matched controls. And several scientific clinical and radiographic studies have shown that the height of the longitudinal arch increases spontaneously during the first decade of life.

A number of critical investigations of these treatment modalities have shown no positive treatment effect. Penneau et al. [28] found no significant radiographic differences between barefeet and those same feet when four types of special shoe modifications and inserts were done. Rose [29] showed that shoe heel wedges did not change the shape of the foot. The foot maintained its original shape by shifting through the heel pad fat unless the forefoot was also supinated. He further noted that the foot remained flat despite years of using the devices. Helfet [31] stated that arch supports are actually dangerous since they lead to dependency, or what he called a life sentence. The foot remains flat and discontinuation of the device later in life increases the likelihood of symptoms. In the best prospective, randomized study on this topic so far reported, Wenger et al. [30] were unable to show a treatment effect for shoe modifications and inserts on the development of the longitudinal arch in normal children followed for 3–5 years when compared with untreated matched controls.

A potentially negative effect of extrinsic factors on the shape and development of the longitudinal arch is suggested, but not proven, by studies from developing countries. The flatfeet in their non-shoe-wearing Chinese study subjects were asymptomatic, mobile, and flexible. Somewhat surprisingly, they found a slightly higher incidence of flatfeet among the shoe-wearing population, some of which were painful and exhibited restricted mobility.

Refuting the often-heard comment that at least these devices do no harm is the study by Driano et al. [32], who reported long-term
negative psychologic effects on adults who had worn shoe modifications as children compared with controls who did not. Nevertheless, the practice remains common place among some health care providers.

Occasionally, flexible flatfoot in a young child is associated with diffuse activity-related pain, causes early fatigue, creates medial foot calluses, and leads to rapid shoe breakdown. Diffuse, non-localized, and nocturnal pain is also occasionally associated with flexible flatfoot. These leg aches, or growing pains, are believed to represent an overuse or fatigue syndrome. This is consistent with the findings of Mann and Inman [22] that flatfooted individuals demonstrate greater intrinsic muscle activity than those with higher arches. Soft over-the-counter and firm custom-molded shoe inserts have been shown to relieve or diminish symptoms, and to increase the useful life of shoes without a simultaneous permanent increase on the height of the arch [33]. There is little information available to recommend one device over another.

The exact diagnosis must be established before prescribing orthotic devices. Their use with FFF-STA and rigid flatfeet could actually worsen the symptoms. The talus in an FFF-STA cannot dorsiflex normally because of the tendo-Achilles contracture. Therefore, an orthotic device that is designed to invert the subtalar joint by elevating the anterior end of the talus will meet resistance and increase pressure under the head of the talus, thereby creating more pressure and pain than that which originally existed. By definition, the shape of a rigid flatfoot will not change with an orthotic device or any other non-surgical intervention. As with the FFF-STA, an orthotic will merely increase pressure and pain under the head of the talus. (57)

It seems reasonable to try to convert a symptomatic FFF-STA to an asymptomatic FFF by heelcord-stretching exercises, which can be
performed by parents on their children when they are very young and can be easily monitored by parents when the children are older. There have been no long-term studies on the effectiveness of this program, but it conforms to present knowledge, does no harm, and costs nothing. Therapists are not required. Heelcord-stretching is accomplished with the knee in extension and the subtalar joint in neutral alignment to slight inversion. It is important, though difficult, to achieve this position of the subtalar joint during stretching. Doing so avoids false dorsiflexion through the everted subtalar joint and concentrates the stretch at the ankle joint. (57)

Surgery is rarely, if ever, indicated for flexible flatfoot. If the goal of surgery is to change the shape of the foot, a shape that does not necessarily create problems, the documented risks and complications related to surgery must be weighed against the generally benign natural history of the foot shape itself. Nevertheless, numerous surgical procedures to correct flatfoot have been proposed during the last century. The indications for these procedures, whether for the correction of deformity, relief of symptoms, or prophylaxis against anticipated pain and disability, are difficult to ascertain from a review of the literature. Therefore, the absolute and comparative success of these procedures is unclear. The procedures can be categorized as soft tissue plications, tendon lengthenings and transfers, osseous excisions, osteotomies, arthrodesis of one or more joints, and the interposition of bone or synthetic implants into the sinus tarsi. Combinations of these procedures have been reported.

Isolated soft tissue procedures have had routinely unreliable results, leading to their virtual abandonment. The failure of tendon transfer procedures underscores the understanding of the insignificant role
of muscles in the maintenance of the arch. Isolated tendo Achilles lengthening has been suggested to convert a painful FFF-STA to a painless FFF when performed before secondary adaptive or degenerative joint changes, the potential sequelae of FFF-STA, have occurred.(57)

However, unsatisfactory results have led most surgeons to combine heelcord-lengthening with a concurrent procedure that changes the shape of the foot. Bone excision operations have been abandoned because of their obvious destructive nature. Arthrodesis of one or more of the joints in the subtalar complex has been abandoned as treatment for FFF because of the detrimental effect of eliminating the shock-absorbing function of that important joint complex. Talo-navicular subtalar and triple [34] arthrodeses shift stress to the ankle and mid-tarsal joints, leading to premature degenerative arthrosis at those sites. Pseudoarthrodesis, or so-called arthroereisis[35], procedures were introduced between 1946 and 1977 as variations on a method to restrict excessive subtalar joint eversion by placing a bone block in the sinus tarsi. The bone grafts occasionally underwent resorption with recurrence of the deformity, or remained and resulted in the restriction of subtalar motion (essentially a pseudoarthrodesis) with its associated problems. Arthroereisis [36,37] by means of synthetic implants was started in the late 1970s because of the reported problems and complications associated with the bony arthroereisis procedures.

In published studies on subtalar and triple arthrodeses, stress transfer to adjacent joints with the development of degenerative arthroses was not seen for at least 10 years [34] which is longer than the follow-up in any of the reports on arthroereisis. Additionally, these implants, not surprisingly, lead to resorption of the adjacent cortical surfaces of the talus and calcaneus (Fig. 9), the long-term effects of which are unknown.
And no one has demonstrated or reported whether the implant stays with the calcaneus or with the talus during inversion and eversion of the subtalar joint, whether it matters, and how the answer relates to the long-term success of the procedure.

Fig. 9 Radiographic and computed tomography (CT) scan images showing resorption of adjacent cortical surfaces of talus and calcaneus due to the presence of a Maxwell–Brancheau arthroereisis (MBA).

Perhaps the most popular procedures used to correct FFF during the last century were the many modifications of Hoke’s limited mid-tarsal arthrodeses [38]. Hoke felt that the greatest abnormality in painful FFF was localized to the navicular and the two medial cuneiform bones. He reported favorable short-term results with the fusion of these three bones combined with tendo-Achilles lengthening. The Hoke procedure modifications combine arthrodesis of one or more mid-tarsal joints with soft tissue plication across the talo-navicular joint. Tendo-Achilles lengthening was performed with all of the Hoke procedure modifications when 10–15 of dorsiflexion could not be demonstrated after correction of the deformity.
Favorable short-term results were consistently reported with these procedures, but unsatisfactory long-term results were reported in 49–80% of cases. The unsatisfactory feet in these series frequently showed persistence or recurrence of pain and deformity, and degenerative changes at the talo-navicular and subtalar joints in addition to the persistence or recurrence of pain and deformity. The originators of these techniques acknowledged that the procedures were not capable of correcting severe hindfoot valgus deformity. This should not have been too surprising, because these procedures do not directly correct the pathologically malaligned subtalar joint, but, instead, address the secondary forefoot supination deformity.

Osteotomy is the last category of procedures that has been used to treat flatfeet. This is a biologic approach that does not depend on soft tissues that are known to stretch out, and it avoids arthrodeses/arthroereisis and the known complications of those procedures. There are two types of osteotomies of the calcaneus that address valgus deformity of the hindfoot. Koutsogiannis [39] described an oblique osteotomy of the posterior calcaneus in which the posterior fragment is displaced medially to correct the apparent heel valgus. It does not actually correct the malalignment of the subtalar joint, but merely creates a compensating deformity to improve the valgus angulation of the heel. Koutsogiannis reported successful “correction” of valgus deformity in 30 of 34 feet, but arch restoration rarely occurred. Other authors confirmed these same results in FFF, as well as in paralytic flatfeet. The posterior calcaneus osteotomy does not correct the multiple components of subtalar joint eversion, such as external rotation and dorsiflexion of the acetabulum pedis.
Rathjen and Mubarak [40] reported good correction of flatfoot deformities by combining a modification of this osteotomy (medially based closing wedge with medial displacement) with a closing wedge osteotomy of the medial cuneiform, an opening wedge osteotomy of the cuboid, and medial reefing of the talo-navicular joint. The Dwyer [41] lateral opening wedge osteotomy of the posterior calcaneus represents another attempt to correct severe heel valgus. It is performed less frequently than the medial displacement osteotomy because it does not correct the deformity as completely. The reason for this is that the location of the osteotomy is not at the CORA [53]. The CORA is located at the subtalar joint, so an adjacent angular osteotomy must be combined with translation of the posterior fragment. Alternatively, one can use translational displacement alone, as with the Koutsogiannis procedure, to center the plantar aspect of the posterior calcaneus under the mid-axis of the tibia.

The other osteotomy for correction of valgus deformity of the hindfoot is the calcaneal lengthening osteotomy, conceptualized by Evans and elaborated by Mosca [42]. Evans believed that the lateral column of the flatfoot was shorter than the medial column, a situation exactly opposite to that found in a cavovarus foot. For painful flatfeets, he equalized the lengths of the columns by inserting a corticocancellous graft into an osteotomy of the anterior calcaneus that was made 1.5 cm proximal to, and parallel with, the calcaneo-cuboid joint. That was the entire extent of his description. By lengthening the calcaneus in this way, he showed that the heel valgus, talo-navicular sag, and lateral subluxation of the navicular on the head of the talus could all be simultaneously corrected. Armstrong and Carruthers [43] recommended the technique and highlighted its advantages to be: correction of hindfoot valgus
without the need for arthrodesis, preservation of some subtalar motion, versatility for pronated and abducted feet of different etiologies, and simplicity of execution.

Phillips [44] reported a 7–20-year (average 13 years) follow-up of Evans’ patients. Seventeen of the 23 feet had good to very good results when assessed by strict criteria. Anderson and Fowler [45] also reported very good results with this procedure in nine feet followed for an average of 6.5 years. They reaffirmed the correction of all components of the deformity by this simple technique and advised performing the procedure between the ages of 6 and 10 years in appropriate individuals to allow remodeling of the tarsal joints, a consideration not mentioned by Evans.
Fig. 10 Painful FFF. a, c Anteroposterior (AP) and lateral preoperative sketches of actual radiographs. The talo-first metatarsal angle is markedly abducted on the AP view. The lateral view shows severe talonavicular sag and a 0 calcaneal pitch. b, d AP and lateral sketches of actual radiographs following a calcaneal lengthening osteotomy and tendo-Achilles lengthening. (42).

In 1995, Mosca [46] reported the short-term results of calcaneal lengthening for valgus deformity of the hindfoot from various underlying etiologies in 31 feet in 20 children. He reported correction of all components of even severe eversion positioning of the subtalar joint complex including dorsiflexion, pronation, and external rotation of the acetabulum pedis around the talar head, at the site of deformity. Function of the subtalar joint was restored, symptoms were relieved, and, at least theoretically, the ankle and mid-tarsal joints were protected from early degenerative arthrosis by avoiding arthrodesis. He stressed the need for
strict indications for surgery, specifically a flexible flatfoot with Achilles or gastrocnemius contracture and intractable pain in the medial midfoot and/or sinus tarsi, despite prolonged attempts at conservative management.

As previously noted, Evans provided very little information on the technique, which made interpretation difficult and surgical success inconsistent by those who read his article. Mosca thoughtfully considered Evans’ concept and applied an understanding of foot biomechanics and the principles of foot deformity-correction surgery to develop a reliable method for achieving consistently good surgical outcomes. His published contributions [46] include the location of the skin incision, the specific location and direction of the osteotomy (exiting medially between the anterior and middle facets), the management of the soft tissue constraints along the plantar-lateral border of the foot and the soft tissue redundancy along the plantar-medial border, stabilization of the calcaneo-cuboid joint to prevent subluxation, the need to recognize and concurrently manage rigid forefoot supination deformity if present, and the importance of lengthening the Achilles or gastrocnemius tendon if contracted (which is usually the case in the symptomatic FFF) (Fig. 10). Other authors have subsequently confirmed the efficacy of the calcaneal lengthening osteotomy for relieving pain and correcting deformity in painful flatfeet [47–54] obviously, more long-term critical follow-up studies are needed for this procedure and all other conservative and surgical methods of treatment for symptomatic FFF. The Evans/Mosca procedure is unique, however, in that it corrects all components of even the most severe valgus deformities of the hindfoot while preserving subtalar joint motion.
Fig 11. Algorithm for management of flexible flatfoot.(24)
Chapter 2
Calcaneal Osteotomy in Flexible Flatfoot
Introduction of calcaneal osteotomy

As part of the “tripod” of the foot, the position of the calcaneus is of critical importance to the alignment of the foot during weight bearing. Although this theory has largely been superseded by a greater understanding of foot and ankle biomechanics the general concept remains true. In the presence of symptomatic foot and ankle malalignment, an osteotomy of the calcaneus is an important component in either restoration of hind foot biomechanics. Osteotomies through the calcaneus body not only realign the tuberosity but also redirect the pull of the Achilles tendon making it a corrective rather than a deforming force. The many options for calcaneal osteotomy allow surgical planning of both planovalgus and cavovarus deformity correction (84).

Pes planovalgus correction by calcaneal osteotomy was first described in 1893 by Gleich, in 1923 by Lord, and in 1960 by Dwyer with a medial translational osteotomy. In 1959 Evans described a lateral column lengthening calcaneal osteotomy procedure as an additional alternative to arthrodesis procedures for pes planovalgus deformity.

Indications/Contraindications

The primary indication for a corrective osteotomy of the calcaneus is a cavovarus or planovalgus foot deformity that is driven, at least in part, by a malaligned calcaneus with a supple subtalar joint. An initial attempt should be made a nonoperative management, using corrective foot and ankle orthoses. “Over the counter” orthotics are frequently attempted with little success. Bespoke or custom made orthotics are recommended with inclusion of forefoot posts as well as heel cups and support for the arch. Medial forefoot posting should be used for a flexible planovalgus deformity; lateral forefoot posting with a flexible cavovarus deformity (84).
If nonoperative treatment is unsuccessful in alleviating the patient’s symptoms surgical correction may be considered, to address the bony alignment and soft tissue tension of the hind, mid, and forefoot. A calcaneal osteotomy is a key bony component of this correction. Contraindications to calcaneal osteotomy include pre-existing subtalar arthritis. In the presence of subtalar arthritis, subtalar arthrodesis alleviates pain and an extra-articular osteotomy is required. Attempted realignment at the site of fusion may lead to nonunion and failure of fusion. Relative contraindications include patient medical comorbidities such as smoking, obesity, diabetes, peripheral vascular disease, peripheral edema, and skin conditions. Many patients find that the incidence and severity of these complications unacceptable risks for elective surgery in addition to the prolonged period of immobilization required.

**Calcaneal osteotomy techniques**

The patient may be positioned in either the lateral or supine position. Placing a sandbag beneath the ipsilateral hip tilts the pelvis and access is allowed with the hip adducted and the knee flexed and the foot held on a second sandbag. This position allows simulated weight bearing to be performed under fluoroscopic control without difficulty but screw placement can be difficult. For proximal calcaneal osteotomies an oblique incision at 45° to the sole of the foot may be used. This minimizes sural nerve injury and is proximal to the peroneal tendons. An L shaped mini extensile lateral incision may be used to elevate a full thickness skin flap. This preserves the integrity of the lateral calcaneal artery reducing the risk of edge ischemia, infection, and wound breakdown. Distal calcaneal osteotomies can be performed through a 5 cm longitudinal incision. Recently, an omega style incision has been described for fixation of fifth metatarsal base fractures to minimize iatrogenic injury to branches of the sural nerve [56].
Using a small Hohmann retractor, the peroneal tendons can be retracted inferiorly and a second retractor placed over the anterior process of the calcaneus.

A) **Single plane translational osteotomies**

Translational osteotomies of the calcaneus aimed to realign the posterior part of the foot tripod through a simple transverse osteotomy at the body of the calcaneus. The tuberosity can then be translated medially, laterally, proximally, distally, or combined depending on the type of deformities (Fig. 12A). Generally, medial translation is used for the correction of planovalgus deformity commonly associated with tibialis posterior dysfunction while the lateral translation is used for the correction of cavovarus deformity. Medial translation has been shown to unload the lateral aspect of the tibiotalar joint and decrease strain of the deltoid and spring ligaments (65). The calcaneal pitch can be corrected for either condition by allowing the tuberosity to migrate proximally or distally. The osteotomy is performed in line with the skin incision using a power saw. Great care is needed to avoid over-penetration of the saw blade toward medial neurovascular structures. Alternatively, the medial corticotomy can be completed using an AO chisel in a more controlled manner. The osteotomy is then gently distracted with a laminar spreader. The calcaneal tuberosity is manually translated while the ankle is in full plantarflexion to relax the Achilles tendon. The osteotomy is usually stabilized with 1 or 2 cancellous screws placed retrograde from the tuberosity or recently developed lateral based plate and screw constructs.

A translational uniplanar osteotomy may be performed using a percutaneous technique. The key here is that the Gilgi saw is tunneled close to the medial wall of the calcaneus, deep to neurovascular structures, through stab incisions medially. Either end of the Gilgi saw is then passed superior and inferior to the calcaneus and to the skin on the
medial side. The sawing action requires careful technique to avoid damaging the lateral stab incisions using an up/down action rather than side to side.

Figure 12. A, Single plane translational osteotomy (solid arrow) and Evans osteotomy (arrow head); B, Closing wedge osteotomy; C, Z-osteotomy. (84)

Medial Displacement Calcaneal Osteotomy (MDCO)

The traditional surgical approach for the MDCO is from the lateral aspect of the calcaneus. The patient is placed in a lateral decubitus position on the operating room table with general anesthesia or a regional nerve block. The incision is made on the lateral aspect of the heel posterior to the peroneal tendons and the sural nerve (fig 13). Sharp dissection is performed and the periosteum of the calcaneus is exposed (fig 14). Hohmann retractors are used both in the superior and inferior aspects of the incision to protect the Achilles and plantar fascia, respectively. A sagittal saw is used to perform the osteotomy from lateral to medial with the saw blade at 90 to the lateral wall of the calcaneus. Care should be used to protect the neurovascular and tendinous structures.
while completing the osteotomy on the medial side. If the saw blade courses too far on the medial aspect of the calcaneus, the toes often plantarflex. To protect the neurovascular structures, it is recommended to complete the osteotomy with a wide osteotome (fig 15). Once the osteotomy is completed, a lamina spreader is used to distract the osteotomy to relax the soft-tissue attachments on the calcaneus to get a proper medial shift(65).

This osteotomy is purely a translational shift of the posterior tuberosity in the medial direction. It is recommended not to apply an additional varus force to the tuberosity during the medial shift. An intraoperative calcaneal axial view is helpful to ensure a vertical heel is obtained without creating an iatrogenic varus deformity (fig 16).

Fixation of the MDCO is done using Kirschner wires, staples, 1 or 2 lag screws, or a laterally based plate (fig 17). The MDCO often heals without minimal concerns of a nonunion.

The postoperative course of this osteotomy is often dictated by the use of additional procedures to correct the flatfoot deformity. However, if an isolated osteotomy is performed, protected weight bearing in a cast can be performed at 3 weeks, with transition to a boot walker by the 6-week period or when consolidation of osteotomy is seen on radiographs.

The MDCO is a technically straightforward procedure used in stage II PTTD. It can be performed in any clinical situation when hindfoot valgus is present to convert the Achilles tendon force from a deforming valgus direction to an inverting one (58).

The MDCO protects the medial soft-tissue structures in flatfoot reconstruction, namely the posterior tibial tendon and flexor digitorum longus tendon. This osteotomy provides the necessary off-loading force to protect a repaired posterior tibial tendon or transferred flexor digitorum longus tendon (59).
Fig. 13. Incision placement for the MDCO along the lateral calcaneus in an oblique manner posterior to the peroneal tendons and sural nerve. (60)

Fig. 14. Exposure of the lateral wall of the calcaneus for the MDCO. (60).
Fig. 15. Completion of the MDCO with a broad osteotome to protect the neurovascular structures on the medial aspect of the foot (60).

Fig. 16. Intraoperative calcaneal axial view of the MDCO demonstrating a pure medial shift of the posterior tuberosity of the calcaneus. (60)
Fig. 17. (A) Fixation of the MDCO with 2 large cannulated lag screws. (B) Alternative fixation of the MDCO with a stepped locking plate along the lateral wall of the calcaneus. (60)

B) Lateral column lengthening osteotomy (Evans)

The lateral column of the foot comprises the anterior facet of the calcaneus, its articulation with the cuboid and the fourth and fifth tarsometatarsal joints. Lateral column lengthening procedures are typically used in patients with a pes planovalgus deformity. Procedures can be carried out at any level of the lateral column, but typically include a medializing calcaneal osteotomy, a distraction calcaneocuboid arthrodesis, or a lengthening osteotomy of the anterior process of the calcaneus. The goals of any or all of these procedures is to treat the patients symptoms by alleviating any discomfort and correct the clinical deformity, which improves foot kinematics during the gait cycle and reduces the likelihood of rapid progression of the disorder with degenerative changes in the hindfoot and midfoot(80).
Chapter 2  Calcaneal Osteotomy in Flexible Flatfoot

Brief History

It is fascinating to think that the origins of this procedure emanated from a mistake made by a surgeon during surgical correction of a clubfoot. In 1961, Dilwyn Evans published a series of relapsed clubfeet corrections. Part of the surgery was to perform a calcaneocuboid shortening excision arthrodesis. In 2 cases, however, he noticed an overcorrection owing to excessive bone excision, which produced a convex medial border and calcaneovalgus. After attempted corrections with calcaneal osteotomies, he finally deciphered that the shortened lateral column had produced lateral rotation of the navicular on the talus that could not be simply corrected by a mechanical shift of the heel. He, therefore, realized the lateral column needed to be lengthened to medialize the heel, reduce the convexity of the medial border, and somewhat restore the natural equinus of the foot.

In the normal foot the medial and lateral columns are about equal in length, in talipes equino-varus the lateral column is longer and in calcaneovalgus shorter than the medial column. The suggestion is that in the treatment of both deformities the length of the columns be made equal.” This quote is an extract from Evans last paper entitled “Calcaneovalgus deformity” published in August 1975. Sadly, he passed away in November 1974 at the age of 64, never to witness arguably his most famous legacy.

Evolution

Before the introduction of the lateral column lengthening, treatment of the flatfoot deformity usually involved arthrodesis procedures. In Evans 1975 article, it is clear he wanted to preserve the calcaneocuboid joint. His original technique was first performed in 1959 for overcorrected talipes equinovarus, calcaneovalgus after polio, rigid
flatfoot, and idiopathic calcaneovalgus. After his surgery on overcorrected club feet, he stated: Perhaps the most interesting single point that has emerged from this series of cases is the conversion of varus into valgus. It then became obvious that excessive shortening of the lateral border of the foot had produced an excessive lateral rotation of the navicular on the head of the talus and that the remedy was to undo the calcaneocuboid fusion and to lengthen the lateral border of the foot by inserting a wedge graft. This was tried and it produced, in varying degree, three effects; the heel moved towards neutral, the convexity on the medial border was reduced, and the foot as a whole moved slightly into equinus.

Overall, Evan then performed this procedure in 56 feet for a variety of conditions. He describes making an osteotomy 1.5 cm behind the joint in the anterior calcaneus but parallel to the plane of the joint. The osteotomy was then filled with ipsilateral tibial cortical bone. Non–weight-bearing in a plaster is instituted for 4 weeks with the plaster on for 4 months. Mosca and colleagues3 modified the Evans procedure. Mosca based his operative technique on the observation that the center of rotation for the correction is near the center of the talar head and not simply the medial calcaneal cortex; thus, the osteotomy is not a plain distracting or opening wedge osteotomy. The direction of his osteotomy was modified by directing it proximal/ lateral to distal/medial in an oblique fashion; however, its starting point was 1.5 cm proximal to the calcaneocuboid joint. He then recommended filling the gap with a trapezoidal shaped tri-cortical iliac crest graft.

**How Does Lateral Column Lengthening Correct the Foot?**

Evans’ 1975 article170 demonstrates how complex relationships and biomechanics in the foot can be theorized by simple observation: “Logic suggested that if this shape (calcaneo valgus) had been produced by excessive shortening of the lateral column (during clubfoot corrective
surgery) it should be possible to improve the shape (of the foot) by lengthening the lateral column by insertion of a bone graft.” Although Evans noticed that as the valgus forefoot deviation disappeared with the navicular moving medially on the talus and the heel took up a more varus posture with restoration of a more cavus midfoot on graft insertion, the exact mechanism by which lateral column lengthening corrects the foot position remains poorly understood. Radiologic evidence for improvement of foot posture was shown by Sangeorzan and associates in 1993. Although a small study of only seven adults following Evans osteotomy by comparing anteroposterior and lateral projection preoperative and postoperative radiographs, they showed that lateral talocalcaneal angle improved by 6.4°, the talonavicular coverage improved by 26° and the calcaneal pitch improved by 10.8°. Their greatest angular improvement was in the talonavicular coverage, suggesting this is quite a good indicator of mid/forefoot alignment. As the foot corrects, it was thought the responsible force was increased tension in the windlass mechanism akin to the Jacks hyperextension test, but Horton and co-workers disproved this theory by using strain gauges in the plantar fascia and actually showed that the medial fascia actually loosens by an average of 2.7 mm. With improvements in computed tomography and generation of 3-dimensional models, DuMontier and associates were able to elegantly show the changes produced in the foot by performing an Evans procedure. The structure of the head of the talus affects the movement of the navicular around it.

The talar head is wider in a medial-lateral direction than dorsal-plantar direction. As the lateral column is lengthened, the forefoot moves medially at the transverse tarsal joint. The navicular also moves slightly plantarward (short radius of curvature) resulting in forefoot adduction and plantarflexion and increased arch height. The navicular rotated 18.6° of
adduction, 2.6° pronation, 3.4° plantarflexion, 5.6 mm medial, 0.4 mm posterior, and 1.8 mm plantar. The cuboid rotated 24.2° of adduction, 13.9° pronation, 1.9° plantarflexion, 9.4 mm medial, 2.6 mm distal, and 1.5 mm plantar. They found the calcaneum did not move into varus relative to the talus or tibia, suggesting that the significant correction of the mid and forefoot on the hindfoot gives the appearance of a calcaneovarus.

**Operative technique**

The lateral column lengthening procedure is achieved through an opening wedge osteotomy of the anterior calcaneus. Patient positioning is identical to what is used for an MDCO, lateral decubitus with general anesthesia. A 5- to 7-cm transverse incision is made starting at the CCJ, traveling proximally along the anterior calcaneus parallel and superior to the peroneal tendons (fig 18). The sural nerve and peroneal tendons are typically identified in the inferior aspect of the incision and are protected throughout the procedure (fig 18).

The extensor digitorum brevis muscle is reflected dorsally off the calcaneus and the CCJ is identified, but the capsule is not violated. Starting approximately 13 mm from the CCJ, a sagittal saw is used to create the osteotomy parallel to the CCJ (fig 19). Completion of the osteotomy is performed with a small osteotome, which also allows the medial cortex of calcaneus to be preserved, but weakened, to obtain proper distraction. Using a lamina spreader or pin-based retractor, distraction of the osteotomy allows for insertion of the bone graft (fig 20). Tricortical patellar or iliac crest allograft has been the traditional form of bone graft for lateral column lengthening (fig 21). However, new technology has now allowed surgeons to choose from prefashioned, size-specific Evans wedges made of either allograft bone or porous titanium metal. These wedges create a custom length for distraction of the
osteotomy, while also allowing the surgeon to dial in the amount of correction needed with trial sizing wedges before final insertion (60).

Fixation options to secure the bone graft have historically included no fixation or percutaneous Kirschner wires; however, most surgeons recommend at least some form of fixation with a small-diameter screw, low-profile locking plates, or an opening wedge plate (fig 22). Although it is reasonable not to fixate the graft, it is recommended that fixation to minimize displacement and micromotion at the graft-host interface.

Postoperative recovery course of an Evans osteotomy often includes 4 to 6 weeks of non-weight bearing immobilization. Serial postoperative radiographs should monitor incorporation of the bone graft. Protected weight bearing in a boot walker from 6 to 10 weeks should be instituted until clinical and radiographic healing occurs. Although the incidence of a nonunion after the Evans osteotomy is low, care should be taken to ensure the osteotomy is fully healed before transitioning to regular shoe gear (62).

Lateral column lengthening is a powerful procedure that reconstructs the medial arch and corrects peritalar lateral subluxation. The clinical indication in stage II AAFD is a patient with a clinically reducible hindfoot with deformity in both the transverse and sagittal planes. DuMontier and colleagues (61) demonstrated the mechanism of flatfoot correction with the Evans osteotomy using a 3-dimensional flatfoot cadaver model. They demonstrated that, as the lateral column is lengthened, the midfoot is directed in an adducted and plantarflexed position relative to the hindfoot, which increases arch height with contributions from the long plantar ligament, plantar talonavicular capsule, and the lateral portion of the calcaneonavicular ligament. In addition, they did not show a varus movement of the calcaneus relative to the talus; however, clinically the foot is in a corrected position because
the midfoot and forefoot are in a more anatomic alignment relative to the hindfoot.

Fig. 18. Incision approach to the Evans lateral column lengthening starting at the CCJ. (60)

Fig. 19. A sagittal saw is used to perform the Evans osteotomy starting approximately 13 mm proximal from the calcaneocuboid joint. (60)

Fig. 20. A pin-based distractor can be placed across the osteotomy to facilitate distraction to fill with bone graft (60)
Fig. 21. Insertion of a tricortical iliac crest allograft wedge for distraction of the Evans osteotomy (60).

Fig. 22. Fixation of the Evans lateral column lengthening osteotomy with an opening wedge locking plate. (60).

**Graft type**

The ideal graft size has been studied extensively and recommendations have been made from both clinical and cadaveric studies. Currently, most authors advocate a graft length between 8 and 12 mm, usually 10 mm. (63,64) Corticocancellous allograft and autograft are the 2 main types used. Dolan performed a randomized, controlled trial comparing iliac crest graft with allograft for calcaneal lengthening in adults. Of the 33 feet, 18 had an allograft and 15 had autograft. All patients achieved union by 12 weeks. In the allograft group, 94% united by 8 weeks, whereas only 60% of autografts had united by 8 weeks. Two
autograft cases had hip scar pain at 3 months, but is unclear whether it persisted. (66) Anecdotally, surgeons are concerned about allograft incorporation, but Mosca also achieved 100% union in 24 cases with allograft and 7 with autograft use in modified Evans procedures, albeit in children. Grier and Walling (67) compared tricortical allograft and autograft both supplemented with platelet-rich plasma in adults in both joint arthrodesis and Evans procedures; they achieved 94% union with allograft and 70% with autograft. Philbin and co-workers (68) achieved 96% union in 28 feet undergoing lengthening with fresh-frozen tricortical grafts. Templin and associates report 97% union in 30 pediatric cases of lengthenings. Other studies report mainly on the use of iliac crest autograft and union rates vary from 80% to 100% in both calcaneocuboid arthrodesis and Evans-type procedures. (69,70).

Iliac crest donor site morbidity can potentially be a site of morbidity; however, in foot surgery the donor volume requirements are usually low, necessitating only a small incision with minimal resection. Morbidity reported varies from 2.4% up to 31% suffering from chronic pain after 2 years.

Graft collapse and loss of correction can potentially be a source of concern after lateral column lengthening procedures, but clinical correlation can be difficult. In a large pediatric, series Danko and colleagues(71) found 17 of 58 of calcaneocuboid joint arthrodesis allografts and 3 of 3 autografts collapsed, but neither allograft nor autograft used in their Evans procedures collapsed. They suggested lateral column lengthening through the anterior process of the calcaneus is a more durable option. Conti and Wong (72) also experienced graft collapse in 16% of distraction arthrodeses. Five out of 6 were fixed with a K-wire and 1 with an H-plate. It is likely that lack of stability with wire fixation contributed to failure and ultimately collapse. Kimball and
associates (73) studied the properties of screw and plate fixation in lateral column lengthening and discovered that nearly 3 times the force was required to create a 1-mm graft–host interface with plate fixation. Collapse of allograft may also be due to the mechanical properties of the material that may be adversely affected by the method of sterilization and storage. Fresh-frozen grafts tend to have least impact on strength although biomechanical studies have shown that irradiating or freeze drying bone does not significantly reduce ultimate tensile stress/strain compared with controls. (74) The authors were unable to uncover any objective clinical evidence for the use of synthetic materials specific to lateral column lengthening procedures as a graft in either calcaneocuboid distraction arthrodesis or anterior process lengthenings; however, current research into the use of synthetic materials in foot and ankle arthrodesis models is showing some promising results. Digiovanni and co-workers performed a randomized, controlled trial with the recombinant form of platelet-derived growth factor, which was utilized as a bone graft substitute material in all hindfoot fusion procedures. They randomized this material with autologous bone graft harvest. At 36 weeks, fusion rates were available in 18 patients, with 10 of 13 (72%) synthetic grafts and 3 of 6 (50%) autologous grafts achieving fusion. Although one may consider these are relatively low fusion rates, the results suggest synthetic grafts may be a suitable alternative to autograft, with no donor site morbidity.

C) Complex osteotomy (Z-osteotomy)

Similarly to osteotomies of the first metatarsal a scarf joint has the ability to be moved in all 3 planes and yet still preserve stability. This Z osteotomy starts supero-proximally, posteriorly to the posterior articular facet, then extends distally and finally a distal plantar cut. The obliquity of the superior and inferior cuts provides bone on bone apposition for
healing. A wedge may be placed into the distal inferior cut in a manner similar to the Evans osteotomy permitting lengthening of the lateral column as well as medial translation of the posterior of the calcaneus.

The calcaneal Z osteotomy is a useful procedure that combines the effects of both the MDCO and the Evans lateral column lengthening into one osteotomy. The surgical approach is similar to that described earlier, with the patient in a lateral decubitus position with general anesthesia. The incision is placed in a transverse manner over the anterior calcaneus; however, it is placed more proximally to incorporate the transverse and vertical arms (fig 23). The periosteum is incised, and the lateral wall of the calcaneus is exposed. Care should be taken to expose both the peroneal longus and brevis tendons, which should be retracted either superiorly or inferiorly during the completion of the osteotomy (60).

The osteotomy is created with 3 portions: (1) the posterior proximal arm exiting superiorly in the posterior tuberosity, (2) a transverse horizontal arm parallel to the plantar surface, and (3) the anterior inferior arm in the region of the traditional Evans osteotomy. These 3 arms of the osteotomy are ideally at right angles to each other. The osteotomy is performed with a sagittal saw starting with the posterior superior arm and ending with the anterior inferior arm. The osteotomy, which is through and through the calcaneus, is completed with an osteotome (fig 24).

The osteotomy is first shifted in a medial direction similar to an MDCO and pinned temporarily with 1 or 2 guidewires for cannulated lag screw fixation. Second, a pin-based distractor is placed in the anterior portion of the calcaneus to provide distraction of the anterior portion to accomplish lengthening of the lateral column (fig 25) (60).
Correction of the flatfoot deformity is then confirmed with intraoperative fluoroscopy, ensuring the talar head coverage has been corrected.

Insertion of bone graft into the anterior calcaneus is then performed before final fixation of the posterior calcaneal arm. Prefashioned allograft or titanium wedges can be placed in the anterior arm to hold distraction for the lateral column lengthening portion.

Next, fixation with 1 or 2 cannulated lag screws is delivered through the posterior proximal arm (fig 26). This fixation must be performed after placing the bone graft for the lateral column lengthening because the posterior arm must be semimobile to accommodate the insertion of the graft.

This osteotomy incorporates a wide bony surface area, which allows early consolidation and inherent stability. Protected weight bearing can usually be instituted with the calcaneal Z osteotomy at 6 to 8 weeks postoperation, depending on radiographic consolidation and the use of additional surgical procedures(60).

The calcaneal Z osteotomy is also a powerful procedure that can be used to replace the double calcaneal osteotomy (MDCO and Evans osteotomy). This osteotomy offers the benefits of both the MDCO and Evans osteotomy, allowing translation medially and lengthening of the lateral column. This osteotomy also provides 3-dimensional correction of the flexible abducted and valgus foot(60).
Fig. 23. Incision placement and approach to the calcaneal Z osteotomy. A transverse approach distally over the anterior calcaneus is made, while the proximal aspect is carried over the posterior tuberosity. (60).

Fig. 24. Completion of the calcaneal Z osteotomy with an osteotome. (60)
Fig. 25. A pin-based distractor is placed on the anterior-inferior arm of the Z osteotomy to facilitate lateral column lengthening. Insertion of an allograft or titanium wedge is then performed. In this figure, a trial size wedge is placed to confirm deformity correction. (60).

Fig. 26. Final fixation of the calcaneal Z osteotomy with 2 cannulated lag screws to fixate the proximal vertical arm and a titanium wedge to accomplish lateral column lengthening. (60).

Complications

Complications with calcaneal osteotomies include over and under correction, the lack of appreciation of heel cord tightness, and those of all osteotomies such as nonunion and local complications to the sural nerve.
and skin. Nerve injury from lateral surgical approaches to the calcaneus has been well studied in the anatomy and trauma literature, and can result in temporary or permanent irritation along the course of the sural nerve at the heel with neuroma formation and distal dysesthesia [75]. A painful scar, with or without identifiable nerve injury, may also be associated with a surgical approach to the calcaneus.

Tarsal tunnel syndrome has been associated with calcaneal osteotomy. Higher risk of tarsal tunnel syndrome is associated with greater translation of the osteotomy and osteotomies performed more anteriorly on the tuberosity [76]. This is presumably because of irritation of the nerve passing through the tarsal tunnel and the sinus tarsi.

Overcorrection is an uncommon complication that demonstrates the power of the calcaneal osteotomy, and has been reported in a single case for a planovalgus foot overcorrected into varus by medial slide osteotomy.

Painful hardware is relatively common for calcaneal osteotomy. Screw heads that are placed in the posteroinferior tuberosity or a lateral plate for a translational or Evans osteotomy are potential sources of hardware related pain [77]. Patients should be counselled for this and the potential requirement for hardware removal in the future.

**Degenerative joint disease**

Lateral column lengthening through the calcaneocuboid joint is an alternative to joint-preserving surgery. Evans suggested preserving the joint through his osteotomy; however, studies have shown that the contact pressure generated across the calcaneocuboid joint after lengthening may actually rise, raising concerns that this may predispose to early degenerative change.
Chapter 2  Calcaneal Osteotomy in Flexible Flatfoot

Lateral foot pain

Continued lateral foot discomfort can be an issue postoperatively after any lateral column lengthening procedure. Although the operation can correct the abduction of the forefoot, it may not reliably correct the supination deformity in the axial plane. This can subsequently cause the patient to overload the lateral border on weight bearing, which can be significantly distressing to the patient. As a result of this column overload, reports of stress fractures to the base of the fifth metatarsal have emerged (69). Tien and colleagues (64) hypothesized that, by performing a distraction arthrodesis at the level of the Chopart joint, it would allow the surgeon more freedom to rotate the forefoot on the midfoot, thus potentially reducing the plantar pressures in comparison with a more proximally based osteotomy for an Evans-type procedure. They found, however, that the plantar pressure increases under the fifth metatarsal head were statistically greater for the distraction arthrodeses procedure than the Evans-type procedure (64). This study to some degree echoed the findings of Thomas and associates, in a clinical study previously mentioned (63). Among 34 feet, 17 underwent Evans procedures and 17 calcaneocuboid joint fusions. In the fusion group, 3 had graft stress fractures, 1 had a fifth metatarsal fracture, and 3 had residual supination deformities. All of these complications may quite easily either result in or lead to lateral foot overload. It is likely that the effect of forefoot overload may be related to the degree of correction achieved at the osteotomy or arthrodesis site. It has been suggested that by carefully templating the correction to be achieved intraoperatively by using trial metal wedges in the osteotomy site during an Evans-type procedure before introduction of the graft can reduce the incidence of postoperative plantar lateral foot pain. Ellis and co-workers (78) developed the simple idea of intraoperative metal wedge templates to subjectively measure the
correction of the talonavicular abduction and degree of forefoot stiffness in eversion after the insertion of the wedge into the osteotomy site. Before the use of trial wedges intraoperatively, the incidence of patient reported lateral foot pain was 14.7%; after the introduction of the wedges, the incidence decreased to 6.3% (P .084). Although not a significant reduction in reported pain, they did find the revision rates were significantly reduced after use of trial wedges (from 12.8% to 3.7%; P 0.03). Their average graft length was 6.8 mm (range, 4–10). It is possible, therefore, by simply reducing the length of the graft, to potentially reduce the effect of lateral foot overload. It has also been suggested that the surgeon should, as well as reducing the graft length, attempt to plantarflex and adduct at the osteotomy site by shaping the graft like a trapezoid Chopart joint. This is similar to the Mosca trapezoidal wedge, which is a wedge with a lateral border 10 to 12 mm long and a medial border of 4 to 6 mm (Mosca did not describe a plantar-flexing effect of the graft). After internal fixation of the lateral column, patients can sometimes complain of prominent metalwork, especially if the foot is not fully corrected. Delayed metalwork removal is necessary in up to 30% of cases,(79) and this should be remembered when planning surgical fixation. Taking this into account, the authors recommend the use of lower profile locking plates that may reduce the risk of structural irritation and of later hardware removal.
Chapter 3

Results and Effect of Calcaneal Osteotomy in Correction of Flatfoot Deformity
Outcomes Planus Correction

Abdel-Salam A. Ahmed (83) reported on a series of 14 patient of FFF in which Mosca technique of calcaneal lengthening osteotomy was performed. Calcaneal lengthening osteotomy was performed using Mosca’s technique in 14 patients including ten males and four females. Five cases were bilateral making the total of 19 feet. The mean age at surgery was 13.53 (range 11.5–16) years. All FFF patients were evaluated as idiopathic. Bilateral cases were operated on at two sessions with an average interval of 15.6 (range 12–21) months. The American Orthopaedic Foot and Ankle Society ankle-hind foot scale was used for clinical assessment, and radiographic assessment was based on six parameters on standard anteroposterior and lateral radiographs.

The mean follow-up period was 27.89 (range 18–44) months. The mean American Orthopaedic Foot and Ankle Society score increased from 57.53 preoperatively to 96.32 postoperatively. All radiographic parameter significantly improved. Four patients had mild occasional pain. There was no nonunion nor secondary subsidence of the arch. All patients stated that they were satisfied with the procedure.

Correction of FFF deformity with Mosca’s lateral calcaneal lengthening was an effective and reproducible method to restore normal foot alignment and good function (83).

The literature reporting on the outcome of the operative treatment of pes planus and hindfoot valgus reveals outcomes of both sliding osteotomies, Evans distal calcaneal opening wedge osteotomies together with either medial column arthrodesis or soft tissue reconstruction.
Mosca reported on a series of 31 feet producing severe symptomatic valgus hindfoot deformities in which Evans osteotomies were performed. After a 2–3.5 year follow-up, 29 out of 31 patients reported satisfactory outcome and radiographically the lateral talar-first metatarsal head angle was reduced from 31° to 5° postoperatively [84].

Hintermann has reported the outcome of calcaneal osteotomies together with tendon transfer, deltoid ligament repair, or spring ligament repair in patients with grade II and III tibialis posterior dysfunction. For those in whom a medial translational osteotomy was performed, the American Orthopedic Foot and Ankle Score (AOFAS) improved from 49 to 91 and all patients were satisfied with the result [81]. In those who were treated with a lengthening of the lateral column 17 out of 19 patients had excellent or good corrections. One patient had future loss of correction and another required subsequent calcaneocuboid joint surgery [81]. Both procedures seem to produce good results.

Iaquinto performed an Evans opening wedge osteotomy which led to double the calcaneocuboid contact pressures in a cadaveric model. A medializing calcaneal osteotomy was found to shift plantar forefoot loads from lateral to medial (85) Recently Cao performed medial displacement calcaneal osteotomies and tendon transfers for flexible flat foot. All 16 patients were satisfied and pain free at 6 months. AOFAS increased from 53 to 91 [86].

A retrospective study of patients with adult flat foot (n =41) treated with a medial column arthrodesis together with a calcaneal osteotomy. Radiographic parameters of talonavicular coverage, the calcaneal inclination and the lateral talometatarsal angle were all improved. There were however, 4 nonunions at the navuculocunieform joint and one at the tarsometatarsal joint [87-88]. A case example is illustrated in figure 26.
Figure 27. Preoperative (A) and postoperative (B) weight-bearing lateral radiographs of a patient with severe pes planus that underwent a combination of medial translational osteotomy, Evans osteotomy, medial column stabilization, and soft tissue repair. Improvement in alignment is shown using Meary’s lines the tibiotalar angle reduced from 26° to 5.5°, 44.5° to 28°, and ° (87-88).

Important Surgical Issues Calcaneocuboid distraction arthrodesis or lengthening calcaneal osteotomy?

There is no level 1 evidence directly comparing these 2 techniques. Most studies of either technique are level 4 evidence, with a variety of other associated procedures performed and are therefore difficult to interpret.
Thomas and colleagues (89) compared the 2 techniques in 37 adult patients who had concomitant flexor digitorum longus transfers (39 feet), but only 27 feet were available for follow-up at a mean of 52 months (Evans procedure, 10 feet) and 24.7 months (arthrodesis, 17 feet). Radiographic loss of position was noted compared with initial postoperative x-rays, but the only significant difference was a small decrease in calcaneal pitch angle that was more evident in the arthrodesis group (3.82° vs 6.44°; P .014). Functional AOFAS (American Orthopedic Foot and Ankle Society) was not significantly different between the groups (80.9 vs 87.9). The complication rates were much higher in the arthrodesis group (7/17 in the Evans group, 16/17 in the arthrodesis group, with 14 common to both groups) despite follow-up being significantly longer in the Evans group. Of note there were 2 non-unions and 3 delayed unions in the arthrodesis group.

Haeseker et al retrospectively analyzed 33 patients with adult acquired flatfeet of which 14 had distraction arthrodesis and 19 had lengthening osteotomy. Both groups in combination with medial soft tissue surgery. There was a significant difference in AOFAS (71.9 in the joint arthrodesis group at mean follow-up of 42.4 months and 84.9 in the osteotomy group at mean follow-up of 15.8 months). There was no difference between the 2 groups’ radiologic parameters preoperatively or postoperatively, which was correlated with length of follow-up. The arthrodesis group reported 3 complications: a wound infection, a chronic regional pain syndrome, and a nonunion. The lengthening group reported 3 also, 1 nonunion, 1 deep venous thrombosis, and 1 wound infection.

In Hiller and Pinney’s survey (90) of 104 surgeons in the United States, when asked how they would treat an adult acquired flatfoot stage 2
posterior tibialis tendon dysfunction, 101 would perform a bony procedure, of which 43 would perform a lateral column lengthening; of these, roughly half would undertake an Evans and half an arthrodesis(90). There is no consensus on which to perform, but it is the authors’ opinion that joint-preserving procedures should really be advocated and an Evans-type procedure be performed when possible.

**Calcaneal osteotomy versus subtalar arthrodesis or arthroereisis**

Numerous surgical procedures to correct flatfoot have been described. Surgeries that rely entirely on soft tissue procedures are known to stretch out and fail in the short term. Arthrodesis of one or more of the joints in the subtalar complex has a detrimental effect of eliminating the shock-absorbing function and shifts stress to the ankle and mid-tarsal joints leading to premature degenerative arthrosis at those sites. Therefore, present surgical recommendations focus on preservation of subtalar motion. Advocates of subtalar arthroereisis suggest that it is minimally invasive and preserves subtalar joint motion. Despite reports of good outcomes, it has associated complications. The complications include those associated with biomaterials problems (breakage, degradation), inappropriate implantation (over correction, undercorrection, malpositioning, extrusion of implant, wrong size of implant) and biologic problems (implant-induced sinus tarsi impingement pain, foreign-body reaction, synovitis, infection, intraosseous cystic formation in the talus, avascular necrosis of the talus, peroneal spasm, calcaneus fracture and stress fractures of the fourth metatarsal [91].

Osteotomy is the last category of procedures that has been used to treat flatfeet. The posterior calcaneus displacement osteotomy does not actually correct the malalignment of the subtalar joint, but merely creates
a compensating deformity to improve the valgus angulation of the heel. Vander Griend [92] described a Z-lengthening osteotomy of the calcaneus. This is more technically demanding, with probably more risk to damaging medially based structures. In 1975, Evans [93] originally described treatment of planovalgus deformity with lateral column lengthening using autogenous tibial cortical bone graft. In 1995, the technique was modified and further developed by Mosca [94] who described the specific location and direction of the osteotomy) exiting medially between the anterior and middle facets), and the trapezoidal shape of the bone graft. This was based on the observation that the centre of rotation for the correction is near the centre of the talar head and not simply the medial calcaneal cortex; thus, the osteotomy is a distraction wedge and not a simple opening wedge or plain distraction. In addition, Mosca described the management of the medial and lateral soft tissues, the need to temporarily stabilize the calcaneocuboid joint and the need to assess and concurrently manage contracture of the Achilles tendon [95].
Flexible flatfoot is a normal foot shape that is present in a large percentage of the population. There are more flatfeet in children than in adults. The arch elevates in most children spontaneously during the first decade of life. There is no evidence that a longitudinal arch can be created in a child’s foot by any external forces or devices. Flexible flatfoot with a short Achilles tendon, in contrast to simple flexible flatfoot, is known to cause pain and disability in some adolescents and adults. Surgery is indicated in flexible flatfeet with short Achilles tendons when conservative measurements fail to relieve pain under the head of the plantar flexed talus or in the sinus tarsi area. Joint preserving, deformity-correcting osteotomy techniques should be used along with Achilles tendon lengthening in those cases. Rigid forefoot supination is an additional deformity in many flatfeet that, if present, must be identified and treated concurrently during surgical reconstruction.

Calcaneal osteotomies are powerful, reliable, joint-preserving surgical procedures that are common components of the correction of planovalgus and cavovarus foot deformities. While its historical roots lie in the late 19th century, the procedure continues to evolve in the present day with the development of technique modifications and implant and technology advances. Clinical research studies show good results of calcaneal osteotomies, most of which include the procedure with other procedures. Continued research and development for surgical techniques and outcomes are indicated, as calcaneal osteotomy will foreseeable remain an important reconstructive option in the correction of foot deformity.
Lateral column lengthening procedures, either an Evans-type procedure or a calcaneocuboid distraction arthrodesis, clearly have a role to play in the management of a pes planovalgus foot deformity, as is evident from clinical outcome studies. Despite an abundance of literature intricately detailing the biomechanical effects of different operative procedures on the hindfoot, there is no clear consensus as to the best procedure or procedures to perform for a flexible pes planovalgus foot deformity. There is, therefore, no single solution to this problem; the surgeon must treat each patient as an individual and choose the procedure that will work best in their hands for any given foot pathology they are presented with. The surgeon must also be aware that to improve the kinematics of a planovalgus foot deformity, one may often have to perform multiple procedures and not a lateral column lengthening in isolation.

Calcaneal lengthening using the Mosca’s technique was effective in deformity correction and pain relief of painful FFF in adolescents. The procedure corrected all components of FFF while preserving subtalar joint motion. The technique is reproducible with minor complications.

The advantages of calcaneal lengthening osteotomy are as follows: it is technically easy to be applied, has a low risk of neurovascular injury and low loss of blood. In addition, it allows other procedures to be applied in the future contrary to arthrodesis. If arthrodesis is required later in these feet, it will be far easier to do because of the corrected alignment of the foot. However, future long-term studies may be needed to detect any deleterious effects on the subtalar joint caused by the osteotomy.
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ان القدم المفلطحة المرنة تعد شكل طبيعي والتي تتواجد بنسبة كبيرة بين الأفراد بدرجة تزيد هذه النسبة بين الأطفال عنها في الكبار. حيث أن التقوس الطبيعي للقدم يظهر تدريجيا في العقد الأول للحياة. ولا يوجد دليل على ان هذا التقوس الطبيعي يمكن ان يظهر في قدم الطفول بمداسة أجهزة خارجية . ان القدم المفلطحة المرنة وخاصه المصاحبة بقصر في وتر الكليس تسبب الام في القدم خاصة في سن المراءفين والناضجين. ولذلك فإن التدخل الجراحي لعلاج القدم المفلطحة يتم عند افضل العلاج الطبي التحفظي وخاصة في الحالات المصاحبة بقصر وتر اكليس. وذلك يمكن اجراء كسر جراحي في عظم القدم وإجراء تطويل في وتر اكليس.

ان الكسر الجراحي لعظمة العقب يلعب دور كبير في اصلاح القدم المفلطحة المرنة وليس ذلك فحسب ولكنه يمكن ان تصلح التقوس الشديد للقدم . وهذه العملية لا توثر على مفاصل القدم. وعلى الرغم ان هذه العملية ترجع بدايتها إلى القرن التاسع عشر الا انه تم اجراء تعديلات فيها وتطوير في خطواتها وظلت هذه التعديلات الي وؤمنا هذا. ولقد أكدت الدراسات المتعددة ان هذه العملية ذات نتائج جيدة وناجحة. وما زالت الدراسات والأبحاث العلمي يتم اجرائها من أجل تطوير هذه العملية وتقنياتها من أجل اصلاح تشوهات القدم.

ان استطالة الجانب الخارجي للقدم بشتى الاجراءات الجراحية سواء عملية ايفانز او استطالة وسمكة الفصل بين عظمتي العقب والمكعبة لديه دور كبير في اصلاح القدم المقلطحة. وقد تبين ذلك من الدراسات المتعددة على الحالات الاكليتسيكية. ويجب على الجراح المعالج ان يختار الاجراء الجراحي المناسب و الذي يقدر الجراح على اجرائه بمهارة واتقان من اجل اصلاح تشوه القدم. وقد يتطلب ذلك اكثر من اجراء جراحي.

ان الكسر الجراحي لعظمة العقب لاصلاح القدم المفلطحة المرنة باستخدام طريقة موسكا لديه تأثير فعال لاصلاح التشوه الشكلي للقدم وكذلك في التخلص من الألم المصاحبه للقدم المفلطحة وخاصه في سن المراءفين. ان هذه العملية تقوم باصلاح كل عناصر التشوه للقدم مع الحفاظ على مفصل التالوس. كما ان معدل المضاعفات الناتجة عنها تعد قليلة جدا.
كما أن عملية إيفانز لديها مزايا متعددة في إصلاح القدم المفلتة منها سهولة الإجراء كما أن احتماليه حدوث مضاعفات مثل تأثر الدورة الدموية أو الاعصاب أو حدوث نزيف قليل جدا. كما أن هذه العملية تسمح بإجراء أي عملية جراحية أخرى في المستقبل مثل عمليات السمكرة وذلك عند الحاجة إليها.

بل على العكس فإن إجراء عملية السمكرة بعد عملية إيفانز يكون أسهل بكثير وذلك لاستعداد القدم سابقا في عملية إيفانز. كماانا في حاجة إلى دراسات متعددة على تأثير عملية إيفانز على مفاصل القدم وخاصة ما تحت التالوس.
دور الكسر الجراحي لعظمة العقب
في القدم المفلطحة المرنة

رسالة مقدمة

توطئة للحصول على درجة الماجستير في جراحة العظام

من الطبيب / أشرف فوزي عبدالجليل
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