Surgical Treatment Of Flexible Flatfoot

Essay

Submitted for Fulfillment of the Master Degree in Orthopedic Surgery

Presented by

Ahmed Ibraheem El-Kady
M.B.B.Ch.

Under supervision of

PROF. DR. SAMIR ZAHID
Professor of Orthopedic Surgery
Benha University

PROF. DR. AMR EL-GAZZAR
Assist. prof. Of Orthopedic Surgery
Benha University

DR. HOSSAM EL-SAYED FARAG
Lecturer Of Orthopedic Surgery
Benha University
Faculty of Medicine
Benha University
2015
Acknowledgment

First and foremost thanks to ALLAH, the most gracious and merciful.

I would like to express my thanks and gratitude to all the efforts which made this essay possible.

I will always be grateful to Prof. Dr. Samir Zahid professor of orthopedics Benha faculty of medicine who inspired me to start this work and introduced me to the scientific way of thinking and with the creative suggestion through the whole course of this work.

I am grateful to Prof. Dr. Amr El-Gazzar assistant professor of orthopedics Benha faculty of medicine not only for his guidance, advice and faithful supervision but also for the positive criticism he provided me to do this work and of course for the sincere help in my career.

I wish to express my thanks Dr. Hossam El-Sayed Farag lecturer of orthopedics Benha faculty of medicine for his valuable advice and support in making this essay come true and I will never forget the help he provided me in my career.

I also wish to express my thanks & gratitude to the staff members of orthopedic department Benha faculty of medicine for their kind help and co-operation.

To my parents and sisters and my lovely wife and great son who inspired me through my whole career, will always be grateful for them for their effort in raising me and helping me throughout my whole life.
<table>
<thead>
<tr>
<th>Contents</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Introduction</td>
<td>1</td>
</tr>
<tr>
<td>• RELEVANT ANATOMY</td>
<td>4</td>
</tr>
<tr>
<td>• ARCHES OF THE FOOT</td>
<td>7</td>
</tr>
<tr>
<td>• STRUCTURES SUPPORTING THE ARCHES OF THE FOOT</td>
<td>9</td>
</tr>
<tr>
<td>• BIOMECHANICS</td>
<td>22</td>
</tr>
<tr>
<td>• DIAGNOSIS</td>
<td>29</td>
</tr>
<tr>
<td>• Clinical examination</td>
<td>31</td>
</tr>
<tr>
<td>• Radiographic evaluation</td>
<td>39</td>
</tr>
<tr>
<td>• Differential diagnosis</td>
<td>43</td>
</tr>
<tr>
<td>• TREATMENT</td>
<td>56</td>
</tr>
<tr>
<td>• Non operative treatment:</td>
<td>58</td>
</tr>
<tr>
<td>• ORTHOTIC DEVICES</td>
<td>60</td>
</tr>
<tr>
<td>• Operative Treatment</td>
<td>63</td>
</tr>
<tr>
<td>• Soft Tissue Reconstruction</td>
<td>64</td>
</tr>
<tr>
<td>• Osteotomy</td>
<td>71</td>
</tr>
<tr>
<td>• Arthrodesis</td>
<td>81</td>
</tr>
<tr>
<td>• Arthroereisis</td>
<td>93</td>
</tr>
<tr>
<td>• SUMMARY</td>
<td>98</td>
</tr>
<tr>
<td>• References</td>
<td>103</td>
</tr>
<tr>
<td>• ARABIC SUMMARY</td>
<td>113</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Fig.No.</th>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>Bones forming arches of the right foot</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>Muscles of the lateral and anterior leg, lateral view</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>Lower extremity muscles</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>Short muscles of the first layer of the foot</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>Ligaments on medial side of the ankle and tarsal joints</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>Ligaments on the plantar surface of the foot</td>
</tr>
<tr>
<td>7</td>
<td>21</td>
<td>Plantar aponeurosis</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>The axis of movement of ankle joint</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>The angle of the axis of the ankle joint</td>
</tr>
<tr>
<td>10</td>
<td>27</td>
<td>Mechanical representation of the complex joint interactions</td>
</tr>
<tr>
<td>11</td>
<td>27</td>
<td>Subtalar joint</td>
</tr>
<tr>
<td>12</td>
<td>33</td>
<td>Flexible flatfeet</td>
</tr>
<tr>
<td>13</td>
<td>34</td>
<td>Jack's toe-raising test</td>
</tr>
<tr>
<td>14</td>
<td>35</td>
<td>Weight-bearing left flexible flatfoot and In toe-standing</td>
</tr>
<tr>
<td>15</td>
<td>36</td>
<td>Forefoot supination can best be appreciated when the hindfoot is inverted to neutral</td>
</tr>
<tr>
<td>16</td>
<td>38</td>
<td>Subtalar joint examination</td>
</tr>
<tr>
<td>17</td>
<td>40</td>
<td>Standing lateral radiograph showing three fairly reliable angular measurements</td>
</tr>
<tr>
<td>18</td>
<td>42</td>
<td>Standing radiographs of a flatfoot showing talus and first metatarsal axis lines</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>19</td>
<td>Congenital vertical talus</td>
<td>44</td>
</tr>
<tr>
<td>20</td>
<td>X ray Calcaneonavicular coalition</td>
<td>45</td>
</tr>
<tr>
<td>21</td>
<td>Reverse club foot</td>
<td>47</td>
</tr>
<tr>
<td>22</td>
<td>Calcaneovulgus flatfoot</td>
<td>48</td>
</tr>
<tr>
<td>23</td>
<td>X ray Accessory navicular</td>
<td>50</td>
</tr>
<tr>
<td>24</td>
<td>Non-pathological double heel raise</td>
<td>53</td>
</tr>
<tr>
<td>25</td>
<td>qualify the degree of loss of the medial longitudinal arch by the number of fingers</td>
<td>54</td>
</tr>
<tr>
<td>26</td>
<td>patient with tibialis posterior dysfunction on the right side displaying too many toes sign</td>
<td>54</td>
</tr>
<tr>
<td>27</td>
<td>Double heel raise test</td>
<td>55</td>
</tr>
<tr>
<td>28</td>
<td>Full legth orthosis</td>
<td>61</td>
</tr>
<tr>
<td>29</td>
<td>UCBL</td>
<td>62</td>
</tr>
<tr>
<td>30</td>
<td>Approach to tibialis anterior tendon</td>
<td>65</td>
</tr>
<tr>
<td>31</td>
<td>Flexor digitorum longus tendon was transferred to the navicular bone</td>
<td>68</td>
</tr>
<tr>
<td>32</td>
<td>The approach of Evan calcaneal osteotomy</td>
<td>72</td>
</tr>
<tr>
<td>33</td>
<td>Osteotomy of the calcaneus</td>
<td>74</td>
</tr>
<tr>
<td>34</td>
<td>Distractor used in manipulative procedure</td>
<td>74</td>
</tr>
<tr>
<td>35</td>
<td>Tricortical graft is fashioned to the precise configuration</td>
<td>75</td>
</tr>
<tr>
<td>36</td>
<td>The bone graft tamped into place in the central portion of the osteotomy</td>
<td>75</td>
</tr>
<tr>
<td>37</td>
<td>Re-approximation of EDB over graft</td>
<td>76</td>
</tr>
<tr>
<td>38</td>
<td><em>Koutsogiannis</em> medial displacement osteotomy</td>
<td>77</td>
</tr>
<tr>
<td>39</td>
<td>Approach of medial calcaneal osteotomy</td>
<td>78</td>
</tr>
<tr>
<td>40</td>
<td>X ray of medial calcaneal osteotomy</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>-----------------------------------</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Talonavicular arthrodesis</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Double arthrodesis</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Subtalar arthrodesis</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Triple arthrodesis</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td><em>The tarsal canal</em></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Intraoperative and anteroposterior view of screw</td>
<td></td>
</tr>
</tbody>
</table>
## LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACO</td>
<td>Anterior calcaneal osteotomy</td>
</tr>
<tr>
<td>AN</td>
<td>Accessory navicular</td>
</tr>
<tr>
<td>CCD A</td>
<td>Calcaneocuboid distraction arthrodesis</td>
</tr>
<tr>
<td>CORA</td>
<td>Center of rotation of angulation</td>
</tr>
<tr>
<td>CP</td>
<td>Calcaneal pitch</td>
</tr>
<tr>
<td>CVT</td>
<td>CONGENITAL VERTICAL TALUS</td>
</tr>
<tr>
<td>EDB</td>
<td>Extensor digitorum brevis muscle</td>
</tr>
<tr>
<td>FDL</td>
<td>Flexor digitorum longus</td>
</tr>
<tr>
<td>FFF-STA</td>
<td>Flexible flat feet with short tendo-achillis</td>
</tr>
<tr>
<td>FHL</td>
<td>Flexor hallucis longus</td>
</tr>
<tr>
<td>T-H</td>
<td>Talo-horizontal angle</td>
</tr>
<tr>
<td>T-1MT</td>
<td>Talus-first metatarsal angle</td>
</tr>
<tr>
<td>TPT</td>
<td>Tibialis posterior tendon</td>
</tr>
<tr>
<td>UCBL</td>
<td>University of California Biomechanics Laboratory</td>
</tr>
</tbody>
</table>
Introduction
Introduction

Flexible flatfoot in most cases is a physiological variant rather than a pathological condition. It occurs in all infants and is common in children and adolescent. Actually the medial longitudinal arch develops during the first decade of life. Many etiological factors contribute to flexible flatfoot, including familial tendency, generalized ligamentous laxity, obesity as well as shoe-wearing in early childhood. While the definit aetiology is unknown (Staheli LT et al, 1998).

Flatfoot serves more as a descriptive term of a lowered or absent medial longitudinal arch, with or without a valgus heel, than as a diagnosis of the underlying cause. This description encompasses pathologic or nonpathologic, rigid or flexible, and symptomatic or asymptomatic conditions (Engel GM et al, 1990).

Flexible flatfoot is almost generalized at birth. Its prevalence diminishes with age reflecting the development of the longitudinal arch that occurs spontaneously during the first years of life (Mosca VS, 1996).

Most cases of painless flexible pediatric flatfoot do not require treatment. Rigid or painful flatfeet, however, are more likely to require orthotics or surgical intervention. There remains considerable debate regarding the use of orthotics in painless, flexible flatfeet. Recent systematic reviews of the current literature demonstrated that there is very limited evidence for the efficacy of nonsurgical interventions for children with flexible flatfoot (Garcia et al, 1999).
Flatfoot is truly a diagnosis of common appearance with variable etiologies. Each patient must be evaluated thoroughly to determine the underlying cause of the flatfeet. Treatment plans should be individualized to the cause and reserved for the symptomatic cases or cases where family history, gait dysfunction, or other co morbidities suggest the likelihood of greater dysfunction over time (Wenger DR et al, 1999).

There was a statistical significant relation between the age of the patient at the time of surgery and the final results. The best results were achieved around the age of ten years. There was significant improvement of pain and patient’s level of activity at the end of the follow up (Tudor A, et al 2009).

The components of the deformity in the form of heel valgus, collapse of the medial longitudinal arch and forefoot abduction were significantly improved at the end of follow up period compared to the preoperative state (Harris RI, 1948).

Surgical treatment options include hindfoot fusion, soft tissue procedures, calcaneal osteotomies, limited midtarsal arthrodesis, combination techniques, and subtalar arthroereisis. Long-term, high success rates have been documented with use of combination procedures and the anterior calcaneal osteotomy (Mosca VS, 1995).
RELEVANT

ANATOMY
RELEVANT ANATOMY

The human foot is a complex structure adapted to allow orthogradc bipedal stance and locomotion and is the only" part of the body which is in regular contact with the ground. There are 28 bones in the human foot, including the sesamoid bones of the first metatarsophalangeal joint and 31 joints, including the ankle joint (Gray's Anatomy, By Susan standring 2005).

The foot is divided into the hindfoot, consisting of the talus and calcaneus, the midfoot consisting of the navicular, cuboid and three cuneiforms and the forefoot consisting of the five metatarsals and the corresponding phalanges (Fig. 1) (Gray's Anatomy, By Susan standring 2005).

The bones of the foot are connected by fibrous structures, intrinsic muscles and extrinsic muscles. The important multiple joints related to the foot are the ankle-joint (tibiotalar); subtalar joint (talocalcaneal), transverse tarsal (Chopart’s joint) and tarsometatarsal - (Lisfianc joint) (Gray's Anatomy, By Susan standring 2005).
Fig. (1): Bones forming arches of the right foot (Snell ,2000).
ARCHES OF THE FOOT

Three main arches are recognized in the foot. They are the medial longitudinal, the lateral longitudinal and the transverse arches (Gray's Anatomy, By Susan standring 2005).

Medial Longitudinal Arch:

The medial margin of the foot arches up between the heel proximally and the medial three metatarsophalangeal joints to form a visible arch (Fig.1). It is made up of the calcaneus, talar head, navicular, the three cuneiforms and the medial three metatarsals. The posterior and anterior pillars are the posterior part of the inferior calcaneal surface and the three metatarsal heads, respectively. The bones themselves contribute little to the stability of the arch, whereas the ligaments contribute significantly. The most important ligamentous structure is the plantar aponeurosis, which acts as a tie beam between the supporting pillars. Dorsiflexion, especially of the hallux, draws the two pillars together, thus heightening the arch: the so-called ‘windlass’ mechanism. Next in importance is the spring ligament, which supports the head of the talus. If this ligament fails, the navicular and calcaneus separate, allowing the talar head, this is the highest point of the arch, to descend. The talocalcaneal ligaments and the anterior fibres of the deltoid ligament, from the tibia to the navicular, also contribute to the stability of the arch (Gray's Anatomy, By Susan standring 2005).
Lateral Longitudinal Arch:

The lateral longitudinal arch is much less pronounced arch than the medial one. The bones making up the lateral longitudinal arch are the calcaneus, the cuboid and the fourth and fifth metatarsals: they contribute little to the arch in terms of stability (Fig. 1). The pillars are the calcaneus posteriorly, and the lateral two metatarsal heads, anteriorly. Ligaments play a more important role in stabilizing the arch, especially the lateral part of the plantar aponeurosis and the long and short plantar ligaments. However, the most important contribution to the maintenance of the lateral arch is made by the tendon of peroneus longus. The lateral two tendons of flexor digitorum longus (and flexor accessorius), the muscles of the first layer (lateral half of flexor digitorum brevis and abductor digiti minimi) and peroneus brevis and peroneus tertius also contribute to the maintenance of the lateral longitudinal arch (Gray's Anatomy, By Susan Standring 2005).

Transverse Arch:

The bones involved in the transverse arch are the bases of the five metatarsals, the cuboid and the cuneiforms (Fig. 1). The intermediate and lateral cuneiforms are wedge-shaped and thus adapted to maintenance of the transverse arch. The stability of the arch is mainly provided by the ligaments, which bind the cuneiforms and the metatarsal bases, and also by the tendon of peroneus longus, which tends to approximate the medial and lateral borders of the foot. A shallow arch is maintained at the metatarsal heads by the deep transverse ligaments, transverse fibres that bind together the digital slips of the plantar aponeurosis, and, to a lesser extent, by the transverse head of adductor hallucis (Gray's Anatomy, By Susan Standring 2005).
STRUCTURES SUPPORTING THE ARCHES OF THE FOOT

A- Tendons of Long Muscles

(1) Tibialis Anterior muscle:

The tibialis anterior (TA), the most medial and superficial dorsiflexor, is a slender muscle that lies against the lateral surface of the tibia (Fig. 2). The long tendon of the TA begins halfway down the leg and descends along the anterior surface of the tibia. The tendon passes within its own synovial sheath deep to the superior and inferior extensor retinacula to its attachment on the medial side of the foot. In so doing, its tendon is located farthest from the axis of the ankle joint, giving it the most mechanical advantage and making it the strongest dorsiflexor (Moore, et al 2006).

Although antagonists at the ankle joint, the TA and the tibialis posterior (from the posterior compartment) both cross the subtalar and transverse tarsal joints to attach to the medial border of the foot and thus act synergistically to invert the foot (Moore, et al 2006).
Fig.(2) : Muscles of the lateral and anterior leg, lateral view (Richardson, 1998).
(2) Peroneus Longus:

The Peroneus longus (PL) is the longer and more superficial of the two peroneus muscles, arising much more superiorly on the shaft of the fibula. The narrow PL extends from the head of the fibula to the sole of the foot. Its tendon can be palpated and observed proximal and posterior to the lateral malleolus. Distal to the superior fibular retinaculum, the common sheath shared by the peroneus muscles splits to extend through separate compartments deep to the inferior fibular retinaculum. The PL passes through the inferior compartment inferior to the fibular trochlea on the calcaneus and enters a groove on the anteroinferior aspect of the cuboid bone (Fig. 2). It then crosses the sole of the foot, running obliquely and distally to reach its attachment to the 1st metatarsal and medial cuneiform bones. When a person stands on one foot, the PL helps, steady the leg on the foot (Moore, Keith L; Dalley, Arthur F 2006).

The PL plantarflexes the foot at the ankle joint and everts the foot at the subtalar and transverse tarsal joints. It plays an important role in holding the lateral longitudinal arch and serves as a tie to the transverse arches (Clinical Anatomy by Systems by Richard S. Snell 2007).

(3) Flexor Hallucis Longus:

The flexor hallucis longus (FHL) is a powerful flexor of all of the joints of the great toe. Immediately after the triceps surae has delivered the thrust of plantar flexion to the ball of the foot (the prominence of the sole underlying the heads of the 1st and 2nd metatarsals), the FHL delivers a final thrust via flexion of the great toe for the preswing phase (toe off) of the gait cycle. When barefoot, this thrust is delivered by the great toe; but with soled shoes on, it becomes part of the thrust of plantar flexion delivered by the forefoot. The tendon of the FHL passes posterior to the distal end of the tibia and occupies a shallow groove on
the posterior surface of the talus, which is continuous with the groove on the plantar surface of the talar shelf (Fig. 3). The tendon then crosses deep to the tendon of the flexor digitorum longus in the sole of the foot. As it passes to the distal phalanx of the great toe, the FHL tendon runs between two sesamoid bones in the tendons of the flexor hallucis brevis. These bones protect the tendon from the pressure of the head of the first metatarsal bone (Moore, et al 2006).

The flexor hallucis longus flexes the distal phalanx of the great toe, assists in plantarflexion of the foot at the ankle joint. It plays an important role in maintaining the medial longitudinal arch in the foot (Richardson E G. 1998).

Fig.(3) Lower extremity muscles (Richardson, 1998).
(4) Tibialis Posterior Muscle:

The TP muscle is contained within the deep posterior compartment of die lower limb, arising from the adjacent posterior surfaces of die tibia, fibula and interosseous membrane. The tendon forms in the distal third of the leg and changes direction to enter the foot where it passes acutely behind the medial malleolus. In this region the tendon flattens (Figure 4a&b) and the tissue structure changes; exhibiting an increased presence of fibrocartilage and an avascular region (Peterson W, et al 2004).

The tendon is enclosed within a synovial sheath and is held firmly in place by the flexor retinaculum which forms the roof of the tarsal tunnel. The location of the TP tendon relative to the axes of the subtalar and ankle joints facilitates inversion and plantarflexion respectively. Tibialis posterior is described as. the most powerful supinator of the hindfoot as a result of the large inverter moment arm acting on the subtalar joint (Ruth Semple, et al. 2009).

The TP tendon has multiple insertions within the foot, dividing into three main components; (i) anterior; (ii) middle; and (iii) posterior (Bloome D, 2003).

The anterior component is the largest and extends to the navicular tuberosity; it is reported to contain a fibrocartilaginous or bony sesamoid at this site. The sesamoid functions to provide a pressure absorbing or gliding mechanism and was found in 23% of 348 adult feet. The middle and posterior components extend to the remaining tarsal bones, the middle three metatarsals and the flexor hallucis brevis muscle. The complex anatomy of the insertion sites function to stabilise the medial longitudinal arch (Ruth Semple, et al 2009).
B- Short (Intrinsic) Muscles of the Sole of the Foot

The short (intrinsic) muscles in the first layer that are inserted into the medial three toes (abductor hallucis and the medial half of flexor digitorum brevis) likewise assist in maintaining the medial longitudinal arch. The muscles of the first layer of the sole (Abductor digiti minimi and the lateral half of the flexor digitorum brevis) maintain the lateral longitudinal arch by preventing separation-of-the-pillars-of the arch. The transverse head of the adductor hallucis muscle supports the transverse arch (McMinn R. M. 1992)(Fig. 4).
Fig.(4) : Short muscles of the first layer of the foot (Williams & Dyson, 1995).
C-Ligaments (Fig. 5,6):

(1) Spring (Plantar calcaneonavicular) ligament:

This is a broad thick band, that connects the anterior margin of the sustentaculum tali to the plantar surface of the navicular bone. It ties the calcaneus to the navicular below the head of the talus as part of its articular cavity; it sustains the medial longitudinal arch of the foot. The dorsal surface of spring ligament has a triangular fibrocartilaginous facet on which part of the talar head rests. Its plantar surface is supported medially by the tendon of tibialis posterior and laterally by the tendons of flexor hallucis longus and flexor digitorum longus; its medial border is blended with the anterior superficial fibers of the deltoid ligament (Gray's Anatomy, By Susan standring 2005).

(2) Short Plantar Ligament:

It is a thick bundle, which fills in the adjacent hollows in front of the anterior tubercle of the calcaneus, and behind the posterior ridge of the cuboid it is covered over by the long plantar ligament (Gray's Anatomy, By Susan standring 2005).

(3) Long Plantar Ligament:

It extends from the plantar surface of the calcaneus and from its anterior tubercle, to the ridge and tuberosity on plantar surface of the cuboid, to which deep fibers are attached, more superficial fibers continuing to the bases of the second to fourth and sometimes fifth metatarsals. This ligament, with the groove on plantar surface of the cuboid, makes a tunnel for the tendon of peroneus longus. It is the most powerful factor limiting depression of the lateral longitudinal arch (Gray's Anatomy, By Susan standring 2005).
(4) Transverse Metatarsal Ligament:

It binds the five metatarsal bones together anteriorly on the plantar aspect supporting a transverse arch. It prevents spreading of the heads of the metatarsals (Gray's Anatomy, By Susan Standring 2005).

(5) Interosseous Ligaments:

They bind together the non-articular surfaces of adjacent bones. They take a small part in supporting the arches (Gray's Anatomy, By Susan Standring 2005).
Fig.(5): Ligaments on medial side of the ankle and tarsal joints (Williams & Dyson, 1995).
Fig.(6): Ligaments on the plantar surface of the foot. (Williams & Dyson, 1995).
(D) Plantar Aponeurosis (Fig. 7):

The plantar aponeurosis is composed of densely compacted collagen fibers. Its medial and lateral parts overlie the intrinsic muscles of the hallux and minimus; its dense central part overlies the long and short digital flexors. It is narrow posteriorly, where it is attached to the medial process of the calcaneal tuberosity; it becomes broader and somewhat thinner as it diverges towards the metatarsal heads. Just proximal to these it divides into five bands, one for each toe. The superficial stratum of each band is connected to the dermis by skin ligaments (retinacula cutis). The deep stratum of each digital band of the aponeurosis divides into two septa; which flank the digital flexor tendons, separating them from the lumbrical muscles and the digital vessels and nerves (Williams and Dyson, 1995).

(E) Bony Arrangement:

The intermediate and lateral cuneiforms are wedge-shaped, and in this single respect the bones are adapted to the maintenance of the transverse arch of the foot. The wedging of bones at the top of the arch forms a self locking mechanism under high compression loads that the stability of arch of the foot is maintained by the tight and compact arrangement of its bony constituents; bound together by thick ligaments (McMinn, 1992).
Fig.(7): Plantar aponeurosis (Williams and Dyson, 1995).
BIOMECHANICS
Biomechanics of the foot and ankle

Ankle joint:

The axis of movement (single axis joint) estimated to run along a line just distal to the palpated tips of the medial and lateral malleoli. The axis of ankle joint is angled $82^\circ \pm 4^\circ$ from the medline of the tibia, which is directed downward and lateral. In transverse plane, the axis is directed laterally and posteriorly about 20 to 30 degree related to the transverse axis of the knee (Fig.8,9) (Lutter et al., 1994).

Therefore dorsiflexion of the ankle results in eversion of the foot, and plantar flexion results in inversion of the foot. The distal fibula may have a more complex function for the ankle joint than that of a static buttress for the talus. The fibula bare one sixth of the weight transmitted downward from the knee during static weight bearing. In vivio, the distal fibula was shown to move distally average (2-4mm) when loaded and thus increase the stability of the ankle by deeping the mortis (Lutter et al., 1994).

Incision of the interosseous membrane reduces the fibular strain to zero during axial loading, suggesting that the membrane transmits load from tibia to fibula (Lutter et al., 1994).
Fig.(8) The axis of movement (single axis joint) estimated to run along a line just distal to the palpated tips of the medial and lateral malleoli (Lutter, 1994).

Fig.(9) : The angle of the axis of the ankle joint to the midline of the tibia (Lutter., 1994)
Subtalar joint:

The subtalar joint is a single axis joint. The articulation between the talus and calcaneus allows further rotation of the proximal limb to occur over the fixed foot because the unique orientation of the axis of rotation. The axis of rotation of the subtalar joint is 42±9 degrees from the horizontal in the sagittal plane and 23±11 degrees from the midline in the transverse plane (Tylkowski., 1990).

The subtalar joint moves around a single inclined axis and functions essentially like a hinge connecting the talus and the calcaneus (Inman and Mann., 1978).

Increasing pronation of the subtalar joint will cause increasing internal rotation of the metatarophalangeal joint of the big toe. Also, when the oscalcis goes into progressive valgus, the attachment of the triceps surae is carried laterally in relation to the subtalar axis, and this muscle becomes an evertor of the subtalar joint in addition to a plantar flexor of the ankle (Rose, 1982).

In persons with flatfeet, the axis of the subtalar joint is more horizontal than in persons with normal feet. Therefore the same amount of rotation of the leg imposes a greater supinatory and pronatory effect upon the foot. This may partially explain why some individuals with asymptomatic and flexible pes planus breakdown their shoes and frequently prefer to go without shoes, which they find restrictive. Furthermore, people with asymptomatic flatfeet usually show a greater range of subtalar motion than do persons with normal feet. The reverse holds true for people with pes cavus; in them, one is often surprised at the generalized rigidity of the foot and the limited motion in the subtalar joint (Inman et al., 1978).
Talocalcanealnavicular complex:(Fig.10)

During the weight bearing the external rotation of the limb and subsequent forefoot supination are followed by a pronation twist of the forefoot to remain plantigrade. This mechanism tends to lock the foot making it a rigid lever. Internal rotation of the leg and its subsequent pronation are followed by a supinatory twist of the forefoot to remain plantigrade. This mechanism unlocks the mid tarsal joints and produces a mobile midfoot noted at the time of heel gait cycle (Tylkowski.,1990)contact and the first 15% of the.

Transverse tarsal articulation:(Fig.11)

The transverse tarsal articulation includes the talonavicular and calcaneocuboid joints. These joints have parallel axes of rotation when the calcaneus is everted. If inverted, this will result in a non-parallel axes. When parallel, the joint rotate in the same direction and the transverse tarsal articulation is flexible. When the axes are non-parallel, the articulation is rigid.

The functional importance of this in gait is that from heel strike to foot flat, the calcaneus shifts from inversion to eversion and the transverse tarsal articulation becomes flexible, allowing adaptation to non-level surfaces; from heel rise to toe-off, the calcaneus is inverted and the transverse tarsal articulation becomes rigid, stabilizing the longitudinal arch to function as a lever for the support of (Lutter et al.,1990)body weight during toe-off.
Fig.(10): Mechanical representation of the complex joint interactions (A) and (c) Tibial external rotation and foot supination (B) and (D) Tibial internal rotation and foot pronation (Mann R surgery of foot 5th ed. St Louis : CV Mosby, 1986)

Fig.(11): (Mann, R.A. and Mann, J.A. 1995).
Metatarsophalangeal joints:

The heads of the second through fifth metatarsals are along a line oblique to the midline of the foot, this angle is measured by Inman to be 62±6 degrees (Tylkowski, 1990).

After wearing a new pair of shoes, there is an oblique crease in the area overlying the metatarsophalangeal joints. Its obliquity is due to unequal forward extension of the metatarsals. The head of the second metatarsal is the most distal head; that of the fifth metatarsal is the most proximal. The metatarsophalangeal joints function is dorsiflexion from heel rise to toe-off (Lutter et al., 1994).

Planter aponeurosis:

It is a passive stabilizer of the longitudinal arch. When the toes are dorsiflexed, the plantar aponeurosis is pulled forward under the metatarsal heads. This elevates the longitudinal arch, and plantar flexor the metatarsal (Lutter et al., 1995).

Support of the longitudinal arch:

In the normal foot during relaxed standing, the intrinsic muscles are electrically inactive. When the neutral resting foot is loaded (100 to 200 Ib) in the absence of postural factors, no activity is noted in the intrinsic or extrinsic muscles. When large loads (400 Ib) are applied, some activity is detected from muscles including tibialis posterior, pronoeus longus and flexor hallucis longus. Therefore, most static support of normal arch occurs by passive factors (bones and ligaments) but muscle activity may contribute to arch support under conditions of excessive stress (Lutter et al., 1994).
DIAGNOSIS
Diagnosis of Flatfoot

Flat foot (pes planus) in its various types is a common complaint in general orthopaedic or more specialised foot and ankle clinics.

A large number of these present in patients without symptoms of pain or functional deficit. These simply need advice and reassurance, especially for the parents of young children under the age of seven, where flat feet are very common, asymptomatic and should not cause any concern.

Therefore, it is vitally important for the treating orthopaedic surgeon to be clear about the different types of flatfoot deformity: congenital or acquired, flexible or rigid, adult or paediatric. It is also important to understand the biomechanics of the foot and the relations of forefoot to midfoot to hindfoot in order to identify and treat the underlying cause correctly (Haendlmayer and Harris, 2009).

Most flatfeet are variations of normal and are considered physiologic or flexible. Pathological forms include the flexible type that falls outside the normal range (such as hypermobile flatfoot with short Achilles tendon), as well as the flatfoot that is due to a structural abnormality often causing stiffness and disability (such as congenital vertical/oblique talus, calcaneal valgus, tarsal coalition, accessory navicular bone and valgus hindfoot deformity in cerebral palsy) (Kim and Weinstein 2000).
Diagnosis of flexible flatfoot

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 a family history of special shoe wearing during childhood.

Clinical examination

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 degrees of 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, 1998) 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.

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, 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. 12a). 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. 12b). The flexibility of flatfoot is a more important feature than the static shape.
Fig.(12) Flexible flatfeet. A. Convex medial border with midfoot sag.

B. Valgus hindfoot (Vincent and Mosca, 2010)

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.13). This so-called "toe-raising test" initially described by Jack (1953) and explained by Hicks (1954), 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 crank.
Fig 13. Jack's toe-raising test. An arch is created in a flexible flatfoot (FFF) by the windlass action of the great toe and planter fascia (Vincent and Mosca, 2010).
A winch (spool and crank) is affixed to one end, and a cable is wound around the winch, pulling a weight that is attached to the opposite end. 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 (the crank) winds the plantar fascia around the heads of the metatarsals (the cylinder). 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. 14).

Fig(14)(a)Weight-bearing left flexible flatfoot (b)In toe-standing ,heel valgus converts to varus and the longitudinal arch can be seen (Vincent and Mosca,2010).
Supination deformity of the forefoot on the hindfoot is revealed when the valgus hindfoot is passively inverted to neutral (Fig. 15).

Fig(15) Forefoot supination can best be appreciated when the hindfoot is inverted to neutral (Vincent and Mosca, 2010).
It should be apparent that this separate, rotationally opposite, segmental deformity exists in a flatfoot. 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 (*Vincent and Mosca, 2010*).

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 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 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.

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 degree 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 degree of dorsiflexion was possible
with the knee flexed, but less than 10 degree of dorsiflexion is possible with the knee extended, the gastrocnemius alone is contracted (Fig. 16).

Fig(16) The subtalar joint must be held in neutral position and the knee extended in order to accurately assess ankle dorsiflexion (Vincent and Mosca, 2010).
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 (Nelson et al., 2004).

**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. 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 talo first metatarsal angle that is about 5 degree (Range from -7 to 20 degree). The calcaneal pitch, its angle is about 25 degree (Range from 15 to 30 degree) and an even greater degree of plantar flexion of the talus, measured by the talo-horizontal angle which is about 27 degree (Range from 15 to 37 degree) (Fig.1 7).
Fig(17) Standing lateral radiograph showing three fairly reliable angular measurements: the calcaneal pitch (CP), talo-horizontal angle (T-H), and Meary’s talus–first metatarsal angle (T-1MT) (Vincent and Mosca, 2010).
Meary (1967) 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. (from 0 to 10 degree but in minus angle the apex is planterwards in flatfoot).

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 (2002) considered 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. 18b).

But the CORA can alternatively be located at the naviculocuneiform joint, or within the body of one of the mid-tarsal bones. Using the CORA method, the true site or sites of deformity can be determined. In a simple flatfoot, the CORA should be in the head of the talus or at the talo-navicular joint, which indicates eversion of the subtalar joint that is manifest as abduction at the talo-navicular joint (Fig.18a). Knowledge of the CORA on the AP and lateral radiographs has implications for surgical treatment.
Fig(18) 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 talo-navicular joint. a Anteroposterior view. b Lateral view.
**Differential diagnosis**

Flexible flatfoot should be differentiated from other causes of rigid flatfoot is characterized by a lowered arch on both weightbearing and nonweightbearing and by a decrease or absence of motion of the rearfoot and midfoot. Rigid flatfoot can be asymptomatic or asymptomatic.

Most cases are associated with underlying primary pathology that can be diagnosed by clinical examinations and imaging.

The differential diagnosis of rigid flatfoot includes:

- Congenital vertical talus
- Tarasal coxalation
- Peroneal spastic flatfoot without coalition
- Skewfoot.
- Reverse club foot
- Calcaneovalgus foot
Congenital vertical talus

CVT deformity, also known as congenital convex pes valgus, the incidence of this deformity was less than 1% in live births with no gender preference and it is characterized by severe equinus of the rearfoot and by a rigid rocker-bottom appearance (Duncan and Fixsen 1999).

Fig.(19): This 9-month-old infant has vertical talus in both feet (Duncan and Fixsen 1999).
Tarsal coalition

Tarsal coalition is a congenital union between two or more tarsal bones that may be an osseous, cartilaginous, or a fibrous connection. The incidence of tarsal coalition is 1% to 2%. Talocalcaneal and calcaneonavicular bars are the most common. Fig.(20). Talocalcaneal coalitions are most commonly found at the middle facet. Talonavicular and calcaneocuboid coalitions also have been described but are much less common (Kulik and Clanton 1996).

Fig.(20): x ray foot showing calcaneonavicular coalition (Kulik and Clanton 1996).
**Peroneal spastic flatfoot**

Peroneal spastic flatfoot is a painful foot deformity made rigid by spasm of the extrinsic muscles.

The patient develops pain in the foot, followed by protective limitation of motion by the extrinsic muscles. Peroneal muscle spasm, restricted subtalar and ankle motion, valgus appearance of the foot, and constant or intermittent pain in response to activity are the hallmarks of the condition. Clinical findings are not limited to the peroneal muscles alone. The extensors, tibialis anterior, and tibialis posterior are involved (*Graves et al., 1991*).

**Skewfoot**

Skewfoot is characterized by forefoot adduction and heel valgus. The more severe cases have midfoot abduction. There are no universally accepted clinical or radiographic criteria for skewfoot and the natural history of skewfoot is poorly understood. There are 4 types of skewfoot: congenital idiopathic, congenital associated with syndromes, neurogenic, and iatrogenic.

Skewfoot may be asymptomatic or associated with activity-related pain and difficulty in fitting shoes. It is often misdiagnosed as metatarsus adductus and flexible flatfoot. (*Napiontek.2002*).
Reverse club foot

Is a condition with deformities opposite to those of talipes equinovarus, but have the same rigidity and resistance to treatment. Clinically the foot is small and has calcaneus deformity at the ankle, valgus deformity at the subtalar joint and weak or absent active inversion of the foot.

Reverse club foot can be differentiated from postural, talipes calcaneovalgus by its subsequent course. The deformity at birth may be identical in both but whereas postural talipes calcaneovalgus tends to spontaneous improvement, reverse club foot deformity does not; moreover, it resists conservative methods of correction. Reverse club foot (Fig. 21), might be mistaken for congenital vertical talus but there is equines deformity nor midtarsal dislocation in the former (Edwards and Menelaus, 1987).

Fig. (21) Photograph of both feet of 16 month child with reverse clubfoot, the lateral view shows that the lateral metatarsal heads are not bearing weight (Edwards and Menelaus 1987).
Calcaneovalgus foot

Calcaneal valgus is one of the most common foot deformities seen at birth. The entire foot is held in the dorsiflexed, everted position and in its most severe form the foot lies adjacent to the anterior border of the tibia. The soft tissues on the dorsal and lateral aspect of the foot are contracted and restrict plantar flexion and inversion. The incidence of this deformity to be 1 per 1000 live births. The sex ratio was 0.6 males to 1.0 females. It occurred most often in the first-born of young mothers. The problem is partially genetic in origin, but no clear pattern of inheritance could be established (Fig.22).

However, there are no tarsal dislocations or subluxations. The deformity is usually supple, and the foot can be brought into some plantarflexion and supination. The foot can generally be manipulated to neutral or just short of the neutral position. It requires counseling to convince the parents that this is not a fixed deformity (Evans, 1975).

Fig.(22)Calcaneovalgus flatfoot (Kim and Weinstein 2000).
The deformity resolves without residual sequelae. In an occasional patient, a series of corrective casts can be used to hasten the recovery of a normal position. Many authors agree that this is essentially a benign condition that can be followed clinically and does not require radiographic evaluation or active treatment (Kim and Weinstein, 2000).

**Accessory navicular bone**

This is the most common accessory bone in the foot, and occurs on the medial, plantar border of the navicular along the insertion of the posterior tibialis tendon.

Three types of accessory navicular bone have been described.

The os tibiale externum type I is a 2-6 mm sesamoid bone within the distal posterior tibialis tendon which has no cartilage connection with the navicular tuberosity. It accounts for approximately 30% of accessory naviculae. The true sesamoid bone has also been referred to as "navicular secundum" or "os naviculare secundarium".

The accessory navicular type II, This variant accounts for 50-60% of accessory navicular bones, refers to the triangular secondary ossification centre of the navicular tuberosity Fig.(23).

The cornuate navicular type III, is thought to result from osseous fusion of the accessory ossification centre to the navicular, resulting in a prominent navicular tuberosity.
X ray: In general, standing anteroposterior and lateral radiographs of the foot are diagnostic of accessory navicular.

Fig.(23): X ray AP foot shows Type II Accessory Navicular (*Mosel et al., 2004*).

Ultrasound can identify the osseus contours of the accessory navicular and medial navicular. Also it allows assessment of the integrity of the tibialis posterior tendon.

Bone scintigraphy has a high sensitivity, demonstrating increased radioactive uptake in symptomatic patients because of the chronic stress reaction at the synchondrosis.
Bone marrow oedema is best demonstrated by MRI, using fat-suppressed T2-weighted sequences. This is seen as increased signal within the accessory navicular and the medial navicular. Fluid within the synchondrosis, soft tissue oedema and posterior tibialis tendinosis can also be demonstrated on MRI (Mosel et al., 2004).

The linkage of accessory navicular formation and pes planus has been present in the literature since the 1920s, but new studies cast doubt on this association. It was thought that the accessory navicular medializes the insertion of the posterior tibial tendon, which interferes with tarsal mechanics, resulting in a weakened, painful flat foot. While many accessory naviculars have been reported to be associated with pes planus, the vast majority appear in feet with a normal arch and are not a causative factor in the production of flatfoot (Walter-etal.r1995).

However, in reality, accessory navicular is not a direct cause -of hypermobile flatfoot, and there is no evidence to substantiate the opinion that the longitudinal arches of the patients with accessory navicular are different from those of normal patients. It is more likely that the accessory navicular, when present in flatfoot, is an incidental finding, and its inclusion among causes of painful symptomatic flatfoot in children is unwarranted (Kim and Weinstein, 2000).
**Tibialis posterior-tendon dysfunction**

In the early stages the patient will often describe medial ankle discomfort along the course of the tendon. If there is an element of tenosynovitis, there may be swelling around the medial malleolus. As the condition progresses, tenderness initially present along the tendon may disappear, and patients may complain of fatigue and aching in the leg and a reduction in walking distance. With further progression they may notice a change in the shape of the foot with a loss of the medial arch and the heel drifting into valgus, but commonly patients complain of loss of function rather than a change in the shape of their foot. They may also have symptoms of instability, a limp and inability to walk on uneven surfaces (*Alvarez et al.,* 2006).

Johnson and Strom described 4 stages of posterior tibial tendon dysfunction. These stages are utilized to dictate treatment:

- **Stage I**, is characterized by peritendinitis and tendon degeneration, but the tendon length remains normal. This stage presents clinically as pain and swelling along the posterior tibial tendon sheath.
- **In Stage II**, the posterior tibial tendon elongates, and a supple flat foot deformity develops. Although deformed on weight bearing, the hindfoot and midfoot deformities are passively correctable to neutral.
- **Stage III**, occurs over time as the hindfoot becomes rigid in a valgus position, and the patient develops a rigid flatfoot deformity.
- **Stage IV**, develops as the deltoid ligament becomes incompetent and the talus tilts into valgus within the ankle mortise (*Hockenbury, 2001*).

In health; the hindfoot is in 5 degrees of valgus, which is best assessed from behind (*Fig. 24*). In stage I tibialis posterior dysfunction the medial longitudinal arch will be maintained and there may be swelling and tenderness along the course of the tendon behind the medial malleolus.
Fig.(24) Posterior view of non-pathological double heel raise. In the resting position the hindfoot angle five degrees of valgus, When the heel raise is performed, the heel swings into a varus position (Edward et al., 2008).

Passing a hand under the arch of both feet using the examiner’s finger creases as a reference allows quantification of any discrepancy in the medial arch (Fig. 25). In the later stages there will be an acquired flatfoot deformity, which initially will be correctable, with free subtalar movements. The ‘too many toes sign’ may be present; when viewing from behind; more than the two lesser toes are seen along the lateral border of the foot (Fig. 26).
Fig.(25) The examiner can qualify the degree of loss of the medial longitudinal arch by the number of fingers that can be passed underneath the midfoot (Edward et al., 2008).

Fig.(26) Posterior view of a patient with tibialis posterior dysfunction on the right side displaying 'too many toes sign' (Edward et al. 2008).
Fig.(27)Double heel raise displaying failure of the hindfoot to swing into a varus position on the left (Edward et al., 2008).

The power of tibialis posterior is assessed by sitting the patient seated higher than the examiner with his/her knee bent and the affected foot resting on the examiner’s lap. The foot is held everted and plantar flexed to eliminate the synergistic action of tibialis anterior. The patient is then instructed to ‘swing the foot inwards’ against the resistance of the examiner’s hand. After palpating tibialis anterior tendon to confirm that it is not being recruited, the tibialis posterior tendon is palpated along its length (Slovenkai, 1997).
TREATMENT
Treatment of flexible flatfoot

The literature discussing the non operative and operative treatment of symptomatic flexible flatfoot is confusing, contradictory, and even anecdotal. Recommendations range from aggressive surgical correction of severe flexible pes planus in children as young as 2 years of age to no treatment, avoiding even shoe modifications or inserts. Obviously the recommendations of most orthopaedists are somewhere between these extremes (Murphy, 2003).
Non operative treatment:

Treatments offered in the past have been based on the assumption that patients will have problems in the future if the condition is not treated. In normal children, aged 1-3 years, reassurance and explanation of the cause and the benign natural history of pes planus are essential to the parents. The parents should be informed about the presence of the normal fat pad, the normal joint hyperlaxity of infancy, and the often familial nature of the condition. They should also be reassured that, in most children, an arch will develop by 5 years of age. Many parents are under the false assumption that so-called corrective shoes are responsible for the natural development of the longitudinal arch.

The parents should be instructed that treatment modalities offered in the past were offered without any scientific basis. A recent prospective randomized study of patients with flexible flatfeet treated by corrective shoes and inserts revealed that all patients improved moderately after 3 years of treatment, and no greater improvement was seen in patients who were treated vigorously, even those treated with custom-made inserts. All treatments in the past, including exercises, varying shoe modifications, and inserts, have been proven to be ineffective.

In a child with a painful flexible flatfoot, the diagnosis must be reassessed and sources of painful flatfeet eliminated. Prophylactic treatment of any type is unwarranted. Treatment for flexible flatfeet is only indicated if the patient presents with pain, usually in the foot or calf, or if the patient has severe excessive shoe wear. The discomfort in the foot and the associated leg aches, which occur in about 15-30% of normal people, should be treated symptomatically by analgesics, local heat and massage. If fatigue symptoms or discomfort with increasing activity persist, shoe modifications can be considered. It is important to emphasize that these modifications are not corrective.
High-top tennis shoes with a good, longitudinal arch can usually be recommended. If symptoms persist, other non-corrective adaptive measures may be tried, such as a medial heel wedge, a long shoe counter or a navicular pad. For the more severe symptomatic physiologic pes planus that fails to respond to conservative measures, a more formal shoe orthosis, such as a University of California Biomechanics Lab (UCBL) insert or custom-made insert, may distribute body weight more evenly across the sole of the foot and reduce the pressure off the prominent talar head.

These modalities, however, are expensive, must be changed frequently with foot growth, and have no scientific basis for their use. The use of shoe modification inserts tends to label the child as having a problem.

In young patients with hypermobile flatfoot and a short tendo Achillis, heel cord stretching exercises should be tried first. If symptoms and the contracture persist, tendo Achillis lengthening can be considered.

The only operative indications in true physiologic pes planus are severe malalignment problems causing excessive abnormal shoe wear and pain (Kim and Weinstein, 2000).
**ORTHOTIC DEVICES**

**Shoes**

For the flat foot, one must bring the ground up to meet the sole instead of allowing the hindfoot to pronate to the ground. The shoe may require cushioned insoles, metatarsal pads, or rocker bottoms to relieve painful forefoot and metatarsal phalangeal joints during the push-off stage of gait. Adding a medial heel wedge helps pronation. The shoe must have sufficient depth and width to accommodate foot with orthosis (*Elftman, 2003*).

**Custom-Made Orthotic Devices**

Orthoses can be fabricated from a variety of materials and classified according to their inherent rigidity as rigid, semirigid, or soft. The foot orthosis is used primarily to support the foot in a desired position and to accommodate the bone deformities, while providing protection for the soft tissue. The custom orthosis, (*Fig. 28*); is fabricated from a plaster model of the patient’s Foot; the goal is to capture a measure of correction in the cast and to construct an orthosis that intrinsically provides correction (*Noll, 2001*).
UCBL (University of California Eio mechanics Laboratory) Orthosis

The UCBL (Fig.29), made of rigid material such as polypropylene; The orthosis is used to stabilize the hind foot of a flexible foot and hold it in a neutral position. When the hind foot valgus deformity is corrected, a subtalar impingement is avoided.

Cast Immobilization or Removable Boot

Indications for casting or the application of a removable boot include acute tenosynovitis of the posterior tibial tendon and pain along the tendon sheath. Care should be taken when molding the longitudinal arch to capture adequately the contour of the arch without putting excessive pressure on any prominent bone deformity. A removable boot padded with Plastazote allows the patient’s foot to mold into the boot and create a foot bed replicating the patient’s individual anatomy. The function of the cast is to decrease inflammation and reduce edema in the treated limb (Noll, 2001).
Fig(29) UCBL (University of California Eio mechanics Laboratory) Orthosis.(Noll,2001).

**Exercises**

The role of exercises is also doubtful that muscles play little role in maintaining the longitudinal arch, and for that reason an exercise program to strengthen intrinsic and extrinsic muscles is not emphasized. However if a tight heel cord is found, a stretching exercise program should be begun (Murphy 2003).

Child going barefoot is believed to help in strengthening the intrinsic foot muscles around the arch area, which may help a strong arch to develop so that no treatment is required unless the patient feels pain after the ages of 6 to 10 years (Charrette, 2003).
Operative Treatment

Indications of surgery:

Failure of all conservative approaches to reduce the patient’s symptoms is the most important factor for consideration of surgical treatment. Pain, which may be described as aching, throbbing, cramping or generalized fatigue, commonly involves the medial longitudinal arch, lateral sinus tarsi region, heel, or posterior calf. This is one of the most common combination of symptoms referred to by pediatrician as "growing pains". Difficulty in walking or running is secondary to the excessive valgus attitude of the foot and the usually present equines condition. Generalized inactivity of the patient with poor participation in physical activities that require running or jumping as well as excessive distortion and wear of shoe gear with breakdown of the medial heel counter and medial planter forepart of the sole are additional considerations. This later condition is frequently present but the least important reason for surgery (Dockery, 1995).

Mosca (1996) has summarized the indications of operation in flexible flatfoot in children where non-operative treatment failed to relieve pain, a callus, or ulceration under the head of the talus.

Types of surgery

Despite operative treatment is rarely required, if ever, indicated for flexible flatfoot, an exhaustive list of operative procedures to correct flatfoot has been proposed during the last century. Options include soft-tissue reconstruction, osteotomy, arthroereisis, arthrodesis, and combination of these procedures.
**Soft Tissue Reconstruction**

*Tibialis anterior transfer into talus:*

**Indication**

The use of tibialis anterior tendon transfer through the talus for severe flexible pes planus has been derived and modified from its use for the congenital convex pes valgus. It has been utilized in selected symptomatic patients with severe talar declination and subluxation.

Young’s tenosuspension involves changing the course of tibialis anterior by sliding it into a "keyhole slot" in the navicular. This operation has been very successful for a less severe medial column deformity, significant elongation of the planter talonavicular joint capsule, spring ligament, and tibialis posterior tendon are noted. These must also be addressed.

**Technique**

The tibialis anterior is transferred through the talus from dorsal lateral to planter medial for direct talar control. The remaining tendon end is sutured to the planter medial foot to form a strong ligament, which also helps to control planter talar subluxation. This procedure has been used in combination with other commonly used flatfoot procedures to restore the medial column deformity of the flexible flatfoot with a severely declinated talus. Other components of the pes planus deformity, such as equinus, must also be addressed with ancillary procedures Fig.(30).
Transfer of the tibialis anterior proximal to the midtarsal joint can add significant medial column correction. After transfere, the tendon provides a strong planter "ligament" to maintain osseus alignment from inferior to the talus neck distally. The addition of spring ligament and talonavicular joint capsular plication, as well as tibialis posterior tendon advancement, completes the securing of the subluxated medial column.

The tibialis anterior is the chosen tendon to transfer. Since it is primarily a swing phase muscle, it can continue to act as an ankle joint dorsiflexor after its transfer into the talus. In a longstanding flatfoot, tibialis anterior assists in producing the forefoot supinatus deformity. When transferred, it allows the peroneus longus to aid in maintaining medial column stability during weightbearing (Kissel and Blacklidge, 1995).
Post operative

The foot is maintained in supination position in a plaster or a short leg cast for 4 weeks in non-weight bearing. At 6 weeks the patient progresses into full weight bearing. A short leg cast is left in place for total of 8 to 10 post operative weeks and is followed 6 to 9 months of a removable walker boot or a commodative shoe, modified with an orthosis that includes arch support and slight medial heel wedging. (*Anderson and Davis, 2000*).

**Flexor digitorum longus (FDL) transfer**

**Indication:**

This procedure should be generally reversed for cases of chronic tenosynovitis and dysfunction but without postural deformity. Intra operative examination usually reveals a diseased tendon, often hypertrophied but that may have spontaneously ruptured distal to the medial malleolus.

**Technique**

The patient is placed supine on the operating table. A curvilinear posterior medial incision is made following the course of the posterior tibial tendon. The flexor retinaculum is released and the posterior tibial tendon is identified. The tendon is frequently enlarged and bulbous and has longitudinal tears. It may also be attenuated, detached from the navicular, or have a midsubstance rupture. If there is no significant excursion when the proximal tendon is pulled, it should be resected at a point proximal to the medial malleolus. This condition is most likely to occur when there is significant attenuation of the tendon or complete rupture. If the posterior tibial tendon has adequate excursion, it can be used in a side-to-side tenodesis to the FDL.
transfer. The incision is extended medially along the foot at the dorsal border of
the abductor hallucis muscle. The fascia of the abductor hallucis muscle is
incised on its dorsal surface and retracted planter wards. The FDL tendon is
identified in its sheath and traced distally to the knot of Henry.

There; it passes superficially to the FHL. Care is taken to avoid injury to
the medial plantar vessels and nerves that are adjacent to the intermuscular
septum. The FDL is cut just distal to the knot of Henry. The stump is brought
up into the wound.

If there is substantial distal Posterior tibial tendon available, the FDL can
be woven into this and sutured in place. If not, the FDL can be attached to the
navicular or the medial cuneiform. The width of the navicular is determined by
defining the talonavicular and navicular-cuneiform joints.

A drill (usually 4.5 mm) is used to create a hole from dorsal to plantar in
the medial aspect of the navicular. Care must be taken to allow sufficient bone
around the hole so the transferred tendon does not break free when tensioned. A
size O nonabsorbable braided stitch is sutured into the free end of the tendon. It
is then passed from plantar to dorsal through the hole in the navicular. The foot
is held inverted and at about 20 degree of plantar flexion while the FDL is
tensioned. The tendon is sutured in place. Tenodesis of the posterior tibial
tendon is performed, if indicated. The wound is closed in layers and a short-leg
well-padded cast or plaster splint is applied with the foot in plantar flexion,
adduction, and inversion (Sitler and Bell, 2003).
Post operative

The patient is kept in a plantar flexed, inverted cast for 4 weeks. The wound is usually inspected at 2 weeks and the cast changed. The patient is then placed in a removable walking cast or cam walker for 4 weeks and encouraged to work on active range of motion exercises. At 8 weeks postsurgery, the patient is allowed to start strengthening exercises but avoid toe raises for 9 to 12 weeks postsurgery (Fig. 31) ; (Sitler and Bell, 2003).

Fig.(31)(A). Flexor digitorum longus tendon was transferred to the navicular bone, adjacent to the insertion of degenerated posterior tibial tendon (B).(Sitler and Bell, 2003).
**Tendo Achilis lengthening:**

**Indication:**

Contracture of the Achilis tendon often accompanies the symptomatic flatfoot, it prevents normal dorsiflexion of the ankle during midstance phase of the gait cycle. The dorsiflexion stress is shifted to the talonavicular joint, subjecting the underlying soft tissues to excessive direct axial loading and shear forces (*EL-Tayeby, 1999*).

In an occasional patient with a tight heel cord despite a vigorous stretching program, judicious heel cord lengthening may have a role in the management of flexible flatfoot, as an isolated procedure or in combination with other procedures (*Kasser et al., 2005*).

**Technique**

Z plasty of the tight-tendo Achillis is always needed to bring the ankle to at least 10 to 15 degree of dorsiflexion (*EL-Tayeby, 1999*).

**Complication**

Includes calf atrophy in 41% . palpable incisional scar tissue on the Achilles tendon 7% and a persistent sensation of falling forward when descending stairs was present in 7% of patients. We had no inadvertent complete tenotomies or neurovascular injuries as a result of the procedure. (*Michael et al., 2010*).
**Spring ligament reconstruction:**

**Indication:**

The spring ligament may be elongated or ruptured. When rupture is present repair with advancement may not be possible but reconstruction options are available.

**Technique:**

In reconstruction the peroneus longus tendon is rerouted to the medial aspect of the foot. The tendon is detached at the musculotendinous junction that remain attached distally. Once rerouted, it is secured to the planter medial aspect of the sustentaculum tali under tension, thus reconstructing the planter calcaneonavicular ligament.

The technique was modified by *Cobb* in *1986* by using the 1/2 of the distal anterior tibial tendon. While attached distally the tendon is rerouted through drill hole in the navicular from dorsum to planter and secured to sustentacular under tension (*Anderson and Davis, 2000*).
**Osteotomy**

Joint-sparing procedures based on osteotomy appear to be the option of choice for a flexible flatfoot at this age group. Such procedures improve alignment while maintain mobility. There are two osteotomies that hold promise for long-term relief of symptoms. Both are calcaneal procedures, but one translates the calcaneal tuberosity medially whereas the other lengthens the calcaneus with a positive effect on hindfoot and forefoot alignment (Kasser et al., 2005).

**Evan's calcaneal osteotomy**

The anterior calcaneal osteotomy (ACO), specifically the Evans procedure, is a commonly performed operation for the treatment of supple adolescent and adult flatfoot deformity after failure of the non-operative care. Evans originally described treatment of calcaneovalgus deformity with lateral column lengthening using autogenous tibial cortical bone graft. Although autograft remains the standard choice of biomaterial, allogenic bone has also been used with success.

**Surgical Procedure**

The patient was placed supine on the operating table with a bump placed beneath the ipsilateral buttock to medially rotate the foot. A pneumatic thigh tourniquet was typically used for hemostasis. An oblique or a curvilinear incision was placed distal to the sinus tarsi and 1 to 1.5 cm proximal to the calcaneocuboid joint (Fig. 32). This approach usually avoids the dorsal cutaneous nerves and provides access to the lateral wall of the anterior portion of the calcaneus, although care must be taken to protect the peroneal tendons and the sural nerve. An image intensifier was sometimes used to confirm the osteotomy location prior to execution.
Once satisfied with the location, periosteum was incised in a vertical fashion, and an elevator was used to dissect periosteum from the lateral wall of the calcaneus. Periarticular dissection was limited to avoid destabilization of the distal segment. A sagittal saw blade was oriented perpendicular to the lateral surface of the calcaneus and perpendicular to the weight-bearing surface to initiate the osteotomy in a lateral-to-medial direction, and a handheld osteotome was typically used to complete the cut without violating the medial osseous hinge and soft tissue structures, (Fig.33). A lamina spreader, or a minidistractor, was then used to manipulate and distract the osteotomy to the desired length to achieve restoration of arch height. (Fig. 34).

Fig.(32)The incision is placed distal to the sinus tarsi and 1 to 1,5 cm proximal to the calcaneocuboid joint to avoid the dorsal cutaneous nerves while gaining access to the lateral wall of the anterior portion of the calcaneus.(John et al.,2010).
The precise degree of correction was determined intraoperatively with fluoroscopy in conjunction with direct visualization of the sagittal, frontal, and transverse plane orientations of the foot, and the allograft bone wedge was sized to fit the corrected alignment. Freezedried tricortical allograft is ideally suited for optimal distraction of the lateral column. The graft was fashioned into a triangular or trapezoidal wedge, with its cortical base measuring 7 to 10 mm in width (Fig. 35).

The cortical base was oriented lateral and apex medial, and then tamped into its final position (Figs. 36, 37). The allograft remained secure without the need for fixation.

Postoperative

After completion of any adjunct surgical procedures and application of a surgical dressing, a short-leg, non-weight-bearing cast was used for 6 to 8 weeks, and serial radiographs were obtained to determine the status of graft incorporation.

As soon as clinical and radiographic signs of healing were noted, the patient was transitioned to full weight bearing in a short-leg walker-boot that immobilized the ankle, after which a gradual transition to an athletic shoe was undertaken (John et al., 2010).
Fig.(33) A sagital saw blade from lateral to medial (John et al., 2010).

Fig.(34) Open the osteotomy with a distractor until reaching the desired correction. Then measure the gap to determine the size of bone graft needed (John et al., 2010).
Fig.(35) Tricortical graft is fashioned to the precise configuration (John et al., 2010).

Fig.(36) Here one can see the bone graft successfully tamped into place in the central portion of the osteotomy and flush with the lateral wall of the calcaneus.(John et al., 2010).
Complications:

Several complications have been reported with the Evans procedure, including calcaneocuboid arthrosis, dorsal displacement of the anterior fragment, complex regional pain syndrome, incision dehiscence sural neuritis, and stress fracture of the fifth metatarsal. Complications specific to the bone graft include displacement, structural failure, and nonunion or delayed union. (John et al., 2010).
**Medial Displacement calcaneal Osteotomy:**

The osteotomy is done through the body of the os calcis, moving the proximal calcaneus medially and derotating it out of valgus and positions the contact portion of the heel more in line with the weight-bearing axis. The osteotomy elevates the medial arch, and centralizes the motion of the subtalar joint. This procedure is indicated in patients who have excessive heel eversion without excessive abduction or varus of the forefoot (fig.38), *(Koutsogiannis, 1971).*

![Diagram](image)

Fig.(38) *Koutsogiannis* medial displacement osteotomy weight bearing line and relation of talus to calcaneus in normal foot flat foot and with medial displacement osteotomy. *(Koutsogiannis,1971).*
Incision:

With the patient prone, make an oblique incision, extending from the lateral border of the tendocalcaneus superiorly approximately 6 cm in a distal plantar direction, to end at the inferior border of the distal end of the calcaneus Fig.(39). Cauterize branches of the small saphenous vein that accompanies the sural nerve as needed. The calcaneal branch of the peroneal artery is ligated or cauterized before the calcaneal osteotomy is made. On reaching the lateral surface of the calcaneus, use a periosteal elevator to expose the superior and inferior, surfaces of the calcaneus posterior to the talus (Richardson, 1998).

Fig.(39): Incision, extending from the lateral border of the tendocalcaneus in a distal plantar direction, to end at the inferior border of the distal end of the calcaneus (Richardson, 1998).
Osteotomy:

With a drill (1/8 inch), make several bicortical holes in an oblique line extending from 1 to 1.5 cm posterior to the posterior margin of the talus distally to the plantar surface of the calcaneus ending 1 to 1.5 cm distal to the inferior calcaneal tuberosity. Medially, Just penetrate the cortex to safeguard the neurovascular bundle. Once the bicortical osteotomy is completed, stabilize the remainder of the foot distally with one hand and manually displace the posterior fragment medially, one third to one half the width of the calcaneus, until the medial border lies in a line with the sustentaculum tali Hold the displacement with one or two Kirschner wires placed obliquely across the osteotomy and cut the ends beneath the skin Fig.(40).

Fig.(40): Intraoperative X ray lateral view of medial calcaneal osteotomy (Felho et al., 2003).
Postoperatively:

A short leg, well-padded, non-walking cast is applied after wound closure for 3 weeks. Radiographs are then taken and if union has occurred the limb is lifted free to mobilize. Occasionally physiotherapy is required (Richardson, 1998).

Results:

Felho et al., (2003) reviewed the results of the modified Koutsogiannis medial displaced calcaneal osteotomy in children and adolescents using clinical and radiographic parameters. Clinically, seventeen out of nineteen patients reported absence of pain and sixteen did not present residual deformity, the correction of the deformity being noticed in the hind foot. Two poor results (pain and deformity resistance) were associated with ligamental hyperlaxity and severe pre-operative deformity. The conclusion was that the Koutsogiannis procedure showed to be effective in the management of patients in the 1-13 year age group with mild to moderate idiopathic flexible pes planovalgus, presenting esthetic improvement and symptom relief.
**Arthrodesis**

Marked deformity associated with arthritis and/or fixed osseous deformity is best managed by arthrodesis. To help stabilize the hindfoot, the choices are a talonavicular arthrodesis, a double arthrodesis at Chopart’s joint, a subtalar arthrodesis, and a triple arthrodesis.

The more extensive the arthrodesis, the more rigid the foot and, therefore, the greater the stress transfer to distal and proximal joints. Thus, a procedure should be chosen that will involve the fewest joints and still stabilize the foot.

**Talonavicular arthrodesis:**

**Indication**

Talonavicular arthrodesis as an isolated procedure can be used for an unstable talonavicular joint when the remainder of the foot is supple. It is best used in an older patient with low physical demands. It is important to place the subtalar joint in 5 degrees of valgus angulation at the time of fusion to preserve maximum motion in the hindfoot. (*Walter et al., 1995*).

**Technique**

The operative intervention was carried out using a combination of a mid-calf pneumatic tourniquet and 0.25% bupivacaine with epinephrine (1:200,000) for hemostasis. A 5-cm medially placed, linear incision was made from the tip of the medial malleolus to the navicular-medial cuneiform joint. A linear incision was made through the capsular layer and all soft tissue and ligamentous attachments were dissected off of the TN joint (*Craig et al., 2010*).
The tibialis posterior tendon was preserved, except for one case involving a complete rupture in which the tendon was excised from its insertion. Degeneration of the posterior tibialis tendon was not routinely evaluated or repaired. A small joint distractor was placed dorsally over the TN joint to allow for contoured joint resection without obscuring visualization. Joint resection was accomplished with rongeur, curettes, and power burs. The joint was fixated with 1 of 3 techniques: (I) two 4.0-mm partially threaded cancellous screws in a distal-to-proximal orientation, (2)a 2-hole one-third tubular plate fixated with two 4.0-mm fully threaded cancellous screws oriented eccentrically for compression,or (3) a 4-hole titanium locking H-plate Fig.(41)(Craig et al., 2010).

Fig. (41). A postoperative lateral radiograph demonstrating consolidation and correction following isolated talonavicular arthrodesis. Note the correction in the calcaneal inclination angle and the talar-first metatarsal angle. (Craig et al., 2010).
Post operative:

In all of the cases, the foot was initially placed in a compressive dressing with a posterior splint in a neutral position following the operation. In the postoperative phase, initial wound inspection was performed 7 to 10 days following the operation. The patient was placed in a permanent dressing consisting of either a posterior splint or a hard Jones compression dressing and remained non-weight bearing for 6 to 8 weeks. Protected weight bearing was initiated 6 to 8 weeks postoperatively, and full weight bearing in regular shoe gear routinely began 10 to 12 weeks postoperatively (Craig et al., 2010).

Disadvantage:

Of this arthrodesis related largely to the associated limitation of motion and excessive stress transferred to adjacent joints. The incidence of arthrosis of other joints of the foot and ankle attributed to stress transfere.

Double arthrodesis Fig.(42):

Indication:

A double arthrodesis involving the talonavicular joint and the calcaneocuboid joint is indicated in the younger patient with an unstable talonavicular joint but a stable subtalar joint. There is less morbidity than is associated with a triple arthrodesis, but the procedure offers the same stability. (Walter et al., 1995).
Operative technique:
The patient is positioned with a bump support under the ipsilateral hip. Under thigh tourniquet control, an incision is made from just distal and anterior to the tip of the fibula toward the fourth metatarsal base, carefully protecting cutaneous nerve branches. The origin of the extensor digitorum brevis is detached and retracted distally, exposing the calcaneocuboid joint. The capsule is incised, and all articular cartilage is removed with an osteotome. The lateral aspect of the talonavicular joint is exposed through this incision, and cartilage is removed. A medial incision extends from the tip of the medial malleolus to the naviculocuneiform joint, between the posterior and anterior tibial tendons. The talonavicular joint is exposed, capsule incised, and articular cartilage removed. Joint visualization may be enhanced with cautious use of a towel clip in the navicular, a small lamina spreader, or a cob elevator in the joint. Joint surfaces are prepared meticulously by fish scaling with a 4-mm osteotome. The foot is manipulated into correct alignment by first placing the subtalat joint in approximately 5 degree in valgus, and then placing the forefoot into a neutral position, correcting any abduction and varus deformity. Fixation first is achieved in the talonavicular joint. Currently, this includes two 4.5mm canulated screws, or one 6.5mm canulated screw in patients with a large navicular tuberosity. Calcaneocuboid fixation is achieved with either 6.5mm canulated screw or staples. The extensor digitorum brevis is reattached to its origin, and the wounds are closed in routine fashion (Mann 1999).

Postoperative:
Protocol includes 2 weeks of non weight-bearing in a short leg splint, then the sutures are removed, 4 weeks non weight-bearing in a short leg cast, then 6 weeks in a short leg walking cast (Mann 1999).
Fig. (42) Double arthrodesis, the calcaneocuboid and talonavicular joint are fused with internal fixation (Walter et al., 1995).
**Subtalar arthrodesis:**

**Indication:**
Isolated subtalar arthrodesis are indicated in the presence of a rigid or incompetent subtalar joint accompanied by a flexible forefoot and a stable talonavicular joint. It is an excellent alternative to a double arthrodesis, and when the heel is left in 5 degrees of valgus angulation, excellent motion of the foot is preserved (Walter et al., 1995).

**Surgical Technique Fig.(43):**

The patient is positioned supine on the operating table. A medial skin incision is made over the course of the posterior tibial tendon from the malleolus to the plantar edge of the first metatarsal. The tendon sheath is incised; the posterior tibial tendon is exposed: and the torn ends, or attenuated portions, of the tendon are debrided. The medial talonavicular capsule is exposed, and the spring ligament is identified. A vertical incision is made in the capsule, and imbrication is performed. The flexor digitorum longus tendon is harvested distal to the knot of Henry, by way of a grasping suture, through a 4.5- mm drill hole is made in the navicular tuberosity from dorsal to plantar All the medial sutures are placed but left untied until the subtalar arthrodesis is performed. The posterior and middle facet of the subtalar joint are exposed through a lateral curvilinear incision. The articular surfaces are denuded to expose subchondral bone (Cohen et al, 2001).
The joint surfaces are feathered with a 4-mm wide osteotome to expose cancellous bone and increase the surface area for fusion. Iliac crest or distal tibial bone graft is inserted into the posterior facet if needed. The talus and calcaneus are reduced. A partially threaded 7.3-mm cannulated cancellous screw is placed from the dorsal neck of the talus into the calcaneal tuberosity, while holding the reduced position of the subtalar joint. The talonavicular capsule and spring ligament sutures are secured with the forefoot held in inversion and the ankle in a plantar-flexed position. The posterior tibial tendon is shortened and repaired if the ends can be approximated. The flexor digitorum longus tendon transfer is pulled taut through the drill hole in the navicular and sutured in place. The distal 4 to 5 cm of the flexor digitorum longus and posterior tibial tendons are sutured side-to-side using horizontal mattress sutures of size 0 nonabsorbable braided sutures (Cohen and Johnson, 2001).
Postoperative:
the foot is immobilized in a compression splint for 24 to 48 hours until a short-leg cast is applied with the foot in plantar flexion and inversion. Until 4 weeks, when the foot and ankle is placed in neutral, and non-weight bearing in a cast is continued. *(Cohen and Johnson, 2001).*

*Triple arthrodesis Fig.(44):*

**Indication:**
The operative treatment of severe disabling arthritic pain, deformity and/or instability of the tarsal joints. The aim of this surgical procedure is to establish a painless, stable and plantigrade foot. The patient age should be 12 years or greater.

**Operative technique:**
Both a lateral and a medial incision were used. A lateral incision was made beginning at the tip of the fibula and extending across the dorsal aspect of the calcaneocuboid joint to the base of the fourth metatarsal. When deepening the incision along the dorsal aspect of the peroneal tendon sheath and along the superior border of the extensor digitorum brevis muscle (EDB), the surgeon must take care not to damage an anterior branch of the sural nerve. The EDB was detached and the muscle belly carefully reflected distally to expose the underlying sinus tarsi. Then the subtalar, calcaneocuboid and the lateral aspect of the talonavicular joint were exposed sharply with a knife and/or rongeur, removing the contents of the sinus and canalis tarsi with the capsuloligamentous structures. A lamina spreader was inserted into the sinus tarsi to visualize the subtalar joint and to open the middle facet joint also *(Stegeman et al., 2006).*
After denuding these joints the subchondral surfaces were scaled with a 4-6 mm steotome or with an awl to create a bleeding cancellous surfaces to enhance fusion. The medial incision started at the medial gutter of the ankle joint, just distal to the medial malleolus and continued longitudinally in the distal direction to the dorsal aspect of the first cuneiform bone. Dissection continued in the interval between the anterior and the posterior tibial tendons and extended so that it obliquely crossed the tibialis anterior tendon. The extensor retinaculum was carefully incised along the direction of the incision, so as not to damage the tibialis anterior tendon. The talonavicular joint was opened longitudinally in line with the original direction of this tendon. A dorsal osteophyte was removed. After identification of the joint, the cartilage was denuded (Stegeman et al., 2006).

Fig.(44) A triple arthrodesis fuses the calcaneocuboid, talonavicular and subtalar joints with internal fixation. (Walter et al., 1995).
After the above mentioned preparation the joints were rotated until a neutral hindfoot position was achieved. In case of severe valgus or cavus deformity an Achilles tendon lengthening was often performed. For a valgus hindfoot, the angle between talus and calcaneus was corrected by outward rotation of the talus in relation to the calcaneus. Adducting and plantarflexing the forefoot in relation to the hindfoot was performed so the talonavicular joint was compressed and the arch restored. At this stage a supinated forefoot could be corrected by pronating the forefoot in relation to the hindfoot in the Chopart joints. A lamina spreader can be used to lengthen the calcaneocuboid joint. The axis of the talus and the axis of the of the first metatarsal should be in line. In case of cavovarus deformity the talar head was positioned laterally, "on top" of the calcaneum. The soft tissues were excised together with release of the medial capsuloligamentous structures, including the attachment of the posterior tibial tendon when necessary. For reduction the talar head was pushed medially and the navicular bone is pulled laterally and dorsally. This manoeuvre coincides with increased pronation of the forefoot. When the foot is flexible enough the tarsus will take a neutral or valgus position. The more fixed the deformity, however, the more bony excision from the talar head and lateral column was needed in order to reposition the tarsus. The talonavicular joint was transfixed with a compression screw/cortical screw in a lag fashion. Because the reduction of this joint completely determines the geometry of the hindfoot this is called the "homerun screw". The screw (usually 60 mm in length) was inserted from the medial border of the naviculocuneiform joint into the body of the talus. Then the talocalcaneal joint was compressed with a 6.5 mm screw directed downwards from the dorsomedial aspect of the talus into the tuberosity of the calcaneus (length between 80 and 100 mm). The calcaneocuboid joint was fixed last, with a cortical screw directed from the anterior process of the
calcaneus to the cuboid (usually 40 mm length). A gap due to lengthening of the lateral column can be closed with bone taken from the dorsal aspect of the anterior process of the calcaneus or bonegraft otherwise. The EDB was closed over the lateral side, after which the subcutaneous tissue and skin were closed. On the medial side the capsular tissue, if possible, and retinaculum were closed, after which the subcutaneous tissue and skin were closed (Stegeman et al., 2006).

Postoperative:

The foot was placed in a below knee cast for a period of 4 weeks and the patients mobilized non-weight bearing. After 4 weeks a below knee cast was applied in which the patients were allowed to increase weight bearing. After 8 weeks the patients were mobilized full weight bearing in a commercial walking brace, unless there is a sign of delayed healing. The Walker was used for another month before gradually weaning off the Walker. Multiple factors will determine variability to the time of complete recovery, but usually this takes a year (Stegeman et al., 2006).
**Calcaneocuboid distraction arthrodesis:**

For various reasons, including increased pressure across the calcaneocuboid joint, some investigators are now recommending lateral column lengthening by calcaneocuboid distraction arthrodesis (CCDA). This procedure fuses the calcaneus and the cuboid by excising the articular cartilage from the joint and inserting a bone graft into the prepared joint. This lengthens the lateral column and creates a solid fusion between the calcaneus and the cuboid. Failures of this procedure are often caused by failure of fixation. The cervical H-plate has been shown to be substantially stronger than crossed screws for graft fixation, which may explain the lower incidence of nonunion with the use of this plate (*Hill et al., 2003*).

Lengthening of the lateral column increases tension on the operative incision that can lead to dehiscence. Adequate exposure and gentle soft-tissue handling are especially important to reduce the incidence of this complication. The medial column may need to be shortened to relieve the tension that is placed on the lateral skin (*Hill et al., 2003*).

*Catanzariti, (1992)* observed that with arthrodesis of the first tarsometatarsal joint, the peroneus longus muscle gained a mechanical advantage at the medial naviculo-cuneiform joint, where the majority of first ray motion occurs. This mechanical advantage indirectly restored functional stability to the medial column.
Arthroereisis

Arthroereisis is the name for stabilization of the subtalar joint by an implant. The implant can be constructed by a variety of materials, and its purpose is to hold the talus in proper alignment with the calcaneus so this corrects the planter-flexed posture the talus assumed in flexible pes planus. The procedure usually is done in young children.

Viladot, (1992) introduced a technique in which by means of an external and internal double surgical approach raising the internal arch and simultaneously correcting the hindfoot is attempted. A cuplike orthosis with a flat base and conical body is inserted in the sinus tarsi. Good results using this operation have been reported. Complications of arthroereisis include peroneal spastic flatfoot, stiffness of the subtalar joint, and foreign body reaction.

Giannini et al., (2003) has performed extra-articular arthroereisis with use of a bioabsorbable implant in the sinus tarsi (fig.45); through a 1cm incision. The procedure is simple and effective in correcting functional flexible flatfoot. They suggested that surgery performed during growth provides an optimal and lasting correction of the deformity, restoring the talocalcaneal alignment with remodeling of the subtalar joint. This correction improves the biomechanics to prevent problems caused by persistent pronation of the foot. The bioabsorbable implant proved to be virtually complication-free and did not need to be removed.
Fig. (45) Tarsal canal (Saxena et al., 2007).
Surgical procedure

Procedures were performed while the patients (in some cases, outpatients) were under either general or local anesthesia monitored by one surgeon! The procedure itself is performed while the patient is under tourniquet and radiograph control. A 1- to 2-cm incision is made within the skin lines on the lateral aspect of the sinus tarsi region. Soft tissue dissection is performed bluntly under the talus in the direction of the tarsal canal. This region is not evacuated of its contents. A 1.5-mm guide pin is then inserted from lateral to medial and can be penetrated through the medial aspect if desired. A cannulated "punch" of 7 mm is placed over the guide wire and advanced under the talus.

The subtalar eversion should be reduced and limited to less than 2° when the subtalar joint is maximally everted. The subtalar joint range of motion was assessed by one surgeon.

This was done by stabilizing the midfoot manually so that the subtalar joint could be maximally everted. If not, sequentially larger "punches" are "trialed" until the range-of motion reduction is achieved. These range from 7 to 9 mm in diameter. Generally, the lateral (trailing) edge of the "punch" is 1 cm medial to the lateral edge of the calcaneus.

With intraoperative fluoroscopic imaging, the medial tip (leading) edge is advanced to the talar bisection on the anteroposterior view (Fig.41 A and B). When sufficient sizing is determined, the punch is removed and the actual implant "interference screw" is placed with a cannulated screw driver. If the implant was too long (implants ranged from 24-32 mm), it was trimmed with a saw, generally to 18 mm (Fig. 46). This was assessed by measuring the amount of the trailing edge of the implant: which would be 1 cm medial to the lateral edge of the calcaneus (Saxena et al., 2007).
In order to prevent deformation of the implant, the screw driver was maintained within the shaft of the implant but was withdrawn to the appropriate length. Again, limitation of range of motion of the subtalar joint is confirmed, and the screwdriver can be temporarily left in place to confirm appropriate placement radiographically. Once this is done, the screwdriver and the guide wire are removed.

The surgical wound is irrigated, and the skin is approximated with 2 horizontal mattress sutures of 3-0 nylon or monofilament polypropylene. Postoperatively, patients are maintained in a below-knee cast boot for 4 weeks, the first 2 weeks, non-weight-bearing. Sutures are removed at approximately 2 weeks (Saxena et al., 2007).

Fig.(46) Intraoperative and anteroposterior view of screw(Saxena et al 2007).
Results:

(Giannini et al., 2003) noted significant radiographic and subjective improvement in a 4-year follow-up study of 21 adolescent patients. They used a bioabsorbable implant of PLLA, and, via MRI, they determined that by 4 years the implant was completely absorbed. They did not note any sinus formation or osseous alteration of the sinus tarsi. At this time, it appears that similarly configured (to metal) bioabsorbable subtalar arthroereisis implants can be safely placed in the tarsal canal, without granuloma formation and hindfoot orthosis.
SUMMARY
Summary

The human foot is a highly complex structure. It has two major functions. To support the body in standing and progression; to lever it forwards in walking, running and jumping.

The human foot, alone among primates, is normally arched in its skeletal basis. Its medial margin arches up between the heel and the ball of the big toe, forming a visible and obvious medial longitudinal arch. Bony factors do not play a significant role in maintaining the stability of this arch. Ligaments are important, but are unable to maintain the arch entirely on their own.

Loss of the medial longitudinal arch of the foot; results in pes planus or flat foot deformity. The term is used to describe a mixture of anatomical variations and pathological conditions. In children and adolescents the most common disorders seen include flexible flatfoot, tarsal coalition, calcaneovalgus foot, accessory navicular bone and congenital vertical talus.

Flexible flatfoot in most cases is a physiological variant rather than a pathological condition. It occurs in all infants and is common in children and adolescent. Actually the medial longitudinal arch develops during the first decade of life. Many etiological factors contribute to flexible flatfoot, including familial tendency, generalized ligamentous laxity, obesity as will as shoe-wearing in early childhood. While the definit aetiology is unknown.
Diagnosis of flexible flatfoot should be based on careful clinical examination. The clinical examination includes assessment of the height of the medial longitudinal arch, tightness of heel cord, integrity of muscles, subtalar joint motion and the degree of flexibility. The x-ray is helpful for diagnosis of flexible flatfoot, various angles have been described for the measurement of flatfoot. The talo-meatarsal "Meary angle" must be measured in lateral weight-bearing plain radiograph.

Treatment should be reserved for patients who have problems as a result of flatfoot. Shoe inserts have been proved to be ineffective in correction of the deformity but may relieve symptoms in some cases. Surgery is indicated when non-operative treatment fails to relieve symptoms. Surgical options include soft tissue reconstruction, that includes the following procedures. Tibialis anterior transfer into talus It has been utilized in selected symptomatic patients with severe talar declination and subluxation. The tibialis anterior is transferred through the talus from dorsal lateral to planter medial for direct talar control, Flexor digitorum longus transfere through which a medial curved incision used for flexor digitorum longus transfere to the navicular through a tunnel and sutured to itself, Tendo Achilis lengthening that is used in patient with a tight heel cord despite a vigorous stretching program. Z plasty of the tight tendo achillis is always needed to bring the ankle to at least 10 to 15 degree of dorsiflexion, Spring ligament reconstruction When rupture is present repair with advancement may not be possible but reconstruction options are available. The peroneus longus tendon is rerouted to the medial aspect of the foot. The tendon is detached at the musculotendinous junction that remain attached distally. Once rerouted, it is secured to the planter medial aspect of the sustentaculum tali under tension, thus reconstructing the planter calcaneonavicular ligament.
Osteotomy which may be either, Evan’s calcaneal osteotomy for treatment of calcaneovalgus deformity with lateral column lengthening using autogenous tibial cortical bone graft. Although autograft remains the standard choice of biomaterial, allogenic bone has also been used with success, Medial Displacement calcaneal osteotomy in which the osteotomy is done through the body of the os calcis, moving the proximal calcaneus medially and derotating it out of valgus and positions the contact portion of the heel more in line with the weight-bearing axis. The osteotomy elevates the medial arch, and centralizes the motion of the subtalar joint. This procedure is indicated in patients who have excessive heel aversion without excessive abduction or varus of the forefoot. Arthrodesis, used in marked deformity associated with arthritis and/or fixed osseous deformity is best managed by arthrodesis. Talonavicular arthrodesis as an isolated procedure can be used for an unstable talonavicular joint when the remainder of the foot is supple. It is best used in an older patient with low physical demands. It is important to place the subtalar joint in 5 degrees of valgus angulation at the time of fusion to preserve maximum motion in the hindfoot. A double arthrodesis involving the talonavicular joint and the calcaneocuboid joint is indicated in the younger patient with an unstable talonavicular joint but a stable subtalar joint. There is less morbidity than is associated with a triple arthrodesis, but the procedure offers the same stability. Isolated subtalar arthrodesis are indicated in the presence of a rigid or incompetent subtalar joint accompanied by a flexible forefoot and a stable talonavicular joint. It is an excellent alternative to a double arthrodesis, and when the heel is left in 5 degrees of valgus angulation, excellent motion of the foot is preserved. Calcaneocuboid distraction arthrodesis, this procedure fuses the calcaneus and the cuboid by excising the articular cartilage from the joint and inserting a bone graft into the prepared joint. This lengthens the lateral column and creates a solid fusion between the calcaneus and the cuboid.
Arthroereisis is the name for stabilization of the subtalar joint by an implant. The implant can be constructed by a variety of materials, and its purpose is to hold the talus in proper alignment with the calcaneus so this corrects the planter-flexed posture the talus assumed in flexible pes planus. The procedure usually is done in young children. Complications of arthroereisis include peroneal spastic flatfoot, stiffness of the subtalar joint, and foreign body reaction.
References


7. *Charrette, M. N* Do children need corrective footwear?. [online] [s.n]. Dynamic Chiropractic. Available from: http://www.findarticles.com/p/articles/mi_qa3987/is_200306/ai_n9280014 [01/04/05]


22. **Engel GM, Staheli LT.** The natural history of torsion and other factors influencing gait in childhood. A study of the angle of gait, tibial torsion,


29. **Graves SC, Kuester DJ, Richardson EG.** Dysplasia epiphysealis hemimelica (Trevor disease) presenting as peroneal spastic flatfootdeformity: a case report. Foot Ankle (1991.) 12:55-58,


31. **Gray's Anatomy. By Susan Standring ; 39th Edition ; chapter 115-Foot and ankle(2005); 1507:45.**
32. **Haendlmayer KT, Harris NJ.** mini-symposium foot and ankle orthopedic and trauma 2009; 23-6.


42. **Kasser JR, In Morrissy RT, Weinstein SL.** Lovell and Winter Pediatric orthopedics. 6th ed; Lippincott Williams&Wilkins 2005, 1258-1321.
43. **Kayc, R.A., Jahss, M.H.**. Tibialis posterior: a review of anatomy and biomechanics in relation to support of the medial longitudinal arch. Foot Ankle Int. 1991-11, 244-247.


47. **Kulik SA Jr, Clanton TO**. Tarsal coalition. Foot Ankle Int(1996)17:286-296,


53. **Michael P. Stauff MDa, William B. Kilgore MDb,l, Patrick W. Joyner MD, MSc,2, Paul J. Juliano MDd** Functional outcome after
percutaneous tendo-Achilles lengthening, (journal foot and ankle surgery FAS 2010-431: No of Pages 4.).


56. **Mosca VS.** flexible flatfoot and skew fool instr course Lect. 1996;(54)347-54.


64. **Paley D.** Principles of deformity correction. Springer-Verlag, Berlin, 2002; 35:75-82.


75. **Slovenkai MP.** Clinical and radiological evaluation. Foot Ank Clin 1997;2:241e60.


القدم المسطحة المرنة في معظم الحالات هي حالة طبولوجية بديلة من حالة مرضية.

وهي تظهر في جميع الظروف وشائع في الأطفال والمراهقين.

الطويل الأنيسي يتطور خلال العقد الأول من الحياة. تساهم العديد من العوامل المسببة للقدم المسطحة المرنة، بما في ذلك استعداد عائلي، التراخي الرباطية المعمم، والسمنة وأيضًا ارتداء الأحذية في مرحلة الطفولة المبكرة في حين أن المسببات المرضية غير معروفة.

تعتبر تعبير وصفي

حيث تشخيص مرضية غير مرضية

تقريباً معمم عند الولادة. انتشرها أقل

الذي يحدث تلقائياً الأولي من الحياة.

القدم المسطحة المرنة غير المنلمة بالأطفال

بينما

تقييم الأعضاء

لا يزال هناك جدل كبير فيما يتعلق باستخدام تقييم العظام في

السطحية المرنة غير المنلمة. أظهرت المراجعات الراهب للاستفادة الأخيرة

أن هناك أدلة

فعالية

لاجرائية

هي حقاً تشخيص

يجب تقييم كل مريض

لتحديد

الحالات التي يكون فيها تاريخ العائلة

اختلال المشية

تشير إلى
كان هناك علاقة ذات دالة إحصائية بين عمر المريض 
والنهاية. كان هناك تحسن كبير في نهاية المريض.

انهيار
في نهاية

وتشمل خيارات استعدادات عظمية بالعقب، وعمليات الأنسجة الليئة، وتقنية وقعية، وتقنية تقويم معدات نجاح عالية طويلة.

وقد تم توثيق معدلات نجاح عالية طويلة.
رسالة مقدمة من الطبيب / احمد ابراهيم القاضي

للحصول على درجة الماجستير
في جراحة العظام - جامعة بنها

تحت إشراف

أ.د / سمير ذاهد
أستاذ جراحة العظام
كلية الطب - جامعة بنها

أ.د / عمرو الجزار
أستاذ مساعد جراحة العظام
كلية الطب - جامعة بنها

د / حسام السيد فرج
مدرس جراحة العظام
كلية الطب - جامعة بنها

كلية الطب
جامعة بنها
2015