Controversies in the Management of Stage II Flatfoot

Pisit Boonma¹, Chamnanni Rungprai²

ABSTRACT
Stage II flatfoot patients will complain about pain on the medial side of midfoot and hindfoot due to tendinitis and tendinosis of medial foot structure, such as, posterior tibialis tendon (PTT) and spring ligament and some will complain the lateral midfoot and hindfoot pain due to impingement of lateral structure; the peroneus, fibula, and lateral process of the talus.¹⁻⁶ The examination will reveal a decrease foot arch while standing, hindfoot valgus, too many toes sign, and inability to perform a single heel-rise test.⁴⁻⁷ There will be swelling and tenderness along the PTT. Resist foot inversion should show weakness and elicit pain. The examiners should evaluate the component of forefoot supination, forefoot abduction and medial ray instability for subclassification of stage II flatfoot.² The isolated spring ligament insufficiency can be observed while the patient has hindfoot valgus but could perform a single heel-rise test.⁶ In 2015, Pasapula et al. invented the “neutral heel lateral push test” to evaluate the integrity of the spring ligament complex. The examination was performed by hold the heel in a neutral position and used the other hand push lateral force of first metatarsal bone. If the translation was >1 cm, it means losing the integrity of spring ligament.⁹⁻¹⁰

BACKGROUND
Stage II flatfoot or the “flexible” flatfoot patients will complain about pain on the medial side of midfoot and hindfoot due to tendinitis and tendinosis of medial foot structure, such as, posterior tibialis tendon (PTT) and spring ligament and some will complain the lateral midfoot and hindfoot pain due to impingement of lateral structure; the peroneus, fibula, and lateral process of the talus.¹⁻⁶ Previously, posterior tibialis tendon dysfunction (PTTDD) was known as the primary problem. Nowadays, many works of literature explain the cause of flat feet that not only the dysfunctional PTT. The reports of isolated spring ligament torn and the shortening of the calcaneus also thought to be the causes.⁵⁻⁷ Due to many subtypes and disease pathologies, the management in stage II flat feet are diverse. This topic will discuss the main approach of type II flatfoot and the controversies topics, such as, the amount of medial calcaneal sliding osteotomy, how to correct forefoot abduction, forefoot varus, arthroereisis, or arthrodesis.

Keywords: Acquired adult flatfoot, Arthrodesis, Arthroereisis, Cotton osteotomy, Flexible flatfoot, Lateral column lengthening, Medial calcaneal sliding osteotomy, Posterior tibialis tendon dysfunction, Spring ligament reconstruction.

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REVIEW RESULTS
According to classification, stage II flatfoot is the foot that presents in clinical of flexible hindfoot valgus and decreases the arch of the foot when weight-bearing. There are up to five subtypes of stage II flatfoot which classified by foot deformity as shown in Table 1.²,⁵⁻¹⁰ There are many etiologies to explain flatfoot deformity pathology. Previously, posterior tibialis tendon dysfunction (PTTDD) was known as the primary problem. Nowadays, many works of literature explain the cause of flat feet that not only the dysfunctional PTT. The reports of isolated spring ligament torn and the shortening of the calcaneus also thought to be the causes.⁵⁻⁷ Due to many subtypes and disease pathologies, the management in stage II flat feet are diverse. However, conservative management should be started initially which compose of rest, immobilization, cold compression, and pain killer medication, such as, NSAIDs, paracetamol, or weak opioid medication. When the symptoms are improved, second-line conservative treatment should follow; the medial arch support insole, foot orthotics, Achilles tendon stretching, and PTT strengthening.²,³,¹⁰⁻¹²

Surgical treatments are recommended when conservative treatment could not relieve the symptoms.¹³ Before surgical treatment, the appropriate investigation should be performed to well-plan preoperative planning. The standard bilateral weight-bearing radiograph of the foot and ankle and the hindfoot alignment view are important to identify the degree of correction and associated pathology. In 2010, Reilingh et al. report the long axial radiograph view is more reliable than a hindfoot alignment view for measuring hindfoot alignment. And they also compare unilateral and bilateral weight-bearing stance. They found that unilateral weight-bearing radiograph does not lead to greater reliability of measurement.¹⁴⁻¹⁵

Magnetic resonance imaging (MRI) of the ankle is essential for preoperative planning. The benefits are to evaluate PTT quality, the spring ligament injury, and other associated problems, such as, impingement on lateral site, cartilage lesion, or deltoid ligament insufficiency.¹⁶⁻¹⁷

A computer tomography scan (CT scan) could provide more complex deformity and degenerative joints.¹⁷ Recently, the use...
Table 1: Subtypes of stage II flatfoot

| Subtypes of stage II flatfoot | Hindfoot | Forefoot supination | Forefoot abduction | Medial ray instability |
|------------------------------|---------|---------------------|--------------------|-----------------------|
| Stage IIA                     | Valgus  | Residual supination | –                  | –                     |
| Stage IIB                     | Valgus  | Flexible            | –                  | –                     |
| Stage IIC                     | Valgus  | Flexible            | –                  | –                     |
| Stage IID                     | Valgus  | Flexible or fixed   | Present            | –                     |
| Stage IIE                     | Valgus  | Flexible            | ±                  | Present              |

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The appropriate treatment for stage IIA and IIB should combine medial calcaneal slide osteotomy (MDCO) with a tendon transfer. The choice of tendon transfer is FDL, FHL, or peroneus brevis (PB). The biomechanics study showed the strength of the tendons when compared with the PTT. However, these tendon options are not strong enough to restore PTT power. The most common tendon transfer is FDL tendon transfer due to its similar line of pull of PTT, match the PB strength (but gain only 30% of posterior tibialis muscle), act in the same phase of PTT and expendable.2,3

The MDCO is biomechanically beneficial due to shifting the over-pronation force of the Achilles tendon to supination which also supports FDL tendon transfer and shifts the weight-bearing axis of the heel closer to the tibial axis.21 The procedure could be performed open or minimally invasive technique.17,22–24 The bone cut can be performed in an oblique fashion, dome-shaped, L-shaped, or Z-shaped.25 The important things are not to shorten the calcaneus which could happen due to associated gastrocnemius and soleus muscle contracture. The shortening of calcaneus could lead to a decrease of arch height and decrease the transferred tendon strength. The Z-shaped osteotomy can prevent this shortening but have to precise when performed bone cut. The fixation can be fixed with screws or a pre-contoured step-plate.26 Some authors suggest using two longitudinal screws for obese or osteoporotic patients, but the latest retrospective comparison study shows no statistical difference between single or double screw calcaneal osteotomy fixation.27 The screw placement should be avoided in the position on which the foot will contract the floor because this will increase the rate of hardware-related pain and subsequent hardware removal surgery. The headless screw was associated with a significant decrease in this incidence. And, the lateral edge after sliding could cause sural nerve and peroneal tendon irritation, so the prominent cortex should be removed.3,21,26

The medial column deformity should be evaluated carefully.18 The fixed forefoot varus or forefoot supination can be examined by correct the valgus hindfoot to a neutral position. After correction of the heel, if the forefoot is still varus over 10–15° when compared to the tibial axis, which means the forefoot was fixed.4 Then, the medial column stability must be evaluated by holding the first metatarsal with one hand and the other hand holds other metatarsals.18,27 The excessive vertical motion of the first ray should suspect the hypermobile of the medial column. When the hypermobile was suspected, the surgeon should evaluate the unstable joint. This step could analyze by evaluating the lateral weight-bearing radiograph of the affected foot. The weight-bearing computer tomography scan can give more detail for understanding more complex deformities.18 The deformity may occur in one or more of the talonavicular, naviculocuneiform, or tarsometatarsal joint. The failure to address the medial column deformity could be unable to restore “triangular of support” which results in a biomechanically unstable foot and cause recurrent flatfoot deformity.28,29

Associated gastrocnemius contracture was commonly found with flatfoot.19 The contracture calf muscles could be one of the causes of flatfoot. The tightness of the triceps surae causes the calcaneal plantar flexion and decreases the transverse arch of the foot. And due to the long-standing of the disease, the hindfoot valgus also causes the Achilles contracture. So, the tightness of gastrocnemius and soleus muscles should be evaluated concurrently with preoperative planning. The Silfverskiold test helps to identify the contracture muscle that needs to release intraoperatively. The procedure can be done with open or minimally invasive techniques. The goal of recession is to restore ankle dorsiflexion to 5°.3,30

Discussion

Medial Calcaneal Sliding Osteotomy, How Much?

The amount of translation for medial calcaneal sliding osteotomy is not well reported. Most works of literature agree to medial sliding about 5–10 mm. These numbers should give an adequate bone surface contract for union and enough space for screw fixation. The medial calcaneal sliding osteotomy will medialize the center of the pressure of the ankle joint which confirmed decrease strain on the deltoid and spring ligament. However, there is literature that found medial calcaneal sliding osteotomy could injure the lateral plantar nerve and medial plantar artery. These could be preventing by cut carefully when performing osteotomy through the medial cortex.1 In 2018, Peiffer et al.31 report three-dimensional displacement after medializing calcaneal osteotomy. They found a large inferior displacement along with calcaneal osteotomy which reduces the medial calcaneal displacement. They suggest using accurate preoperative planning and good intraoperative control of calcaneal osteotomy surgery which can be achieved by computer-aided surgery.32

Forefoot Abduction; Spring Ligament Reconstruction or Lateral Column Lengthening?

If there is forefoot abduction (Stage IID) which means there is abnormal talonavicular coverage, the treatment should combine...
the procedure that could be correct forefoot abduction. The primary goal for correcting forefoot abduction is to restore talonavicular coverage. This could divide into soft tissue and bone procedure. The soft tissue procedure is spring ligament reconstruction. There are many various procedures for the reconstruction of the spring ligament. The nonanatomic and anatomic spring ligament reconstruction. They concluded that nonanatomic spring ligament reconstruction provided the greatest correction for midfoot and hindfoot misalignment in flexible flatfoot. But if the forefoot abduction is >50% of talonavicular coverage, the bone procedure should be addressed.

Although some surgeons believe that the cause of flatfoot is calcaneal shortening, so they decide to lengthen the calcaneus and add spring ligament reconstruction if there is residual forefoot abduction. The bone procedure, lateral column shortening, has many options that differ in the location of osteotomy and osteotomy shape. The bone procedures are superior to soft tissue procedures due to it is not degrade with time and correct the arch height (sagittal plan deformity). For this reason, some authors prefer to perform lateral column shortening first before do the medial calcaneal sliding osteotomy. In a cadaveric study, Zanoli et al. found that lateral column shortening alone provides more coronal and sagittal correction than medial sliding calcaneal osteotomy with FDL transfer. They also found that additional spring ligament repair in both medialized calcaneal osteotomy or lateral column shortening did not improve any parameter.

Another benefit of bone procedure over soft tissue procedure is it reduces the tension of medial site soft tissue, such as, PTT and spring ligament. However, many works of literature report its drawback. First, the lateral column shortening will increase the joint reaction force of the calcaneocuboid joint which may lead to early joint degeneration. There are some reports which found stress fracture of the fifth metatarsal bone that is associated with a lateral column shortening procedure. Some surgeons choose to perform lateral column shortening through the fusion of the calcaneocuboid joint to prevent this complication. However, the biomechanical study has shown that lateral column shortening decreases pressure in the calcaneocuboid joint. Second, it is reported some of the patients have unspecific lateral foot pain. This may be due to sural nerve irritation or implant discomfort. Third, the nonunion and delayed union could occur. The lateral column shortening should be about 5–12 mm depending on the severity of forefoot abduction. The iliac strut graft or metal wedge plate can be used to maintain the abduction.

**Foot and Varus; Classical Cotton Osteotomy or Closing Wedge Osteotomy?**

The forefoot supination should be corrected by Cotton osteotomy (Medial Cuneiform Dorsal Opening Wedge Osteotomy). The amount of opening wedge is evaluated after the complete correction of hindfoot and midfoot, mostly the gap will open around 4–8 mm. The gap can be filled by a wedge plate, trabecular titanium wedge, or strut bone graft. The current literature has shown that trabecular titanium wedge provides good clinical comparable to bone wedge graft. The goal of correction forefoot supination is to correct forefoot supination to 0–10°. The study by Conti et al. showed that excessive opening wedge plantar flexion of medial cuneiform (Cotton osteotomy) was the inferior postoperative clinical outcome when compared to mild plantar flexion. But according to the deformity, the postoperative medial cuneiform plantarflexion should be related to the severity of forefoot supination which means patients who need excessive plantar flexion should have more severe disease. In 2016, Ling et al. report the technique of plantar closing wedge of the medial cuneiform. The study concluded closing wedge osteotomy can treat the forefoot supination and the advantage was simplicity and no bone graft required. Recently, Mortimer et al. study in the cadaveric feet the biplanar effect of the medial cuneiform osteotomy. Surprisingly, the plantar flexion dorsal opening wedge osteotomy, Cotton osteotomy, corrects forefoot supination but worsen forefoot abduction. They concluded the appropriate medial cuneiform osteotomy for flatfoot is plantar flexion plantar closing wedge osteotomy.

**Arthroereisis in Adult Flat Feet?**

Arthroereisis derived from the combination of the Greek word arthro- (joint) and -ereisis (the action of sustaining, supporting, pushing against something). Subtalar arthroereisis is a surgical option in the treatment flatfoot to limit the movement of the subtalar joint without blocking it and restore the medial foot arch. Arthroereisis has been used predominantly to treat flat feet in a pediatric patient. Many literature report success rate up to 96–99% in children. Nowadays, the quality of available studies in an adult is poor. The benefit of this procedure is a minimally-invasive procedure, decrease postoperative swelling, shorter hospital stay. Subtalar arthrodesis induced triplanar correction; calcaneal eversion, talar adduction, and plantar flexion. However, there are many drawbacks, such as, pain in sinus tarsi, loss of fixation, high incidence of removal, and no study of the long-term result. The subtalar arthroereisis should not use as a stand-alone treatment in adult flexible flatfoot. The grade of recommendation for this procedure should be considered as C, due to the inadequate quality of studied published.

**Posterior Tibialis Tendon Resection?**

The most common cause of adult acquired flexible flat feet is due to PTTD. In most cases, the PTT is degenerative. The tendon could be degenerative and thickening with a fibrosis scar or could be ruptured around the insertion site. But in some early presentation patients, the PTT was partially torn. Due to the high index force of the PTT, some surgeons suggest debridement of the synovitis and the torn apart and augmentation with a tendon transfer. Although some surgeons believe that the remnant of the PTT will be the cause of pain and not properly function. They suggest rest it and perform tendon transfer instead.

**Arthrodesis?**

Hindfoot arthrodesis for the treatment of stage II flatfoot is controversial. There is to be concern about the loss of hindfoot motion and the best constant correction. The arthrodesis could give a stronger construct which causes less recurrent but could cause adjacent joint arthritis in the future. Limited arthrodesis may be indicated when there is a moderate to a severe deformity that cannot be corrected with reconstruction and joint-sparing osteotomy alone. The arthrodesis options are talonavicular joint arthrodesis, double arthrodesis, medial column stabilization with
calcanecuboid joint distraction arthrosis, and repositional subtalar joint arthrosis. The arthrodesis options should be considered in morbid obesity patients, sedentary lifestyle patients, and salvage of a failed reconstruction. 49

**Conclusion**

Stage II flatfoot deformity has many etiologies of the disease. The surgeon should know the principle of deformity correction and “a la carte” procedures selection for every patient.

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