Applying the “Twisted Plate Theory” of Foot Stability to Flatfoot Surgery

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Fig. 7. The truss is a triangular structure. Under the load (W) the struts are under compression (C) and the tie-rod (AB) is under tension (T). Any joint, for example point A, is in vectorial equilibrium as indicated in the insert diagram. C compresses the point A and T tenses the same point.

Twisted Plate Theory

Twisting of the lamina pedis, or skeleton of the human foot involves Eversion or Pronation of the forefoot or... Inversion or Supination of the rearfoot

Un-twisting of the lamina pedis involves Inversion or Supination of the forefoot or... Eversion or Pronation of the rearfoot
The Twisted Plate Theory of Foot Stability

**Key Point:** Twisting the plate will raise the medial longitudinal arch, plantarflex the First Ray, decrease strain on the medial central band of the plantar aponeurosis, and decompress and improve ROM of the 1st MTP.

**First described by:**

Introduces the term "lamina pedis" to describe the footplate

**And then again by:**

**And Finally:**
The Twisted Plate

Twisting of the lamina pedis follows the lateral rotation of the head and neck of the talus, which occurs in-utero

This valgus, or eversion rotation of the neck of the talus results in pronation positioning of the forefoot on the rearfoot...

Twisting the plate

McCarthy, 1994
In-Vitro Study

- Nine fresh frozen specimens
- Axial load in static stance 225-900N
- 6 degree wedges: Medial & Lateral, RF & FF
- Strain in plantar fascia measured with reluctance transducer


Plantar Fascia Strain

Wedge under lateral forefoot decreased strain (p<0.05)

Wedge under medial forefoot increased strain (p<0.05)

Rearfoot wedges had no significant effect

Effects of Medial & Lateral Wedges under the Foot

- 15 Male running subjects, asymptomatic
- 4 conditions w/foot inserts w/4.5 mm posting: Full Lateral, Full Medial, Half Lateral, Half Medial
- COP data collected with PEDAR system

Results: Only the Full Lateral Insert caused a significant change in shift of center of pressure: this shift was towards the LATERAL SIDE


“Indeed, as displayed for forefoot wedging and for rearfoot wedging of a typical individual, the COP shifts more medially with a varus wedge and more laterally with a valgus wedge. Internal wedges behave in the opposite manner from externally applied wedges.”

Van Gheluwe B, Dananberg HJ: Changes in Plantar Foot Pressure with In-Shoe Varus or Valgus Wedging. JAPMA 94(1) 1-11 2004
Twisting the plate

In the weight bearing foot:

Increase ground reaction forces under metatarsals 4 and 5

Untwisting the plate

In the weight bearing foot:

Increase ground reaction forces under metatarsals 1 and 2

Other descriptions of the “Twisted Plate”

(During loading phase of gait):

Congruent motion is communicated to the subtalar joint and the talus is effectively screwed home into the acetabulum pedis, about the comparatively upright subtalar axis, and the leg bones reflect this movement by showing medial rotation.

As the full weight is thus applied to the foot the lamina pedis becomes flattened or untwisted and this plays its part in causing the centre of gravity to veer back towards the other side. The major part of this untwisting movement occurs at the calcaneocuboid joint - effectively the calcaneus is exorotated. The lamina pedis is now in a close-packed position with the plantar calcaneocuboid (short plantar) ligament, plantar calcaneonavicular (spring) ligament and bifurcated ligament all tensed.

The Twisted Plate

The lamina pedis becomes twisted upon itself as we compare primates and humans:

In primates, the lamina pedis is a flat plat resting on the ground. The calcaneus is lateral to the talus, on the same flat plane as the metatarsals. The subtalar joint is oriented vertical, separating the horizontal arrangement of the talus and the calcaneus.

In humans, the lamina pedis is “twisted” i.e the calcaneus has become “twisted” to move under or beneath the talus. This change occurs in-utero.

The subtalar joint complex is now horizontal, separating the vertically oriented talus and calcaneus.
Un-twisting the lamina pedis allows the human foot to assume the appearance of the adult acquired flatfoot: Lowering of the medial longitudinal arch, eversion of the calcaneus, widening of the Talo-Calcaneal angle, supinatus deformity of the forefoot.

The Twisted Plate
Removing FF Suppinatus

Twisted Plate Theory:
How Can We Raise the Arch?

Evert the Forefoot:
Increase Ground Reaction Forces under Lateral Metatarsals

Invert the Rearfoot:
Increase Ground Reaction Forces under Medial Calcaneus

Twisted Plate Theory:
How do we increase GRF under lateral metatarsals?

Lateral Forefoot wedging
Lengthen Lateral Column

Twisted Plate Theory:

¬ Is there any other evidence that increasing pressure under the lateral forefoot will raise the medial arch and/or decrease strain in the plantar aponeurosis?

Answer: Look at studies of lateral column lengthening for flatfoot correction

Lateral column lengthening: Correction of Flatfoot

Corrects forefoot abduction
Increased talonavicular coverage
Restore medial longitudinal arch

DuMontier, TA; Falicov, A; Mosca, V; Sangeorzan, B: Calcaneal lengthening: investigation of deformity correction in a cadaver flatfoot model. Foot Ankle Int. 26:166 – 178, 2005.

Myerson, MS, Corrigan, J; Thompson, F; Schon, LC: Tendon transfer combined with calcaneal osteotomy for treatment of posterior tibial tendon insufficiency: a radiological investigation. Foot Ankle Int. 16:712 – 718, 1995


Lateral column lengthening: Negative Effects

Increased forefoot varus
Increased lateral forefoot pressure
Lateral column pain
Fifth metatarsal stress fx


Tien, TR; Parks, RG; Goyen, GP: Plantar pressures in the forefoot after lateral column lengthening: a cadaver study comparing the Evans osteotomy and calcaneocuboid fusion. Foot Ankle Int. 26:520 – 525, 2005.


Medializing Calcaneal Osteotomy

Also Increases Lateral Forefoot Pressure

Hadfield, MH; Snyder, JW; Lianos, PC; et al.: Effects of medializing calcaneal osteotomy on Achilles tendon lengthening and plantar foot pressures. Foot Ankle Int. 24:523 – 529, 2003.

Hadfield, M; Snyder, J; Lianos, P; et al.: The effects of a medializing calcaneal osteotomy with and without superior translational on Achilles tendon elongation and plantar foot pressures. Foot Ankle Int. 26:365 – 370, 2005.

Twisted Plate Theory:
How do we increase GRF under medial hindfoot?

Medial Rearfoot wedging
Medializing Calcaneal Osteotomy
Medial Calcaneal Displacement

- 129 Patients.
- Mean follow up, 5.2 years post op
- 118 Patients entirely satisfied, 7 patients partially satisfied, 4 patients dissatisfied.
- 125 Patients (97%) experienced pain relief.
- 121 Patients (94%) showed improvement of function.

- After medial displacement calcaneal osteotomy, strain decreased at the attachment point of the deltoid ligament.

Myerson MS, Badekas A, Schon LC: Treatment of stage II posterior tibial tendon deficiency with flexor digitorum longus tendon transfer and calcaneal osteotomy. Foot & Ankle Int, 25: 448-450

“The medial displacement calcaneal osteotomy resulted in decreased length and, likely, less tension in the spring ligament.”


“From these results, we concluded that reconstruction LCL provides more correction of the longitudinal arch at the midfoot and overall realignment of the medial column of the foot than a reconstruction with MTO.”

“This result establishes that the final correction achieved in the LCL group was significantly greater than the one achieved in the MTO group.”

“In summary, reconstructions performed with LCL produced a greater change in the realignment of a flexible flatfoot, maintained more of their initial correction over time, and were associated with a lower incidence of additional surgery than reconstructions with a MTO of the calcaneus.”

MDCO vs Evans Osteotomy: Comparison of Correction


“Why would lateral forefoot wedging and lateral column lengthening not cause pronation of the foot at the subtalar joint?”

Answer: It has to do with ligament strain and motion of the foot at joints other than the subtalar joint

Twisted Plate Theory:

Mosca has suggested that the effects of lengthening of the lateral column results in elevation of the longitudinal arch and correction of the valgus deformity due to the windlass effect of the plantar fascia.

Lateral Column Lengthening: Facilitate the Windlass??


MDCO and Evans: No increased tension on the plantar fascia!

In fact, the opposite:

“The original hypothesis was that these manipulations would result in increased tension on the plantar fascia with elevation of the medial longitudinal arch secondary to an increase in the windlass mechanism. The results obtained reveal that tightening of the plantar fascia does not occur with either medial calcaneal displacement or lateral column lengthening. Medial translation resulted in an average of 1.1 mm of loosening of the plantar fascia. Lateral column lengthening through the calcaneocuboid joint resulted in even more loosening of the plantar fascia (average, 1.9 mm). Lateral column lengthening was shown to produce statistically significantly looser plantar fascia than medial displacement.”

Calcaneal Lengthening Osteotomy

The navicular center of rotation is within the head of the talus. The shape of the talar head is therefore important to the degree of deformity correction.

The effective center of rotation of the cuboid is within the calcaneus and is compatible with rotation about the long plantar ligament.

The bony architecture and the plantar soft tissues, including the long plantar ligament and possibly the plantar talonavicular capsule and the lateral portion of the calcaneonavicular ligament, appear to contribute to the mechanism of deformity correction.


Long Plantar Ligament

It has been suggested that the long plantar ligament is important in the success of the calcaneal neck osteotomy for correction of flatfoot.

Lateral Plantar Ligament (LPL)

“Thus after an Evans procedure, the lateral one-third of the LPL is under maximum strain, the spring ligament is extremely lax, and the medial band of the plantar fascia is also lax.”

“In addition, when shortening bony procedures to the medial column are performed in addition to the Evans procedure, the rippling effect may be compounded: even more laxity in the PF and spring ligament could be created.”


The Twisted Plate Theory of Foot Stability

**Key Point:** With the foot resting on the ground, inverting the hindfoot will increase ground reaction forces (plantar pressure) against the 4th and 5th metatarsal heads.

Applying a 6 degree lateral (valgus) wedge across the forefoot will increase ground reaction forces (plantar pressure) against the 4th and 5th metatarsal heads.

A calcaneal lengthening osteotomy will increase ground reaction forces (=plantar pressure) against the 4th and 5th metatarsal heads.

The Twisted Plate Theory of Foot Stability

**Key Point:** With the foot resting on the ground, everting the hindfoot will increase ground reaction forces (plantar pressure) against the First metatarsal head.

Applying a 6 degree medial (varus) wedge across the forefoot will increase ground reaction forces (plantar pressure) against the First metatarsal head.

A Cotton osteotomy or plantar flexion osteotomy anywhere along the First Ray will increase ground reaction forces (plantar pressure) against the First metatarsal head.

Solution to Increased Lateral Forefoot Pressure:

*Plantarflexion, opening wedge osteotomy (Cotton) of the medial cuneiform*


Methods: Eight matched pairs of cadaver lower extremities were axially loaded onto a TekScan HR Mat. (TekScan, Inc., South Boston, MA) After intact testing, each specimen had a lateral column lengthening (either a calcaneocuboid distraction arthrodesis [CCDA] or Evans procedure), a medializing calcaneal osteotomy (MCO), and a plantarflexion (Cotton) osteotomy of the medial cuneiform. The measured plantar pressures were divided into three forefoot regions, two midfoot regions, and two hindfoot regions. For each region, average pressure, peak pressure, and contact area data were collected.

Conclusions: The present study demonstrated increased lateral forefoot pressures after a combined lateral column lengthening and MCO and does not support the idea that a Cotton osteotomy significantly reduces loading of the lateral forefoot.

Clinical Relevance: The incidence of lateral forefoot pain and fifth metatarsal stress fractures subsequent to either lateral column lengthening procedure may not significantly decline after a Cotton osteotomy.

Cotton Osteotomy: Improved Alignment?

Radiographic and Pedobarographic Comparison of Femoral Head Allograft Versus Block Plate with Dorsal Opening Wedge Medial Cuneiform Osteotomy: A Biomechanical Study

Alan C. League, MD; Brent G. Parks, MSc; Lew C. Schon, MD

Foot & Ankle International/Vol. 29, No. 9/September 2008

"Radiographic change in this model was inconclusive. The small radiographic differences noted in this study fall within the 2- to 3-degree variation in angle measurements taken by different examiners."

The Twisted Plate

When the rearfoot inverts, ground reaction force increases under mets 4 & 5: Forefoot pronates, tension increases in long and short plantar ligaments, medial arch raises, first ray passively plantarflexes: Twisting the Plate

When the rearfoot everts, ground reaction force increases under 1st Met: First ray dorsiflexes, forefoot supinates: Un-twisting the plate

STUDIES SHOW NO IMPROVEMENT OF METATARSUS PRIMUS ELEVATUS OR HALLUX EQUINUS MEASUREMENTS AFTER DISTAL FIRST METATARSAL HEAD OSTEOTOMIES


Untwisting the Plate:  

Increasing GRF under the First Metatarsal will not raise the arch of the foot

**Untwisting the Plate: Theory**

Medial column procedures intending to increase GRF under the First Metatarsal will not change alignment of the arch because the joints of the twisted plate will react with a reciprocal lowering of the arch. Only when arthrodesis is performed will the twisted plate mechanism be nullified.

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Raising the Medial Longitudinal Arch

**Role of the Ligaments**

- **Spring Ligament does not increase tension after calcaneal lengthening**

- **Plantar Fascia reduces tension after calcaneal lengthening**

- **Increased tension in the long plantar ligament is the key to deformity correction with lateral column lengthening**

**Conclusion:** Interventions which INCREASE STRAIN on the Long Plantar ligament will raise the arch of the human foot.

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Twisted Plate Theory:

Do Lateral Column Lengthening Procedures improve alignment by:

- **Change forefoot alignment to increase supination moment at the STJ?**
  - **Answer:** No. At least no evidence thus far

- **Increase pressure (GRF) under the lateral metatarsals?**
  - **Answer:** Yes. Numerous studies have verified.

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The Twisted Plate Theory of Foot Stability

**Essential Key Point!**

Any measure which increases plantar pressure at the 1st metatarsal will deliver dorsiflexion moment, resulting in dorsiflexion motion across the key joints of the First Ray. As long as there is motion available in the N-C and Med Cun-1st Met joints, any surgical procedure which increases pressure against the plantar surface of the first metatarsal will cause an immediate dorsiflexion of the first ray back to its original state of equilibrium.

In the lateral column, increased plantar pressure under 4th and 5th metatarsals does not cause dorsiflexion motion of the Calc-Cuboid or Cuboid-4th and 5th mets because these joints are inherently stable.

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The Twisted Plate Theory of Foot Stability

**Key Point:** Increasing pressure under the plantar surface of the 4th and 5th metatarsals will decrease pressure under the 1st metatarsal head due to:

- Direct mechanical offloading (the more pressure you put under one side of the foot, the less pressure on the other side)
- Tensioning of the long plantar ligament, which raises the Calcaneal inclination angle, inverts the hindfoot, raises the medial longitudinal arch

**...in other words, this increased pressure under mets 4 and 5 “Twists the Plate”!!**
The Twisted Plate Theory of Foot Stability

**Key Point:** Decreasing plantar pressure under the 1st metatarsal head will allow the First Ray to passively plantarflex.

*When the First Ray plantarflexes:*

- There is decreased tension in the medial slip of the central band of the plantar aponeurosis.
- Improved dorsiflexion range of motion of the 1st MTP
- The medial longitudinal arch will elevate