The Adult Acquired Flatfoot

PATHOMECHANICS

CLINICAL EVALUATION

TREATMENT GUIDELINES

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OBJECTIVES

Review current understanding of the pathomechanics of AAF
Present an updated classification of AAF
Review studies of conservative care of AAF
Propose protocol for ankle foot orthotic (AFO) therapy for AAF
Loss of the dynamic and static supportive structures of the arch hindfoot and ankle

Adult Acquired Flatfoot
Pathomechanics

Dynamic supporting structures of the arch
- Plantar Aponeurosis
- Posterior Tibial Tendon
- Plantar Intrinsic Musculature

Static supportive structures of the arch
- Spring Ligament Complex
- Superficial Deltoid Ligament
- Long and Short Plantar Ligaments
- Plantar Aponeurosis

Bracing the Adult Acquired Flatfoot
RECENT INSIGHTS

Not solely due to TPD
**Adult Acquired Flatfoot**

*Isolated loss of the PT tendon without ligamentous disruption will not lead to a progressive flatfoot deformity.*

**Ligament Attenuation in Flatfoot**

- Spring Ligament Complex
- Plantar Aponeurosis
- Deltoid
- Talo-Calcaneal
- Long & Short Plantar
- Medial Calcaneo-Cuboid

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The adult acquired flatfoot deformity cannot be reproduced experimentally by releasing the tibialis posterior tendon alone.


“In conclusion, we have shown that, to create flattening of the plantar arch, there is a need to cut the medial structures, including the spring and plantar ligaments and possibly the plantar fascia.”


Tendon vs Ligament

- Eight Lower Leg Specimens
- All tendons vs all minus PTT
- Create AAF: cutting spring lig.
- Restore PTT to AAF model


Intact osteo-ligamentous structures can maintain alignment after initial loss of PTT
- With creation of a flatfoot (cut lig.) restoring PTT function could not significantly improve alignment
- PTT had greatest influence on hindfoot kinematics during heel rise
- “Bracing should provide support during heel rise.”

In this study, strain in the deltoid ligament was shown to increase significantly during the heel rise portion of the joint cycle after a properly positioned triple arthrodesis was performed. This finding is supported by the fact that the posterior tibial tendon has been shown to be most active during early heel rise.”


Pathomechanics of the Adult Acquired Flatfoot: Summary of the Literature

1. Pre-existing flatfoot
2. Increased gliding resistance of the Posterior Tibial Tendon
3. Everted Hindfoot unlocks midtarsal joint during mid-stance, terminal stance and heel rise
4. Increased strain on supportive ligaments and tibialis posterior
5. Attenuation and rupture of posterior tibial tendon
6. Sequential rupture of spring ligament, superficial deltoid, and interosseous talo-calcaneal ligaments.
Pre-existing Flatfoot as a Cause of PTTD


Causative Factors

Holmes & Mann, 1992

67 pts. - 76% women, 57 years
Obesity in 33% (p=.005)
HTN in 34% (p=.025)
52% had either DM, HTN or obesity

Tendon of Tibialis Posterior

1. Zone of hypovascularity from tip of malleolus:
   14 mm prox 10 mm distal
2. Abrupt change of direction
3. 1st Pulley: Malleolar groove
   2nd Pulley: Navicular

Vascularity

Frey, JBJS 72A: 884, 1990

TP Tendon

• No mesotendon distally
• blood supply : PT & DP art.
• Hypovascular zone begins 40mm prox. to navicular, extends 14mm prox.
ABSTRACT

Background: Degenerative pathology of the posterior tibial tendon, a common cause of foot and ankle dysfunction, frequently affects women over 40 years of age. Its etiology is still controversial. The literature reports decreased vascularization coinciding with the most common site of the lesion, near the medial malleolus.

Methods: Forty pairs of PTT obtained from human cadavers were transversally cut into six levels, from the musculotendon transition to its insertion point. In each segment, a histologic cut was made and stained with Masson’s trichrome allowing viewing of the vascular structure of the tendon under a light microscope. By using an integrating eyepiece on the microscope, vascular density was calculated. This verified any variation of the vascular concentration in the normal tendon, a possible cause of its degeneration.

Results: When the results were compared by sex, side, and age, no statistically significant difference was observed. When the levels were compared, no area of decreased vascularization was seen in the midportion of the tendons, the most common site of degeneration of the posterior tibial tendon. Conclusion: These results indicate that an area of decreased vascularity is not a factor in degeneration of the posterior tibial tendon at the medial malleolus.


Methods: An experimental system was developed that allowed direct measurement of gliding resistance at the tendon-sheath interface. Seven normal fresh-frozen cadaver foot specimens were studied, and gliding resistance between the posterior tibial tendon and sheath was measured. The effects of ankle and hindfoot position and the effect of flatfoot deformity on gliding resistance were analyzed. Gliding resistance was measured for 4.9 N applied load to the tendon. Results: Mean gliding resistance for the neutral position was 77 ± 13.1 (×10−2 N). Compared to neutral position, dorsiflexion increased gliding resistance and averaged 130 ± 38.9 (×10−2 N), and plantarflexion decreased gliding resistance and averaged 35 ± 12.6 (×10−2 N). Flatfoot deformity increased gliding resistance compared to normal feet, averaging 104 ± 17.0 (×10−2 N) for neutral, 205 ± 55.0 (×10−2 N) for dorsiflexion, and 58 ± 21.3 (×10−2 N) for plantarflexion.

Conclusions: The findings indicate that patients with a preexisting flatfoot deformity may be predisposed to develop posterior tibial tendon dysfunction because of increased gliding resistance and trauma to the tendon surface.


“The increased gliding resistance measured for the flatfoot suggested that for patients with PTTD who begin to develop a flatfoot deformity, there is additional resistance about the tendon that accelerates tendon degeneration and dysfunction. These findings also suggested that a patient with longstanding flexible flatfoot may be predisposed to PTTD.”


“It is likely that the increased gliding resistance is related to the anatomical course of the posterior tibial tendon as it turns sharply around the medial malleolus towards its medial and plantar foot insertion. From an anatomical and mechanical point of view the posterior tibial tendon closely approximates the bony surface of the medial malleolus rather than that of a tendon sheath. The tendon curves more acutely than the adjacent tendons in the medial aspect of the ankle, the flexor digitorum longus and flexor hallucis longus. The posterior tibial tendon is, therefore, under considerable tension in the area posterior and distal to the medial malleolus, especially during the dorsiflexed position and with flatfoot deformity.”
Pathophysiology of Adult Acquired Flatfoot: Gliding Resistance of the Posterior Tibial Tendon and Pre-Existing Flatfoot Deformity

Tadashi Fujii, MD; Eiichi Uchiyama, MD; Harold B. Kitakora, MD; Zong-Ping Luo, PhD; Kristin D. Zhao, MA; Kai-Nan An, PhD. The Influence of Flatfoot Deformity on the Gliding Resistance of Tendons About the Ankle. Foot & Ankle International/Vol. 30, No. 11/November 2009

Materials and Methods: The gliding abilities of the posterior tibial, flexor digitorum longus, and flexor hallucis longus tendons at the ankle hindfoot level were compared, in terms of gliding resistance, with use of a system that was developed in this laboratory. Six cadaveric specimens were used and tested in a dorsiflexed position, then in simulated flatfoot in a dorsiflexed position.

Results:

The gliding resistance was found to be significantly greater in the simulated flatfoot in dorsiflexion compared to the dorsiflexed position with an intact arch for the PT, FDL, and FHL tendons. The gliding resistance was significantly higher in the PT tendon than FDL or FHL tendons in the flatfoot/dorsiflexion condition.

There was no significant difference between the FDL and FHL tendons in resistance in either condition.

Conclusion: We concluded that the gliding ability of the PT tendon was inferior to that of the FDL and FHL tendons in a simulated flatfoot model.

Clinical Relevance: The findings of the present study are consistent with the clinical observations that tendinitis and rupture of the PT tendon commonly occurs at the malleolar level, whereas FDL and FHL ruptures do not. A pre-existing flexible flatfoot deformity may be associated with PT tendon dysfunction in the adult due to poor gliding ability of the PT tendon.
Tibialis Posterior Tendon

Insertions

Anterior - Navicular tuberosity
N-C joint capsule
1st cuneiform

Middle - 2nd cuneiform
3rd cuneiform
cuboid, PL tendon
2nd, 3rd, 4th, 5th mets

Posterior - Sustentaculum Tali

"the present study, however, reveals that the tibialis posterior muscle in man has a multi pennate origin from the fibula, and that the fibular sided fibers of the muscle are very numerous but very short. On this account, the fibular-sided fibers of the muscle are more powerful than the tibial"

Between these two unequal levers (unequal in bulk, length and strength) lies the talus. When the foot is dorsiflexed at the ankle, the talus becomes firmly lodged in the tibiofibular socket and serves as part of the proximal lever or the leg.

Two Lever Theory

“Between these two unequal levers (unequal in bulk, length and strength) lies the talus. When the foot is dorsiflexed at the ankle, the talus becomes firmly lodged in the tibiofibular socket and serves as part of the proximal lever or the leg.”

Kelikian, 1985
Internal rotation of tibia = Internal rotation of talus

“Unique to this study, the change in PT muscle excursion associated with forefoot positions suggested a large moment arm of the forefoot around an abstraction and adduction joint axis. The range of movement in forefoot abstraction and adduction was approximately 20 degrees.”
ABSTRACT

Ten patients were identified with traumatic, complete common peroneal nerve palsy, with no previous foot or ankle surgery or trauma distal to the knee, who had undergone anterior transfer of the posterior tibial tendon to the midfoot. Six of these patients had a transfer to the midfoot and four had a Bridg procedure with tenodesis of half of the posterior tibial tendon to the peroneus longus tendon. Average follow-up was 74.9 months (range, 18-361 months). All patients' feet were compared assessing residual muscle strength, the longitudinal arch, and motion at the ankle, subtalar, and Chopart's joint. Weight-bearing lateral X-rays and Harris mat studies were done on both feet. In no case was any valgus hindfoot deformity associated with posterior tibial tendon rupture found. It seems that the pathologic condition associated with a posterior tibial tendon deficient foot will not manifest itself if peroneus brevis function is absent.
Kinematic Studies of PTTD Subjects


Jeff R. Houck, PhD, PT; Christopher G. Neville, PT, PhD; Josh Tome, MS; Adolph S. Flemister, MD: Ankle and Foot Kinematics Associated with Stage II PTTD During Stance. Foot & Ankle International Vol. 30, No. 6/June 2009.

Healthy vs. PTD Walking Kinematics

• PTD:
  – Rearfoot (RF relative to Leg):
    • SP: ↓ plantar flexion at terminal stance.
    • FP: no difference in rearfoot eversion/inversion.
    • TP: ↑ abduction at terminal stance.

Rattanaprasert et al., 1999

• PTD:
  – Forefoot (FF relative to RF):
    • SP: ↓ dorsiflexion in early stance, and marked ↑ in mid-late stance phase.
    • FR: marked ↑ in eversion velocity from heel strike to 20% stance.
    • TP: marked ↑ in FF abduction in terminal stance.

Rattanaprasert et al., 1999
Locking Mechanism of the Midtarsal Joint

Blackwood CB; Yuen TJ; Sangeorzan BJ; Ledoux WR: The midtarsal joint locking mechanism. Foot Ankle Int. 26: 1074 – 80, 2005.


Altered Sagittal Plane Motion in PTTD Patients

Excessive plantarflexion of the hindfoot (at the ankle) contributes to arch lowering and First Ray dorsiflexion at midstance.

Unlocking the MTJ and increasing Foot Flexibility

Patients with PTTD display greater relative HF eversion and FF dorsiflexion than controls across the stance phase of gait, suggesting even greater foot flexibility. These abnormal foot kinematics increase the length of the PT muscle and reliance of the foot on ligaments for support during push off.

Adult Acquired Flatfoot

Stage II Disease: Critical Changes

- Progressive ligament rupture
- Loss of movement transfer


Background: The purpose of this observational study was to identify the pattern of ligament involvement using standardized, high-resolution magnetic resonance imaging (MRI) in a series of 31 consecutive patients diagnosed with PTTI compared to an age matched control group without PTTI.
Results: Statistically significant differences in frequency of pathology in the PTTI group and controls were found for the superomedial calcaneonavicular ligament ($p < 0.0001$), interosseous ligament ($p = 0.0001$), anterior component of the superficial deltoid ($p < 0.0001$), plantar metatarsal ligaments ($p = 0.0002$) and plantar naviculocuneiform ligament ($p = 0.0006$).

The ligaments with the most severe involvement were the spring ligament complex (superomedial and inferomedial calcaneonavicular ligaments) and the tarsocalcaneal interosseous ligament.

Conclusion: Ligament involvement is extensive in PTTI, and the spring ligament complex is the most frequently affected. Because ligament pathology in PTTI is nearly as common as posterior tibial tendinopathy, treatment should seek to protect or prevent progressive failure of these ligaments.

“All patients in the PTTI group had some degree of MRI abnormality of the superomedial calcaneonavicular ligament. MRI evidence of pathology in this component of the spring ligament complex was nearly as severe as that in the posterior tibial tendon.”

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**Adult Acquired Flatfoot**

Ligament Insufficiency: Why does it matter?

<table>
<thead>
<tr>
<th>STAGE</th>
<th>PATHOLOGY</th>
<th>CLINICAL SIGNS</th>
<th>REARFOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Tenosynovitis</td>
<td>Swelling, Tenderness</td>
<td>Flexible</td>
</tr>
<tr>
<td>II.</td>
<td>Attenuation or Rupture</td>
<td>Arthrosis, FF abduction, too many toes can or cannot heelrise</td>
<td>Flexible</td>
</tr>
<tr>
<td>III.</td>
<td>Complete Rupture</td>
<td>Lateral foot pain increased heel valgus cannot heel rise</td>
<td>Rigid</td>
</tr>
<tr>
<td>IV.</td>
<td>Valgus talocrural jt.</td>
<td>DJD of Rearfoot, Fibular Mall. Fx.</td>
<td>Rigid</td>
</tr>
</tbody>
</table>
Stage I: Tenosynovitis without deformity

In Stage I disease, the tendon is inflamed or partially ruptured, deformity is absent or minimal and the overall continuity of the tendon is maintained, and is subdivided into three categories:

A. Inflammatory disease. Posterior tibial tendon (PTT) rupture that results from a systemic disease such as rheumatoid arthritis and the other inflammatory arthropathies is recognized as a separate entity. In Stage IA, hindfoot anatomy is maintained and the foot alignment is normal.

B. Partial PTT tear with normal hindfoot anatomy.

C. Partial PTT tear with hindfoot valgus. This is a slight deformity to distinguish it from Stage II disease, and represents an incipient rupture.
Stage II: Ruptured PTT and flexible flatfoot

Stage II disease implies PTT tendon rupture, as evidenced on physical examination by a clinically apparent flatfoot, weakness with inversion of the plantarflexed foot, and inability to single leg heel rise. Because some patients exhibit several of the following features, some degree of overlap may exist.

A. Hindfoot valgus. In Stage IIA, once the heel is reduced from valgus to neutral, there is a minimal if any residual forefoot supination.

B. Flexible forefoot supination. In Stage IIB, reducing the hindfoot from valgus to neutral results in forefoot supination, which is however flexible. If the ankle is plantarflexed to relax the gastrocnemius muscle, the forefoot supination is corrected.

C. Fixed forefoot supination. In Stage IIC, because of long-standing hindfoot valgus, adaptive changes have occurred in the frontal plane of the forefoot. Thus, although the hindfoot deformity is supple and reducible to neutral, the forefoot deformity becomes fixed once the heel is held reduced. In other words, when the ankle is plantarflexed while the hindfoot is held reduced, the forefoot remains supinated.

D. Forefoot abduction. This may occur at the transverse tarsal joint (most commonly) or at the first tarsometatarsal (TMT) or naviculocuneiform joint. The first TMT joint instability can be either a primary deformity or a result of TMT joint arthritis. The simplest way to determine this distinction is through examination of the lateral foot X-ray (XR) image for a gap at the plantar joint surface, which is present with primary deformity. Primary deformity of the first TMT joint may also result in secondary hindfoot deformity, including rupture of the PTT.

E. Medial ray instability. As in Stage IIC (fixed forefoot supination), the Stage IIE foot retains forefoot supination with reduction of the valgus heel to neutral. This persists even with ankle plantarflexion. This is due to instability of the medial column i.e. at the talon-avicular, naviculocuneiform, or medial cuneiform-first metatarsal joint, or a combination thereof. This situation is similar to IIA; however, after the heel is corrected to neutral, the unstable medial ray will tend to dorsiflex, and this dorsiflexion causes the foot to collapse into pronation and leads to painful subtalar joint impingement.

Stage II: Ruptured PTT and flexible flatfoot (continued):
Stage III: Rigid hindfoot valgus

Stage III disease is generally associated with a more advanced course of tendon rupture and deformity and is typically characterized by rigid hindfoot valgus. Forefoot deformity may also be present, and it usually consists of rigid forefoot abduction or instability at the first TMT joint.

A. Hindfoot valgus.
B. Forefoot abduction and or sagittal plane instability.

Stage IV: Ankle valgus

Stage IV disease occurs after chronic tendon rupture and is associated with deltoid ligament rupture and medial ankle instability, leading to ankle (tibiotalar) joint valgus deformity. It often occurs in the setting of previous triple arthrodesis. Several variants of this condition have been seen; it may be associated with or without ankle instability and arthritis and a flexible or rigid hindfoot.

A. Flexible ankle valgus.
B. Rigid ankle valgus. This is the more common presentation of Stage IV disease.
STUDIES OF CONSERVATIVE TREATMENT OF AAF

Chao W; Wapner KL; Lee TH; Adams J; Hecht PJ: Non-operative management of posterior tibial tendon dysfunction. Foot Ankle Int. 17(12): 736 – 41, 1996.

Chao et al. retrospectively studied the conservative treatment of stage II and III disease. Stage II disease was treated with the UCBL type orthotic while Stage III disease was treated with the molded ankle foot orthosis (MAFO). Forty-nine patients (53 feet) participated with a mean follow up of 20.3 months. Using a clinical scoring system, 69.7% of patients had excellent/good results. Of these, 12.2% of patients discontinued use of the brace because of improvement, while 53.1% continued use of the brace at follow up.

Augustin et al. prospectively studied the use of a short custom-molded AFO (“Arizona brace”) in treatment of PTTD. Despite a short follow up period (mean, 12 months), they found significant changes in AOFAS, FFI, and SF-36 scores. The AOFAS score increased from 37.7 to 70.7.

The FFI activity, pain, and disability scores improved to 14.8, 29.3, and 32.3 respectively.
The use of a structured exercise program in addition to an orthosis for treatment of Stage I and II disease was reported. A short articulated AFO (SAAFO) was used if symptoms were present for greater than 3 months and a three-quarter-length foot orthosis used if they were present less than 3 months. The median treatment period was 129 days with a minimum followup of 1 year.

The average VAS was 1.0 after treatment. 89% were subjectively satisfied with their treatment while 11% were dissatisfied and went on to surgery. 8.5% were unable to wean from the SAAFO. Therefore, 80.5% were successful in avoiding surgery and staying brace free.

Results: Thirty-three feet in 32 patients were included with an average follow up of 8.6 years. Success defined as being brace-free and avoiding surgery was 69.7%. Five patients (15.2%) were unable to completely wean from a brace. Five patients went on to surgery. The mean AOFAS and FFI score was 78.4 and 18.4, respectively. Compared to national norms, SF-36 sub scores for each age sub-category showed no significant difference in any of the age groups ($p < 0.05$). Average VAS pain scale score was 1.9. Satisfaction was rated as “satisfied” in 20 patients (60.6%), “satisfied with minor reservations” in 11 patients (33.3%), partially satisfied in one (3.0%), and “unsatisfied” in one (3.0%). None of the patients rated as “satisfied with major reservations”.

Conclusion: Treatment of Stage II PTTD with a DUAFO has been shown to be a viable alternative to surgery with a high likelihood of adequate function, avoidance of surgery, and being brace-free at 7- to 10-year follow up.
Nonoperative Care for the Treatment of Adult-acquired Flatfoot Deformity
Matthew D. Nielsen, DPM; Erin E. Dodson, DPM; Daniel L. Shadrick, DPM; Alan R. Catanzariti, DPM; Robert W. Mendicino, DPM; D. Scot Malay, DPM, MSc, FASFC, FASFN

In this article, we describe the results of a retrospective cohort study that focused on nonoperative measures, including bracing, physical therapy, and anti-inflammatory medications, used to treat adult-acquired flatfoot in 64 consecutive patients. The results revealed the incidence of successful nonsurgical treatment to be 87.5% (56 of 64 patients), over the 27-month observation period.
The longest surgical outcome study of Stage II PTTD was reported by Myerson et al. The mean follow up was 5.2 years after calcaneal osteotomy and FDL tendon transfer. The mean AOFAS score was 79 points. They also reported satisfaction rates of 91.5%, pain relief in 97%, function in 94%, and ability to wear shoes without modification or arch support in 84%.

The only use of the FFI for grading surgical treatment of Stage II PTTD was Van der Krans et al. They prospectively evaluated 20 patients after lateral column distraction arthrodesis and FDL transfer with an average follow up of 2.1 years using the FFI and AOFAS hindfoot score. The average total AOFAS and FFI was 79.2 and 22.1, respectively.

### Final Outcome: Surgery vs Non-Surgical Treatment

<table>
<thead>
<tr>
<th></th>
<th>AOFAS score</th>
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<tr>
<td>Augustin</td>
<td>70.7</td>
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<tr>
<td>Lin</td>
<td>78.4</td>
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<tr>
<td>Krause</td>
<td>82</td>
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<tr>
<td>Myerson*</td>
<td>79</td>
</tr>
<tr>
<td>Van der Krans*</td>
<td>79.2</td>
</tr>
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</table>

*surgeal treatment

### SUMMARY

The Adult Acquired Flatfoot is a condition which represents a cascade of soft tissue failures leading to dysfunction of the foot and ankle during ambulation.

Progression of deformity and disability can be monitored by clinical exam and gait analysis which can be partially supported by imaging studies.

Intervention with ankle foot orthoses has become the gold standard of treatment in the United States before surgical intervention should be recommended.

The majority of patients with Stage II deformity can be expected to be successfully treated with a combination of ankle bracing (AFO devices) and physical therapy. They can expect to be free of wearing a brace within 12 months of start of treatment.

No surgical intervention has proven to be more successful than conservative treatment of AAF, while complications from both treatment options are far more likely when surgery is performed compared to bracing.
THE FLEXOR DIGITORUM LONGUS TENDON TRANSFER: WHY DO WE DO IT?

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DIAGNOSIS:
Stage II Posterior Tibial Tendon Dysfunction
TREATMENT:
Medial displacement calcaneal osteotomy with flexor digitorum longus tendon transfer.
First papers reporting success with the FDL transfer as a solitary procedure for PTTD:


Studies which refute initial success with the FDL Transfer:

"The FDL transfer alone does not consistently correct the valgus malalignment. In one series it had a 50% failure rate at two years. As a result, the standard teaching now recommends bony deformity correction in addition to a soft tissue procedure. Even with adequate deformity correction coupled with a standard medial soft tissue reconstruction, the FDL tendon and resultant inversion force may still be significantly less than that of the normal posterior tibialis. The FDL has been shown to be on average one-half to one third the size of the PTT. This is most likely to be borderline adequate."


Suzette J. Song, MD; Jonathan T. Deland, MD: Outcome Following Addition of Peroneus Brevis Tendon Transfer to Treatment of Acquired Posterior Tibial Tendon Insufficiency Foot & Ankle International, Vol. 22, No. 4, April 2000

Power and excursion

5 cadaver specimens
Lower leg muscle dissection
Length and weight measurement

Silver RL, Garza J: The myth of muscle balance JBJS 673:432, 1985
Fig. 4. Graph depicts fibre length (excursion) vs. percentage strength. Muscles in the same region of the graph have similar strength and excursion characteristics.
Influence of Tendon Transfer Site on Moment Arms of the Flexor Digitorum Longus Muscle

Background: Adult acquired flatfoot is a common condition that leads to significant morbidity. Along with bone procedures to operatively treat this condition, transfer of the flexor digitorum longus (FDL) tendon to the medial cuneiform or navicular is routinely performed. The goal of this tendon transfer is to increase the capacity of the FDL to invert the hindfoot and control the transverse tarsal joints. However, it is not known whether this biomechanical goal is met or whether one transfer site produces a larger mechanical advantage compared to another site. The purpose of this study was to calculate FDL muscle moment arms at the hindfoot with two clinically relevant transfer locations to quantify the change in mechanical advantage of the FDL after tendon transfer.

Methods: In seven cadaver specimens, muscle moment arms of the FDL with respect to hindfoot motion were measured using the tendon excursion method before and after the FDL was transferred to the plantar aspect of the navicular and medial cuneiform. The position and orientation of the foot and excursion of the FDL tendon were measured with an optoelectronic measurement system.

Results: The FDL moment arm did not increase after tendon transfer to either the medial cuneiform or navicular when compared to its native site. There were significant decreases in FDL moment arms when transferred from its native site to the medial cuneiform (56% decrease, p = 0.018) and navicular (46% decrease, p = 0.026). Conclusions: In contrast to the clinical proposition that FDL transfer to the navicular or medial cuneiform increases this muscle’s mechanical advantage to invert the hindfoot, this cadaver study suggests that, to the contrary, FDL moment arms decrease after tendon transfer.

“The FDL is operatively transferred to the plantar aspect of the medial cuneiform or navicular tuberosity in patients with adult acquired flatfoot in part to improve the capacity of the FDL to invert the hindfoot. In this study, the capacity of the FDL to invert the hindfoot was measured in terms of its muscle moment arm before and after tendon transfer. For the two clinically relevant transfer sites tested, there was no increase in moment arm in comparison to the native FDL. On the contrary, the native FDL demonstrated a larger mechanical advantage to invert the hindfoot than did the transferred FDL, suggesting that given equal muscle force generated at the two sites, the intact muscle provides a larger moment about the hindfoot complex before transfer surgery.”

Why transfer the FDL?

Background: Adult acquired flatfoot is a common condition that leads to significant morbidity. Along with bony procedures to operatively treat this condition, transfer of the flexor digitorum longus (FDL) tendon to the medial cuneiform or navicular is routinely performed. The goal of this tendon transfer is to increase the capacity of the FDL to invert the hindfoot and control the transverse tarsal joints. However, it is not known whether this biomechanical goal is met or whether one transfer site produces a larger mechanical advantage compared to another site. The purpose of this study was to calculate FDL muscle moment arms at the hindfoot with two clinically relevant transfer locations to quantify the change in mechanical advantage of the FDL after tendon transfer.

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“Flexor digitorum longus transfer has been an integral part of the treatment of adult acquired flatfoot for over 20 years. It is unclear if patient satisfaction with such multifaceted operative procedures used to treat adult acquired flatfoot is a direct result of tendon transfer, PT debridement, or the realignment of the limb through osteotomy or fusion. This biomechanical cadaver study suggests that FDL transfer does not increase the mechanical advantage and consequently may not contribute to improved patient outcomes. In contrast, FDL transfer to either the navicular or the medial cuneiform may actually decrease its capacity to invert the hindfoot once transferred from its native state.”

Table 2: FDL moment arm magnitudes in mm at neutral position for corresponding surgery cases in accordance to specimen Native Cuneiform Navicular

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Native</th>
<th>Cuneiform</th>
<th>Navicular</th>
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</thead>
<tbody>
<tr>
<td>Specimen 1</td>
<td>18.5</td>
<td>15.1</td>
<td>13.7</td>
</tr>
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<td>Specimen 2</td>
<td>10.9</td>
<td>7.7</td>
<td>9.9</td>
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<tr>
<td>Specimen 3</td>
<td>20.0</td>
<td>17.7</td>
<td>18.1</td>
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<td>Specimen 4</td>
<td>15.4</td>
<td>6.4</td>
<td>1.8</td>
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<td>Specimen 5</td>
<td>15.6</td>
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<td>Specimen 6</td>
<td>20.2</td>
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<td>5.3</td>
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<td>Specimen 7</td>
<td>26.9</td>
<td>4.2</td>
<td>16.6</td>
</tr>
</tbody>
</table>

Group Mean 19.6 ± 5.5 8.7 ± 5.8 10.7 ± 5.9

5. Conclusions

Our analysis shows that as posterior tibial tendon and medial arch ligament insufficiency develops the forces on the medial arch increase, and as the foot becomes flat the moments at the joints of the medial rays show very large increases. A 10 mm medial slide calcaneal osteotomy substantially decreases the moments on the talo-navicular joint and the load on the medial arch in the flat foot toward normal. Our analysis also shows that adding the flexor digitorum longus transfer to the navicular further decreases the load on the talo-navicular joint by less than 1% beyond that achieved with the MDCO alone.
Transverse Plane Motion at the Ankle Joint

- In vivo kinematic study, 25 subjects
- Static and dynamic conditions
- Mean Ankle/STJ ROM:
  - 27.2° transverse plane
  - 7.6° frontal plane
- Ankle transverse ROM: >15°

"The angulation of the ankle/subtalar axis to the transverse plane calculated from the data from the static study was consistently high, ranging from 53.2° to 88.9°, and this reflects the predominance of transverse plane motion at the complex."

"...the ankle and subtalar joints contribute approximately equal amounts of transverse plane motion to the overall function of the ankle/subtalar complex."
Treatment of Posterior Tibial Tendon Dysfunction without Fenor Digitorum Tendon Transfer: A Retrospective Study of 34 Patients

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Abstract

A retrospective study of patients with posterior tibial tendon dysfunction, ankle arthroscopy, and hindfoot arthrodesis was conducted to assess the outcomes of a nonoperative approach for the treatment of posterior tibial tendon dysfunction. The study included 34 patients with posterior tibial tendon dysfunction who underwent hindfoot arthrodesis without fenor digitorum tendo transfer. The patients were divided into two groups: group 1 received the hindfoot arthrodesis alone, and group 2 received the hindfoot arthrodesis followed by a 6-month period of bracing. The results showed that the use of bracing improved the outcome in group 2 compared to group 1. The study concludes that a nonoperative approach for the treatment of posterior tibial tendon dysfunction may be an effective alternative to surgical intervention, with the use of bracing improving the outcomes.