



Current Concepts

Reconstruction of the interosseus talocalcaneal ligament in progressive collapsing foot deformity: A review of the literature and description of a novel surgical technique

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ARTICLE INFO

Level of clinical evidence: 5, evidence and expert opinion

Keywords:

Deltoid ligament
Interosseous talocalcaneal ligament
Peritalar subluxation
Progressive collapsing foot deformity
Spring ligament
Weight bearing computed tomography

ABSTRACT

Background: The Interosseous Talo-Calcaneal Ligament (ITCL) is a key stabilizer of the subtalar joint, essential in preventing talo-calcaneal divergence. Its attenuation significantly contributes to the pathogenesis of Progressive Collapsing Foot Deformity (PCFD). Thus, anatomical reconstruction of the ITCL could offer promise in treating flexible (Stage 1) PCFD, aiming to restore subtalar joint stability and prevent deformity progression. The aim of the present work was to report existing ITCL reconstruction techniques and present a novel approach in PCFD.

Study Design: Current concept and technical note

Methods: A focused current concepts review of existing literature on ITCL reconstruction was performed to identify opportunities and existing gaps. Subsequently, we introduced a novel surgical technique for anatomically reconstructing the ITCL, spring ligament, and superficial deltoid ligament complex using a semitendinosus allograft. Dedicated targeting guides were employed to ensure precise identification and accurate placement of ligament attachment sites.

Results: Current literature primarily discusses ITCL reconstruction within the context of subtalar instability associated with Chronic Lateral Ankle Instability (CLAI). However, no prior method has explicitly addressed ITCL reconstruction for managing PCFD, which constitutes a significant gap in the literature. We describe a novel surgical technique to address ITCL reconstruction in flexible (Stage 1) PCFD.

Conclusion: ITCL reconstruction the logical next step in conservative treatment of flexible PCFD with peritalar subluxation (class D), to circumvent the need for joint-sacrificing procedures. A novel surgical procedure is presented. Further clinical studies are warranted to evaluate the radiographic and patient-reported outcomes of ITCL reconstruction.

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Introduction

Progressive Collapsing Foot Deformity (PCFD) is a prevalent and complex multiplanar condition that predominantly affects middle-aged

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adults [8,13]. Treatment options are initially conservative including insoles, bracing and physical therapy [1,21,22,34]. When conservative treatments are unsuccessful, surgical intervention is typically recommended. In cases of rigid PCFD (Stage 2 deformities), where there is often arthritic degeneration of the hindfoot joints, fusion procedures are generally the preferred treatment option [42]. In cases of flexible PCFD (Stage 1 deformities) without associated hindfoot arthritis, a combination of multiple realignment osteotomies and soft-tissue reconstructive procedures is often employed to address and correct all aspects of the deformity comprehensively. For example, Medial

Displacement Calcaneal Osteotomy (MDCO) and Flexor Digitorum Longus (FDL) tendon transfer are commonly employed to correct hindfoot valgus deformity, classified as Class A in Progressive Collapsing Foot Deformity (PCFD) [30,31]. For addressing forefoot/midfoot abduction, which falls under Class B PCFD, procedures like Lateral Column Lengthening (LCL) and Spring Ligament Reconstruction (SLR) are utilized [4,40]. Additionally, a Cotton osteotomy is performed to manage medial column collapse, identified as Class C PCFD [6,28]. Moreover, combining these procedures can effectively address peritalar subluxation (PTS), known as Class D PCFD [5,32].

The hindfoot aspect of PCFD primarily manifests as an external rotation deformity centered around the subtalar joint (SJ). This deformity has been precisely localized to the middle facet of the SJ and in proximity to the ITCL [33]. Degeneration of the ITCL has been identified as the only soft tissue pathology directly correlating with subfibular impingement (SFI), a defining feature of severe PTS [7,20,25]. This condition arises when there is a disconnection between the talus and calcaneus, leading to a loss of the rotational tether/link between these bones. Consequently, this results in multidirectional SJ instability and lateral translation, and external rotation of the calcaneus beneath the talus, causing direct impact against the fibula.

Given these insights, reconstructing the ITCL to maintain the SJ's centre of rotation and allow for de-rotational correction of PTS based on a robust ITCL is biomechanically rational and could directly correct PTS around the SJ's center of rotation. Although attempts to repair or reconstruct the ITCL are documented in the literature [14,18,23,26,35,38,39], the complex anatomy and deep location within the sinus tarsi make surgical access challenging, resulting in a lack of reliable surgical techniques, especially in cases of PCFD. The stage is set for concept of ITCL reconstruction in the surgical management of flexible PCFD but it has not yet emerged.

In the present work, we review past literature on ITCL reconstruction and propose a newly developed method for ITCL reconstruction. Additionally, this technique allows for the concurrent reconstruction of the spring ligament and the superficial deltoid ligament, enhancing the overall stability and functionality of the hindfoot and ankle.

Literature review

Descriptions of ITCL reconstruction have to the best of our knowledge only been reported for use in lateral ankle instability as part of CLAI, mostly in association with lateral ligament repair, augmentation or reconstruction [14,18,23,35,38,39]. This is despite the fact that several studies have reported that the ITCL is an important stabilizer of the subtalar joint both in all 3 planes, both in inversion and eversion [15,41]. The first description of ITCL reconstruction was by Kato et al. in 1995 [18]. They proposed to use a 4 mm wide slither of homolateral autologous Achilles tendon wrapped in a 5 mm tubed artificial ligament through an open approach over the sinus tarsi, 4.5 mm talus and calcaneus tunnels and staple fixation on both sides next to the tunnel entry points. They reported excellent results on function, pain and lateral instability which is not relevant to the subject of the present work, but it is noteworthy that they reported little complications: only one patient complained of pain over the medial aspect of the talar neck, which receded upon removal of the staple. Iglesias-Durán et al. [14] subsequently described an arthroscopic technique to reconstruct the ITCL (still in the setting inversion lateral subtalar instability associated with CLAI) in a 2020 publication. They used a Gracilis, Flexor or Extensor Hallucis Longus calibrated at 4.5 mm on the talus end and 5.5 mm on the calcaneus end. Fixation involved a 5.5 × 15 mm inside-out tunnel on the talus side with endobutton, and a through, 5.5 mm tunnel on the calcaneus side with a 5.5 or 6.25 mm bioabsorbable interference screw. Recently, Su et al. [39] reported the mid-to-long term retrospective results of arthroscopic ITCL reconstruction, often associated with lateral ligament Broström-Gould

plasty. They described their own technique, using Gracilis allografts and 2 fixation groups, with staples versus endobutton and bioabsorbable interference screw. Positioning was described as on the footprint of the ITCL on the calcaneus side and in the roof of the sinus tarsi on the talus side. They reported that staple fixation led to discomfort and hardware removal at 12 months, with complete subsequent symptom relief, while only one case required endobutton removal in the other group following symptoms of sinus tarsi pain and range of motion impairment of 25°, a limitation which did not recede despite hardware removal.

Since then, several studies have emerged to back the importance of ITCL reconstruction in the setting of PCFD. A 2021 study by Liu et al. [24] reported that in a rabbit model, ITCL section led to talonavicular and posterior subtalar arthritis while reconstruction prevented this evolution. Furthermore, a 2024 study by Mania et al. [26] performed a computerized 3D kinematic simulation of ITCL reconstruction for PCFD. They found that from talus to calcaneus, a proximal to distal and medial to lateral ITCL direction offers the best isometric respect of subtalar motion, whilst providing the most resistance to elongation in both inversion and eversion. Of note to our subject, they concluded that further biomechanical studies are warranted to understand whether ITCL alone is valid as a standalone procedure or to which extent it should be associated with other soft tissue procedures such as deltoid, spring, cervical ligament reconstructions and osteotomies [3,10,12,19]. Therefore, a clear gap in the literature persists to this day in the description of a surgical technique to address ITCL reconstruction, which we propose to address as the second part of this work.

Description of a novel surgical technique for interosseous talocalcaneal ligament reconstruction in progressive collapsing foot deformity

Background

In this section we describe a proposal for concomitant reconstruction of the ITCL, spring and deltoid ligaments. The case presented here as an illustrative example was a 54-year-old woman, BMI 38.89, presenting with stage 1 (flexible) PCFD on the left side.

Conventional weightbearing radiographic and Cone Beam Weight Bearing CT (WBCT) revealed findings consistent with severe hindfoot valgus (Class A PCFD), moderate hallux valgus deformity, considerable forefoot/midfoot abduction (Class B PCFD), severe collapse of the medial column of the foot (Class C PCFD), with plantar gapping of the first tarsometatarsal joint, and also severe PTS with sinus tarsi impingement and subluxation of both the middle and posterior facets of the SJ (Class D PCFD) (Fig. 1). A summary of all the measurements performed for the patients utilizing the WBCT images is reported in the Table 1. An ankle MRI revealed a degenerated and previously torn posterior tibial tendon (PTT), an intact deep deltoid ligament, a stretched yet intact superficial deltoid ligament, a degenerated, elongated, and partially torn spring ligament, and a degenerated but intact interosseous tibio-fibular ligament (Fig. 2A, B).

The patient was staged as 1ABCD or A1B1C1D1 [32].

The comprehensive surgical strategy for addressing the patient's soft-tissue and bony abnormalities included the following procedures: medial displacement calcaneal osteotomy, lapicotton first tarsometatarsal arthrodesis with metal distraction and plantarflexion wedge, FDL tendon transfer to the navicular tuberosity, Achilles tendon lengthening, peroneus brevis to longus tendon transfer, bunionectomy, ITCL reconstruction, spring ligament reconstruction, and superficial deltoid ligament reconstruction.

Surgical Technique

The patient was positioned supine on the operating table with their toes oriented upward. A percutaneous triple hemi-section lengthening of the Achilles tendon was carried out, which enhanced the dorsiflexion

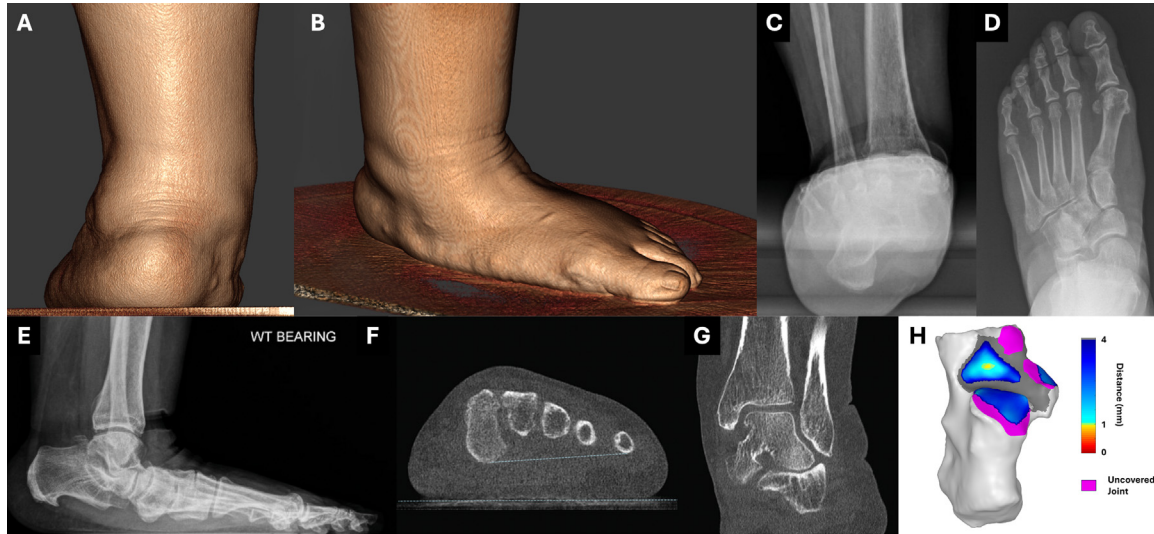


Fig. 1. Preoperative imaging demonstrating all four components of flexible stage-1 progressive collapsing foot deformity (PCFD):

Severe hindfoot valgus visualized on 3-D WBCT reconstruction (A,B) and Saltzman view on weight-bearing radiograph (C), consistent with Class A1 PCFD.

(D) Weight-bearing anteroposterior radiograph showing hallux valgus and uncoverage of the talonavicular joint, indicative of forefoot abduction (Class B1 PCFD).

(B, E, F) Medial column collapse demonstrated by medial view of 3-D WBCT reconstruction (B), lateral weight-bearing radiograph (E), and a negative forefoot arch angle obtained on coronal WBCT slides (F), consistent with Class C1 PCFD.

(G, H) Coronal WBCT slice revealing severe peritarsal subluxation with sinus tarsi impingement and subluxation of both middle and posterior subtalar joint facets (G)(class D1 PCFD). (H) color-coded distance and coverage mapping depicts the joint space between the talus and calcaneus under weight-bearing conditions. The scale represents distance in millimeters, with warmer colors (red–orange) indicating areas of joint narrowing (≤ 1 mm), cooler colors (blue) indicating increased joint space (up to 4 mm), and magenta representing uncovered joint areas (no apposition).

Table 1
Patient radiographic measurements.

	Radiographic parameters	Measurements
PCFD Class A	Foot and Ankle Offset	13.94
	Hindfoot Alignment Angle	36.84°
	Hindfoot Moment Arm	18.92 mm
PCFD Class B	Talonavicular Coverage Angle	74.25°
	Talus-First Metatarsal Angle (axial)	42.65°
PCFD Class C	Forefoot Arch Angle	−3.2°
	Talus-First Metatarsal Angle (sagittal)	−50.70°
PCFD Class D	Middle Facet Subluxation	78.64 %
	Presence of Sinus Tarsi Impingement	Yes
PCFD Class E	Presence of Subfibular Impingement	No
	Talar Tilt	−0.08°

of the ankle. Subsequently, a 2 cm longitudinal incision was made 8 cm proximal to the tip of the lateral malleolus, over the peroneal tendons. The brevis tendon was transected at the intramuscular level, and the proximal segment was sutured under tension to the peroneus longus.

A long, hockey-stick-shaped medial incision was made, starting at the medial malleolus, extending past the sustentaculum tali toward the navicular tuberosity, then angling dorsally to the medial first tarsometatarsal joint, and continuing distally to the medial first metatarsophalangeal joint (MTPJ). The superficial deltoid was found to be significantly stretched. A longitudinal incision was made through the flexor retinaculum. The PTT appeared considerably attenuated distally to the medial malleolus. The insertional portion of the PTT was detached from the navicular tuberosity. At the level of the



Fig. 2a. Preoperative ankle MRI demonstrating soft-tissue pathology in flexible stage-1

PCFD: (A) coronal image showing a degenerated posterior tibial tendon (PTT, red arrow) and an intact deep deltoid ligament (yellow arrow).

(B) Coronal image depicting a stretched but structurally intact superficial deltoid ligament (green arrow).

(C–D) Oblique and coronal images demonstrating a degenerated, elongated, and partially torn spring ligament (white arrows).

2b. MRI evaluation of the interosseous talocalcaneal ligament (ITCL):

Coronal (A) and oblique (B) images showing a degenerated but continuous ITCL (blue arrows) within the sinus tarsi.

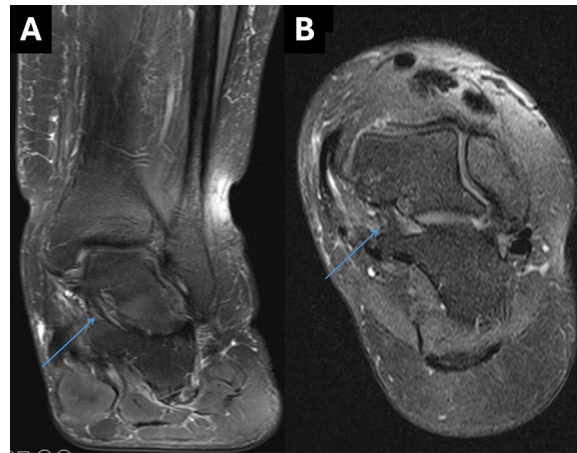


Fig. 2. Continued

sustentaculum tali, the FDL tendon was identified (Fig. 3), dissected distally towards the knot of Henry, revealing the flexor hallucis longus (FHL) tendon. The FDL was carefully separated from the FHL, and then transected just distal to the knot. A tag suture was placed on the stump of the FDL for a later transfer during the procedure.

An oblique 4 cm long approach to the lateral aspect of the calcaneal tuberosity was performed. The calcaneus was osteotomized and the tuberosity displaced medially by 9 mm and distally by two. Final fixation and compression was achieved with two 5.5 mm parallel headless compression screws (Fig. 4).

Using an oscillating saw with custom-made guides, the articular surfaces of the first tarsometatarsal joint were resected. This approach allowed for correction of the intermetatarsal angle and plantar flexion through the arthrodesis site. Subsequently, the joint surface was roughened. A patient-specific metallic wedge, designed to provide 12 degrees of plantar flexion, was then positioned within the fusion site (Fig. 5A). The final fixation was accomplished using 4.0 mm and 3.5 mm headless compression screws and a dorsomedial plate, strategically placed within the first tarsometatarsal joint, passing through the metallic wedge. Custom-made targeting guides, facilitated precise screw placement (Fig. 5B). Distally, an L-shaped medial capsulotomy of the first metatarsophalangeal joint (MTPJ) was performed, followed by a medial eminence resection. Subsequently, a capsuloplasty of the first MTPJ was carried out improving the alignment of the first toe.

The reconstruction of the ITCL was then initiated. The apex of the sinus tarsi on the foot's lateral side is identified through palpation and guided by fluoroscopy. A small percutaneous incision is made. Using a metal dilator with a blunt spherical tip, the sustentaculum tali is reached, which is located anterior to the posterior facet of the calcaneus and just lateral and proximal to the middle facet of the subtalar joint, corresponding to the exact footprint of the ITCL. The position is verified using fluoroscopic imaging to ensure accuracy. The semi-circumference external jig is then connected to the metal dilator. The jig allows for triangulation between the metal dilator and a targeting guide that needs to be positioned medially at the sustentaculum tali of the calcaneus. When the position is identified, the dilator and the targeting guide are locked into the external jig, and a K-wire is advanced through the targeting cannula, through the sustentaculum, and into the sinus tarsi, meeting the tip of the metal dilator. The position is checked under fluoroscopy (Fig. 6). A second targeting guide is subsequently attached to the same external jig to facilitate the creation of a talar neck tunnel. The positioning of the guide is verified through palpation and fluoroscopy, ensuring it is ideally positioned just lateral to the anterior tibial tendon. The entry point is precisely located at the middle third of the talar neck in the mediolateral plane and the proximal third in the proximal-distal plane. A small longitudinal incision, approximately 1 cm in length, is made, followed by blunt dissection down to the level of the talar neck bone. Using the targeting cannula, which is now secured to the external jig, the triangulation of the talar neck wire with the sustentacular wire

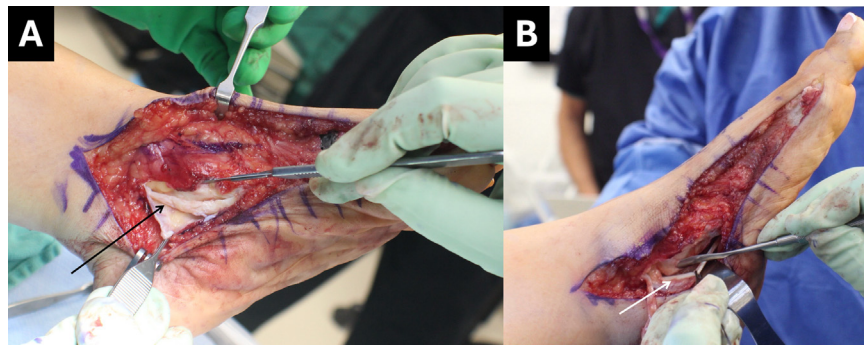


Fig. 3. Medial approach:

(A) Chronic degeneration of the posterior tibial tendon (PTT, black arrow).

(B) Identification of the flexor digitorum longus (FDL, white arrow) at the level of the sustentaculum tali. A freer elevator is pointing at the degenerated spring ligament.

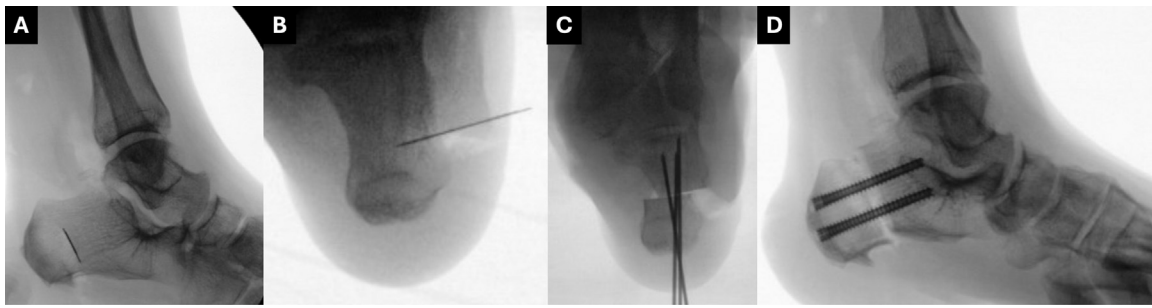


Fig. 4. Intraoperative fluoroscopic sequence of medializing calcaneal osteotomy:

The procedure began with positioning of the oscillating saw for osteotomy (A, B), oriented anterior and parallel to a line connecting the posterosuperior tuberosity and the origin of the plantar fascia. Following the cut, the calcaneal tuberosity was displaced medially by 9 mm and slightly distally and provisional stabilization was achieved with K-wires (C), and final fixation and compression were completed using two parallel 5.5 mm headless compression screws (D).

is facilitated. A K-wire is then carefully inserted into the talar neck, advancing until it penetrates the sinus tarsi and intersects with the sustentacular wire (Fig. 7).

The reconstruction was performed using a semitendinosus allograft, which was prepared by securing both ends with robust absorbable sutures. The graft dimensions were recorded, measuring 5 mm in width and 24 cm in length (Fig. 8A). To accommodate the graft, a 5 mm drill bit was used to create the sustentacular tunnel and the talar neck tunnels, following the path delineated by previously placed K-wires. Subsequently, a sturdy eyeleted metal retriever was inserted into the talar neck tunnel, orienting the eyelet medially to facilitate the passage of a flexible nitinol loop-tipped wire. This wire was threaded from the medial side through the sustentacular tunnel, across to the lateral side into the sinus tarsi, and then hooked through the eyelet of the metal retriever. The correct positioning and passage of the wire were confirmed through tactile feedback and fluoroscopic imaging. Following verification, one of the tagged sutures from the semitendinosus allograft was threaded through the nitinol wire loop. The wire, now carrying the graft's suture tag, was pulled back through the sustentaculum, the eyeleted metal retriever, and emerged in the sinus tarsi. The suture was then drawn through the talar neck tunnel by retracting the metal retriever. Under direct medial visualization, the semitendinosus allograft was meticulously pulled dorsally through the sustentaculum, traversed the sinus tarsi, and exited dorsally at the talar neck (Fig. 8B).

Fixation is subsequently carried out. The length of the allograft tendon protruding from the talar neck is kept relatively short, whereas the

end emerging at the sustentacular level is left longer. Initially, a 5 mm PEEK interference screw is placed into the sustentacular tunnel, anchoring the allograft to the calcaneus. Subsequently, manual correction of the peritalar subluxation and the abduction deformity is achieved by internally rotating and adducting the foot. With the foot held in this corrected position, a second 5 mm PEEK interference screw is then inserted dorsally through the tunnel in the talar neck, securing the graft into the talus and effectively reconstructing the ITCL. The residual allograft, previously exiting the sustentaculum tali, was subsequently used to reconstruct both the spring ligament and the superficial tibionavicular ligament. A guidewire was accurately positioned at the navicular tuberosity, extending from the plantar to the dorsal side, to facilitate the creation of a navicular tunnel. The placement of the wire was meticulously verified using fluoroscopy, ensuring optimal positioning with sufficient residual bone support medially and proximally within the navicular tuberosity (Fig. 9B,C). Once the position was deemed safe, a 5 mm drill bit was employed to construct the tunnel, with careful attention to protecting the adjacent soft tissues. The tip of the semitendinosus allograft from the sustentaculum tali was threaded from the plantar to the dorsal side through the navicular tunnel using a flexible nitinol wire. Concurrently, the forefoot/midfoot was corrected for abduction and pronation by adducting and supinating the foot. The allograft was then tensioned dorsally. Subsequently, a 5 mm PEEK interference screw was inserted into the navicular tunnel in a dorsal-to-plantar direction, effectively securing the allograft. This step completed the reconstruction of the spring ligament (Fig. 9).



Fig. 5. 5a. Preparation and positioning of the patient-specific Lapicotton wedge:

(A) Custom-made cutting guide used to perform precise resection of the first tarsometatarsal joint surfaces.

(B) Trial wedge inserted to assess correction and alignment prior to definitive implantation.

(C) Final positioning of the definitive metallic wedge after confirming proper plantarflexion and fit.

5b. Fixation of the Lapicotton wedge:

(A) Custom-made targeting guides integrated into the wedge allowed for precise screw placement.

(B–D) Fluoroscopic views confirming alignment and wedge positioning. Final fixation was achieved using 4.0 mm and 3.5 mm headless compression screws inserted from both proximal-to-distal and distal-to-proximal directions, passing through the metallic wedge and a plate to secure the desired correction and fusion.

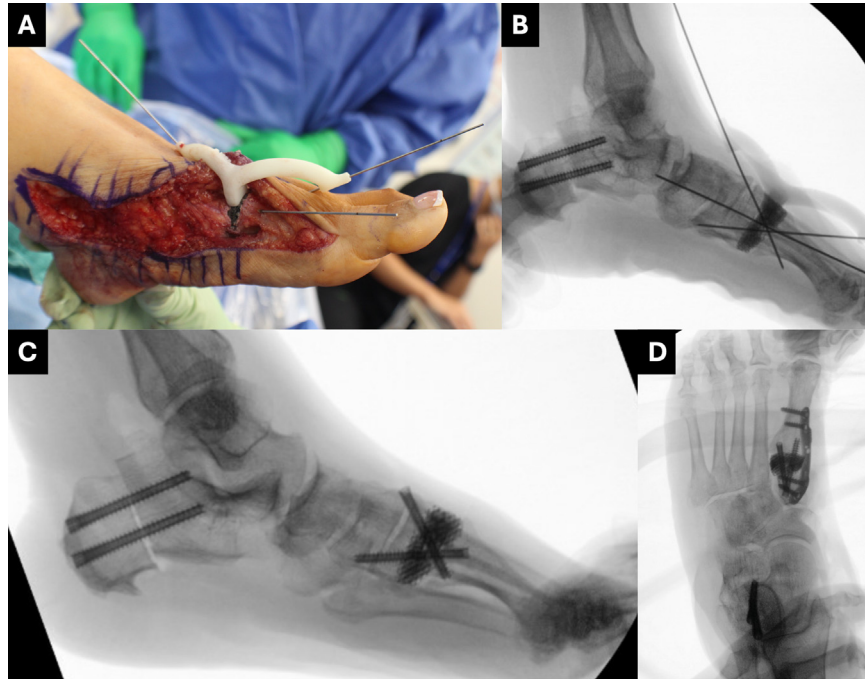


Fig. 5. Continued

The final segment of the allograft was utilized to reconstruct the tibionavicular component of the superficial deltoid ligament. Under fluoroscopic guidance, an eyeleted guide wire was carefully positioned in the medial malleolus, directed laterally and anteriorly toward the distal tibia, ensuring it did not encroach upon the medial gutter of the

ankle joint. Subsequently, the wire was advanced through the antero-lateral cortex of the distal tibia and emerged through the skin on the anterolateral aspect of the distal leg, where it was secured with a hemostat. A 5 mm drill bit was then employed to create a tunnel in the medial malleolus by drilling over the guide wire. After forming the

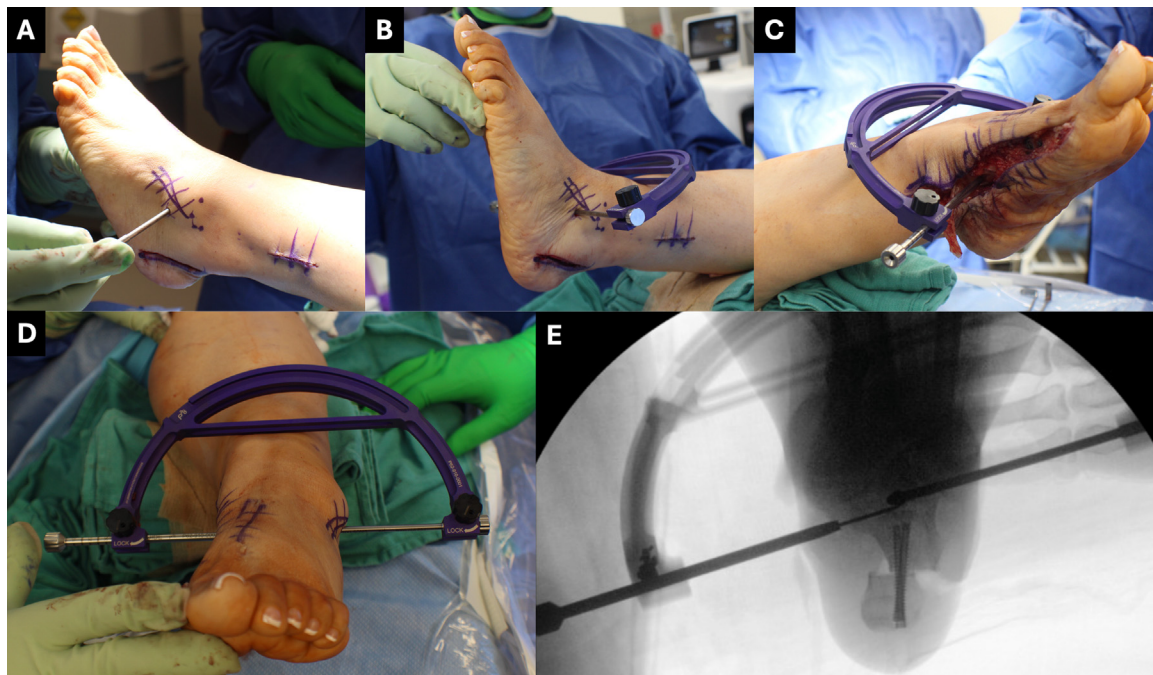


Fig. 6. Guided placement of the calcaneal tunnel for interosseous talocalcaneal ligament (ITCL) reconstruction using an external targeting system:

- (A) A metal dilator with a blunt spherical tip is inserted laterally into the sinus tarsi.
- (B) The semi-circumferential external jig is connected to the dilator to facilitate triangulation.
- (C) Targeting of the sustentaculum tali medially
- (D) Anteroposterior intraoperative view showing alignment of the external jig and targeting guides.
- (E) Fluoroscopic confirmation of the K-wire trajectory from the sustentaculum with the full guide assembly in place.

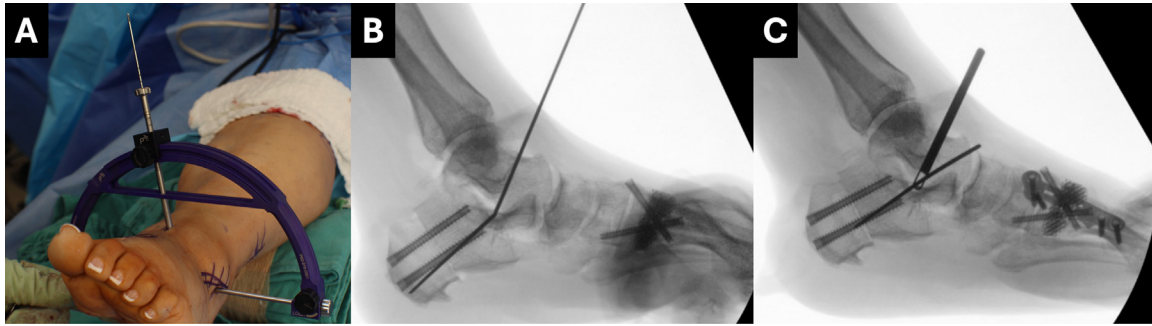


Fig. 7. Guided creation of the talar neck tunnel for ITCL graft passage:

(A) Placement of the second targeting guide onto the external jig to establish the talar neck tunnel. The entry point is positioned at the middle third of the talar neck, just lateral to the anterior tibial tendon.

(B) Advancement of a K-wire through the talar neck toward the sinus tarsi, following the pre-established trajectory for tunnel drilling. A 5 mm drill bit is subsequently used to create the graft passage.

(C) Introduction of a sturdy eyeleted metal retriever into the talar tunnel with the eyelet oriented medially, enabling shuttling of the flexible nitinol loop-tipped wire for graft transfer.

tunnel, the semitendinosus allograft was threaded through, entering at the medial malleolus and exiting through the anterolateral distal tibia. With the ankle maintained in neutral dorsiflexion and slight inversion, the allograft was tensioned appropriately and fixed into the medial malleolus with a 5 mm PEEK interference, completing the reconstruction of the tibionavicular superficial deltoid ligament (Fig. 10).

An all-suture anchor was positioned into the navicular tuberosity to facilitate the secure attachment of the FDL tendon transfer. Care was taken to tension the FDL appropriately while keeping the foot in a slight inversion and the ankle in a neutral dorsiflexion position. Additionally, the stability of the FDL transfer was enhanced by meticulously suturing it to the remaining portion of the PTT at its insertion point (Fig. 11).

After closure and dressings, a bulky Jones short leg splint, positioning the foot in neutral inversion-eversion and the ankle in neutral plantar-flexion/dorsiflexion. The patient was instructed to remain non-weight-bearing for six weeks. After this period, progressive weightbearing commenced, utilizing a supportive boot starting at the six-week mark.

Discussion

The treatment of PCFD is well codified in most cases, but tough cases where major and multiple ligamentous insufficiencies exist are not

uncommon. As the main driver of symptomatic PCFD, peritalar subluxation (referred to as class D in the recent consensus classification [32]) remains a technical challenge when tibialis posterior, cervical, interosseous, spring and deltoid ligament lesions exist [9]. In those cases, fusions are the rule of thumb, which have significant impacts in patients functional abilities [27]. Previously published techniques in this scenario, outside of fusions and along with the necessary associated osteotomies include reconstruction of the spring ligament, FDL or Flexor Hallucis Longus transfers [4,31]. However, reconstruction of the interosseous is mostly advocated in subtalar instability [14,18,23,35,38,39]. One recent publication mentioned its use in PCFD but that was only in a computer simulation based on random anatomic non-weightbearing CT data [26]. This lack of interest for the ITCL in PCFD literature is surprising since the interosseous is one of the main stabilizers of the talo-calcaneal axial angle which is the biomechanical driver of the deformity. Biomechanical studies demonstrate its importance to that regard [17,29]. One recent study highlighted the presence of CL and ITCL lesions in 60.3 % and 44.9 % of PCFD cases, respectively, underlining a potentially underestimated role of the subtalar ligaments in PCFD [19,26]. Furthermore, the spring ligament and tibio-navicular band of the superficial deltoid are frequently associated [9]. In summary, although the pivotal role of the ITCL as a driver of PCFD is well documented, joint sparing surgery in this condition has failed to include solutions for its reconstruction. The current treatment algorithms, recently formalized in the 2020 PCFD consensus, revolve around the ITCL, centre of rotation of the subtalar joint, addressing bone displacements, deformities and soft tissue attenuations [10,11,16,36,40], albeit without directly reducing the position of the talus over the calcaneus. It could be argued that sinus tarsi implants provide this, but they are non-anatomical and their use is more reported and accepted in paediatric flatfoot than PCFD, where they remain debated for concerns of hardware removal and longer term loss of correction [2].

To this day, no technique had been described to address simultaneously those 3 components of stage 1, class D PCFD with severe peritalar instability, without associated subtalar arthritis. The authors recognised this void in the treatment arsenal and thus described a solution in the present work. While previous studies mentioned in our review of the literature did provide insights, they were standalone [18] and in the more recent iterations by Iglesias [14] and Su [39], arthroscopic. Arthroscopy in this case offers several advantages in terms of morbidity and visualization in the sinus tarsi where access is limited by surrounding anatomy, but it does not allow to access the spring or deltoid ligaments. Furthermore, neither the precise locations of the ITCL footprints are clearly described, nor is ITCL validated as a standalone

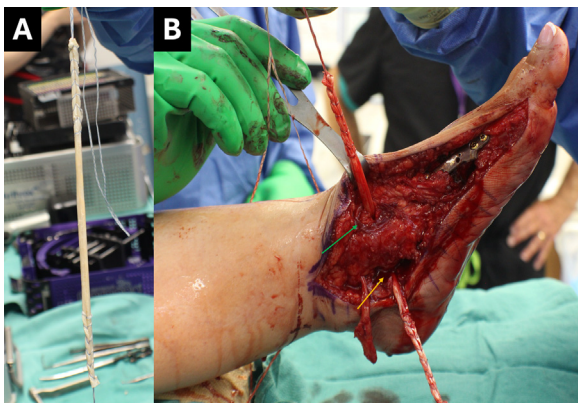


Fig. 8. Semitendinosus allograft passage through the calcaneal and talar tunnels for ITCL reconstruction:

(A) Prepared semitendinosus allograft measuring 5 mm in width and 24 cm in length, with reinforced suture ends for controlled passage.

(B) Under medial visualization, the graft is shuttled dorsally through the sustentaculum tali tunnel (yellow arrow), across the sinus tarsi, and exits dorsally from the talar neck tunnel (green arrow), guided by the nitinol loop and metal retriever.

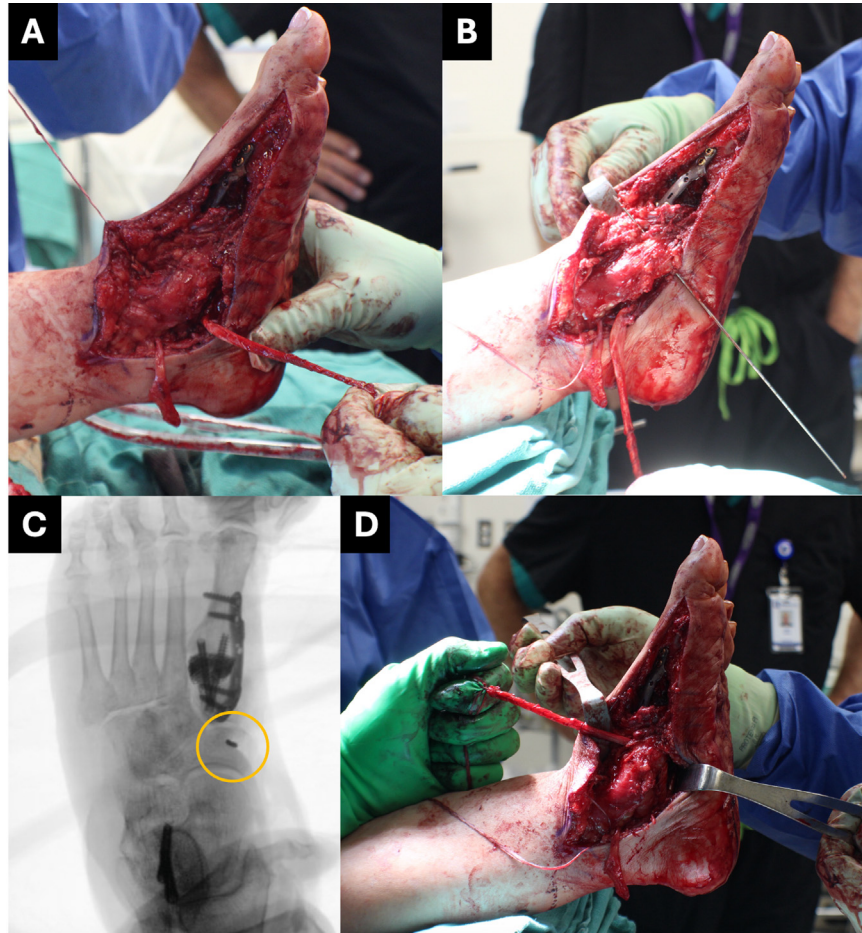


Fig. 9. Spring ligament reconstruction using the distal segment of the semitendinosus allograft:

- (A) The graft exiting the talar neck is kept short, while the sustentacular end is left longer for navicular fixation.
- (B) A guidewire is placed from plantar to dorsal through the navicular tuberosity.
- (C) Fluoroscopic confirmation ensures optimal wire positioning with adequate bone stock.
- (D) The graft is passed through the navicular tunnel using a nitinol wire, tensioned dorsally, and secured with a 5 mm PEEK screw in a dorsal-to-plantar direction, completing spring ligament reconstruction.

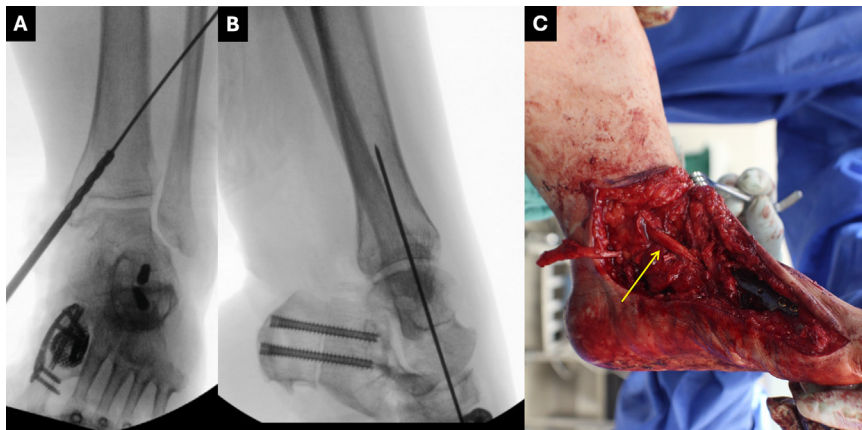


Fig. 10. Reconstruction of the tibionavicular component of the superficial deltoid ligament:

- (A, B) Fluoroscopic AP and lateral views showing guidewire positioning and drilling of the medial malleolus with a 5 mm drill bit.
- (C) The final segment of the semitendinosus allograft is passed through the tunnel, entering the medial malleolus and exiting anterolaterally, completing reconstruction of the tibionavicular portion of the deltoid ligament (yellow arrow). The graft is tensioned with the ankle in neutral dorsiflexion and slight inversion.



Fig. 11. FDL tendon transfer: An all-suture anchor was placed into the navicular tuberosity to secure the flexor digitorum longus (FDL) tendon transfer. The foot was held in slight inversion and the ankle in neutral dorsiflexion to achieve proper tensioning. After anchoring, the remaining portion of the FDL was sutured to the tibionavicular segment of the semitendinosus allograft, enhancing the overall stability and integration of the reconstruction.

procedure from the data available in the literature at this stage in PCFD. Hence, it seemed important in the description of our method that the spring and deltoid could be approached in the same procedure, as per the recommendations of Brodell [3] and Deland [10], which we propose to do with using a single semi-tendinous graft and all-round 5 mm calibration. While we performed an extensive incision on the medial side to address this, we refrained from using more than a keyhole incision directly over the sinus tarsi where blood supply is scarce [37].

In conclusion, the current literature is focused on "lateral" subtalar instability associated with CLAI and does not permit to anticipate the results of ITCL reconstruction as a treatment of talo-calcaneal divergence in PCFD. However, the present work has identified this gap with fundamental studies emphasizing the role of ITCL attenuation as a driver of peritalar subluxation and therefore, PCFD. The authors believe that the stage is now set for the emergence of this concept and potential surgical solutions to help avoid or delay joint sacrificing procedures. Future studies should aim at describing early results, benefits and inconvenients, radiographic and clinical results of ITCL reconstruction in PCFD.

Author contributions

François Lintz: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. Enrico Pozzessere: Formal analysis; Software; Writing – review & editing. Carla Carfi: Formal analysis; Software; Writing – review & editing. Kanyakorn Riewruja: Formal analysis; Software; Writing – review & editing. Wolfram Grün: Formal analysis; Software; Writing – review & editing. Canon Cornelius: Formal analysis; Software; Writing – review & editing. Scott Ellis: Formal analysis; Software; Writing – review & editing. Cesar de Cesar Netto: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding source

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors. Paragon28 (Englewood, CO, USA) provided the surgical hardware.

Declaration of competing interest

Cesar de Cesar Netto declares the following Conflict of Interest: Paragon28 (consultant, medical advisory board, royalties), CurvebeamAI (consultant, shareholder), Ossio (consultant), Zimmer (consultant), Stryker (consultant), International WBCT Society (co-founder, President), exactech (consultant), arthrex (consultant), tayco brace (shareholder), extremity medical (consultant), AOFAS committee member, foot ankle clinics (editor in chief).

François Lintz declares the following Conflict of Interest: Paragon28 (consultant, shareholder), CurvebeamAI (consultant, shareholder), Newclip Technics (consultant, royalties), Podonov (consultant, royalties), LINNOV (founder, shareholder), Followinvest (shareholder), International WBCT Society (co-founder, past-president).

Scott Ellis declares the following conflict of Interest: Consultant for Vilex, Nextremity/Medartis, Stryker, and Paragon 28. American Orthopedic Foot and Ankle Society (AOFAS) board of directors. All other authors declare no conflicts of interest.

Acknowledgements

François Lintz wrote the manuscript and contributed to the literature review. Enrico Pozzessere was responsible for intraoperative photography, figure editing, and captioning. Carla Carfi conducted the literature review, collected data, and revised the manuscript. Kanyakorn Riewruja assisted with data collection. Wolfram Grün contributed to figure editing, captioning, and text revision. Canon Cornelius participated in the surgery and revised the manuscript. Scott Ellis revised the manuscript. Cesar de Cesar Netto provided the original idea, designed and described the surgical technique and hardware, and reviewed the manuscript.

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