

## Technical Tips

# Lapicotton technique in the treatment of progressive collapsing foot deformity

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## Abstract

We present a technical surgical description of a 36-year-old female diagnosed with Progressive Collapsing Foot Deformity (PCFD) treated with a medial displacement calcaneus osteotomy, a lateral column lengthening, and a modified Lapidus fusion. In order to increase the plantar flexion power of this arthrodesis and minimize the loss in ray length with joint preparation, a bone block structured graft was used. Fixation was performed using a post implant in the medial cuneiform with crossing screws through the surfaces and the graft. Forefoot varus was properly corrected intraoperatively by using the described surgical technique. Satisfactory functional short-term results and an excellent alignment was accomplished.

**Level of Evidence V; Therapeutic Studies; Expert Opinion.**

**Keywords:** Flatfoot; Foot deformities, acquired/diagnostic imaging; Arthrodesis/methods; Osteotomy/methods; Fracture fixation, intra-medullary/instrumentation; Joint instability/surgery.

## Introduction

Progressive Collapsing Foot Deformity (PCFD) is a three-dimensional complex condition that may affect up to 10% of adults above 65 years-old<sup>(1,2)</sup>. Pain on the medial side of the foot and ankle associated with gradual flattening are common symptoms of the disease<sup>(3)</sup>. Lateral pain is related to the possibility of subtalar and subfibular impingement as well as peroneal involvement<sup>(4,5)</sup>. Patients usually display a valgus alignment of the hindfoot, combined with midfoot abduction and forefoot varus (forefoot supination)<sup>(6)</sup>. Peritalar subluxation and medial ankle instability are potential adjunctive findings to the scenario and should be properly investigated<sup>(7-9)</sup>.

Deformities may present as flexible or rigid. This can be determined by clinical and radiological findings, and places the patient in the a corresponding PCFD Classification<sup>(1,2,6)</sup>. Existence of medial column instability (MCI) is not solely determined by forefoot varus (FV) and should always be investigated due to its importance in prognosis and treatment planning<sup>(10-12)</sup>. First ray hypermobility, hallux valgus, midfoot arthritis, gapping at the tarsometatarsal (TMT) joint and dorsal metatarsal migration are findings associated with MCI<sup>(13,14)</sup>.

Acknowledgement of this instability requires inclusion of a procedure to the medial column in order to correct the forefoot varus, stabilize the ray and bring the foot to a plantigrade tripod position that protects the whole foot construction and ankle joint<sup>(10,15)</sup>.

The Cotton opening wedge medial cuneiform osteotomy and the Lapidus tarsometatarsal arthrodesis are the usual procedures of choice in the MCI/FV scenario<sup>(11,12,16)</sup>. Determination of the proper method is usually based on patient profile and deformity presentation<sup>(17)</sup>. Severe instability, TMT arthritis, and hallux valgus usually move the indication towards fusion<sup>(3)</sup>. Despite the reliability in terms of stability and functional results, the Lapidus does not come without inconveniences. Shortening of the medial column (2mm at minimum) and difficulty in achieving a proper plantarflexion of the first ray are the most common burdens of the technique when treating PCFD<sup>(18,19)</sup>. Solutions for these challenges are scarce within the literature, with authors usually recommending a plantar first metatarsal translation to compensate the possible losses<sup>(20,21)</sup>. There is no previous study depicting the use of a bone block wedge in TMT fusions for PCFD<sup>(22,23)</sup>.

Study performed at the University of Iowa, Carver College of Medicine, Iowa City, Iowa, USA.

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This article describes the surgical treatment of a 36-year-old female patient with a symptomatic PCFD in the scenery of an adjuvant medial column instability and forefoot varus. A medial calcaneal displacement osteotomy (MDCO) combined with a lateral column lengthening (LCL) and a modified TMT arthrodesis were performed. The fusion was carried using a bone block wedge amongst both the medial cuneiform and the metatarsal base to avoid bone shortening and produce first ray plantarflexion.

### Case description

This study received approval from the Institutional Review Board and complied with both the Health Insurance Portability and Accountability Act (HIPAA) and the Declaration of Helsinki. The patient signed the Consent Form for this research.

A 36-year-old female (BMI 39.45) presented to the foot and ankle orthopedic service with a right chronic medial foot and ankle pain since childhood. She was diagnosed with psoriatic arthritis two years ago and is currently treated with methotrexate and analgesics. The patient claimed that she suffered an ankle injury when she was 7 years old which was treated with braces and crutches. Since then she experiences chronic pain. Physical therapy and use of insoles in the past did not relieve pain.

During clinical evaluation, she demonstrated a severe flat-foot deformity with significant hindfoot valgus of approximately 20-25°, midfoot abduction (too many toes sign), and a supinated forefoot (Figure 1). She was also tender to palpa-

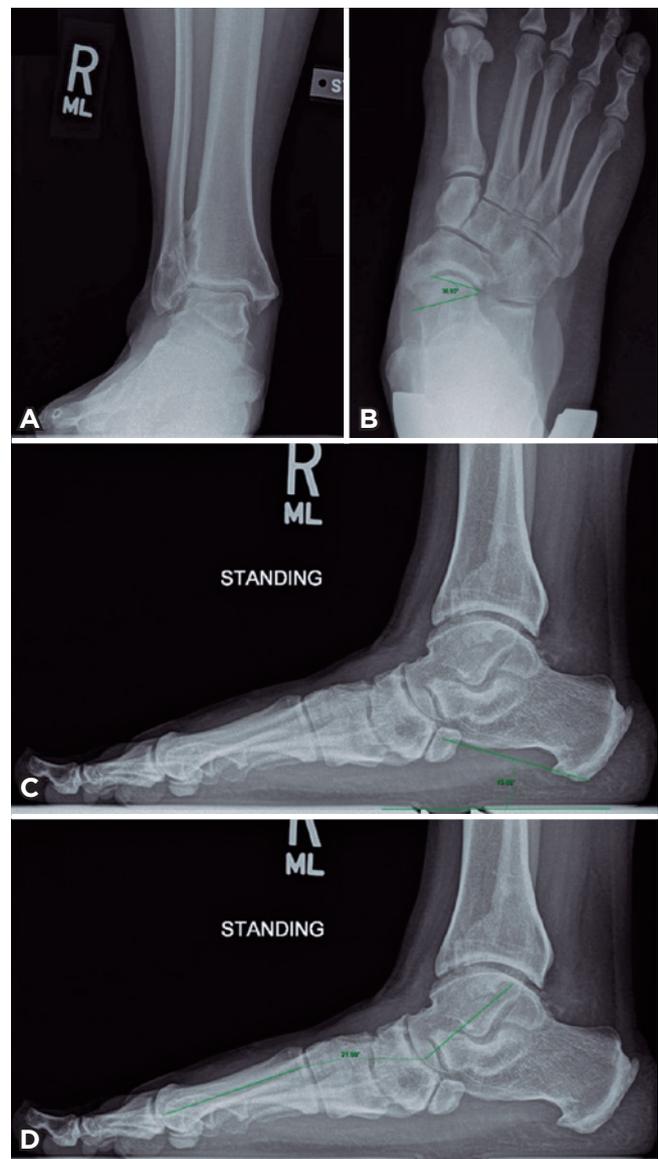
tion along the medial side of the foot and ankle as well as on the sinus tarsi area. All joints were flexible, and a fixed congruent forefoot varus (supination) was found. Medial column was found unstable by demonstrating plantar-dorsal metatarsal translation above 10mm<sup>(13,24)</sup>. Heel rise and Silverskiöld tests were positive; posterior tibial strength was normal.

Preoperative functional scores were 41 for Tampa Kinesiophobia Scale, 20 for Pain Clinic Scale, 67 for PROMIS Pain, 91.17 for the FFI, and 9.52 for the FAAM.

Conventional radiographs showed an accessory navicular, a Meary's angle of 21.6°, a calcaneal pitch of 15.8°, and a talonavicular coverage angle of 30.9°<sup>(25)</sup> (Figure 2). No talar val-



**Figure 1.** Patient's photographs showing the hindfoot valgus, midfoot abduction and the collapse of the longitudinal arch.



**Figure 2.** Preoperative radiographic series demonstrating absence of ankle tilt (A), talonavicular angle (B), calcaneal pitch angle (C) and Meary's angle (D).

gus tilt was observed. Cuneiform-metatarsal length measured 89.95mm (AP) and 89.31mm (P) on x-rays. Weightbearing CT (WBCT) findings included the presence of subtalar impingement, 24.9° in Meary's angle, 18° in calcaneal pitch, 36.2° in talonavicular coverage angle, 2.7° in the forefoot arch angle, 17.51mm in cuneiform-to-floor coronal distance, 20.13mm in navicular-to floor sagittal distance, 35.6% in middle facet subluxation, 21.6° in subtalar horizontal angle (50%), 20.73mm in hindfoot moment arm, 56.0° in hindfoot alignment angle, and absence of subfibular impingement (Figure 3)<sup>(9)</sup>. The preoperative Foot Ankle Offset (FAO) was 10.37. Cuneiform-metatarsal length was 87.07mm in the WBCT. Magnetic Resonance Images (MRI) portrayed minor posterior tibial tendon degeneration and preservation of the spring and deltoid ligaments (Figure 4). Absence of arthritic findings was observed in all imaging acquisition methods.

Considering the above findings, the patient was classified as a 1ABCD as she presented a flexible heel valgus and a flexible midfoot abduction combined with a forefoot varus and subtalar impingement. After careful explanation of the disease and treatment options, the patient decided to proceed with surgical treatment. A percutaneous MDCO combined with an LCL and a TMT arthrodesis was planned to reestablish the alignment. Resection of the accessory navicular associated with a modified Kirdner procedure and a gastrocnemius recession were also included in surgical strategy.

### Surgical technique and technical tip

Operation began with aspiration of bone marrow from the right iliac crest for concentration and later injection into the joint fusion mass. A gastrocnemius recession procedure was then performed with a 3cm incision over the posterior medial aspect of the leg using the Strayer technique. A nasal specu-

lum was inserted separating the gastrocnemius aponeurosis and the muscle belly of the soleus. At least 10 to 15 degrees of increasing dorsiflexion was noted following sectioning of the gastrocnemius aponeurosis.

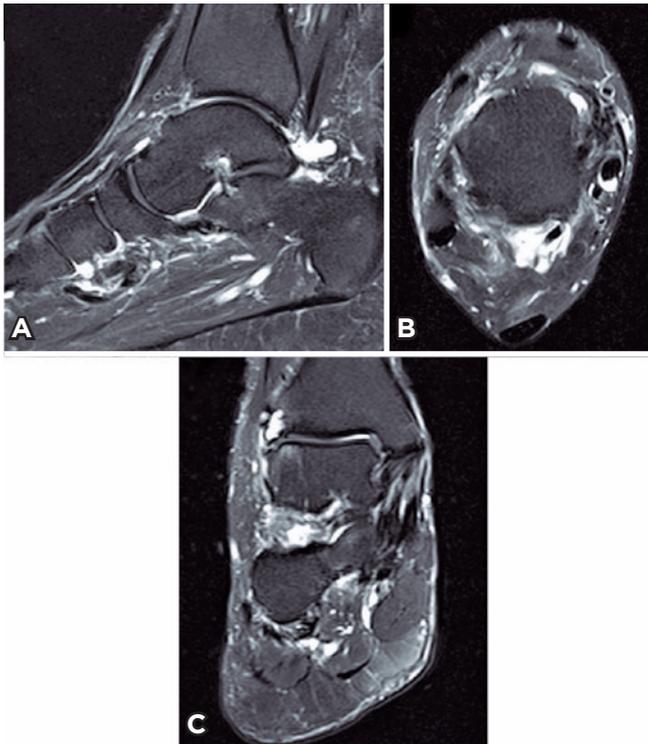
We proceeded with percutaneous medial displacement calcaneal osteotomy using a Shannon burr with constant irrigation. Using fluoroscopic guidance, the burr was used to perform an oblique osteotomy of the calcaneal tuberosity percutaneously. The tuberosity was medially displaced and cannulated headless 4.0mm screws were positioned in a slightly divergent pattern. The amount of displacement noted was about 10 to 12mm in the axial fluoroscopic view.

A 6cm longitudinal separate incision was then made over the sinus tarsi and anterior aspect of the calcaneus. Subperiosteal dissection of the calcaneus was made plantarly and dorsally, exposing the lateral surface of the calcaneus at the level of the same angle. The lateral calcaneus osteotomy was then made across the calcaneus with a sagittal oscillating saw at the level of the Gissane angle, just anterior to the posterior facet of the subtalar joint. Care was taken not to injure the medial and anterior facets of the subtalar joint. The opening wedge osteotomy was distracted using a Hintermann distractor. Different size of trials for lateral column lengthening wedge were tested. Adequate correction was noted under fluoroscopy with an 8mm wedge. Construct was found to be stable (Figure 5).

After the hindfoot was corrected into neutral alignment, attention turned to the forefoot. Palpation of the heads of the first and fifth metatarsals demonstrated residual fixed supination of the forefoot. The first TMT joint was then exposed with a 5cm long dorsal approach at the level of the first TMT joint and medial cuneiform. Extensor hallucis longus and the anterior neurovascular bundle were identified and retracted laterally.

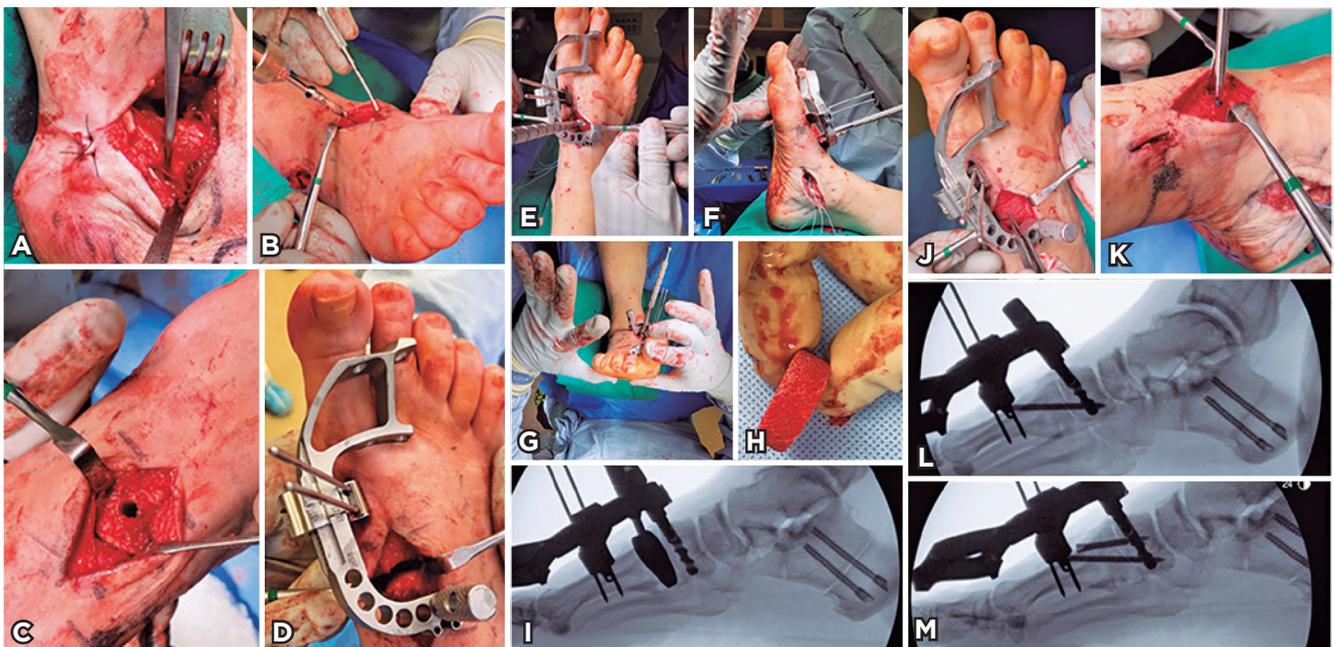


**Figure 3.** Preoperative WBCT images displaying the talonavicular coverage angle (A), calcaneal pitch angle (B), subtalar impingement (C), Meary's angle (D), forefoot arch angle (E), cuneiform-to-foot height (F), navicular-to-foot height (G), middle facet subluxation (H), subtalar horizontal angle (I), hindfoot alignment angle (J), hindfoot moment arm (K) and Foot and Ankle Offset (L).



**Figure 4.** MRI showing spring (A), posterior tibial tendon (B) and deltoid (C) integrity.

The capsule of the first tarsometatarsal joint was incised longitudinally and elevated to expose the joint. The guidewire for the Zimmer Biomet InCore® system was inserted into the medial cuneiform from plantar to distal aiming slightly distally to accommodate a dorsal rash into the first TMT joint. We then used the appropriate drill to create the hole for the implant inside the medial cuneiform. The drilling was carried out from dorsal to plantar. The vertical implant into the medial cuneiform was then manually inserted. The external jig was then attached to the implant. An additional 2 cm dorsomedial approach was performed distally along the medial border of the first metatarsal to allow for adequate positioning of the jig. With the jig appropriately positioned, two additional K-wires were inserted distally through the jig and into the dorsomedial aspect of the first metatarsal to adequately control rotation. The jig was then used to distract the arthrodesis site. About 8 mm of distraction was performed, exposing the base of the first metatarsal and the distal aspect of the medial cuneiform. The joint was prepared, removing the articular cartilage of both sides of the joint using an oscillating saw, a sharp chisel, and a curette. An 8mm dorsal base Lapidus Paragon 28® allograft wedge was then inserted into the fusion site. Before insertion, the wedge was soaked in the bone marrow aspirate. The first tarsometatarsal joint was reduced by performing compression using the implant jig. Adequate correction was noted under direct visualization and under fluoroscopic assessment. Insertion of the allograft provided



**Figure 5.** Intraoperative images portraying the medial column displacement osteotomy and the lateral column osteotomy (A). Following a dorsal incision, the cuneiform is exposed, and the post site is drilled (B, C). After the post is inserted, the guiding device is inserted, and joint distraction obtained (D). The surfaces are prepared, and trial sizing performed (E, F) aiming to level the metatarsal heads (G) with first ray plantarflexion (H, I). The graft is inserted (J) and the construct secured with two screws (K, L, M).

adequate stability and resulted in the correction of forefoot supination, bringing the heads of the first and lesser metatarsals to a more harmonic plantigrade position. Through two additional percutaneous approaches and adequate blunt dissection down to the level of bone, 2 screws were inserted through the jig holes to allow adequate fixation into the medial cuneiform post. Intraoperative fluoroscopy and direct visualization confirmed adequate apposition at the arthrodesis site. No plantar gapping of the first TMT joint was noted (Figure 5).

A longitudinal medial incision was then made to expose the posterior tibial tendon and the navicular tuberosity. Some synovitis was noted in the distal aspect of the tendon. The posterior tibial tendon was debrided off of the navicular, exposing the plantar medially located large accessory navicular bone in the substance of the posterior tibial tendon. The

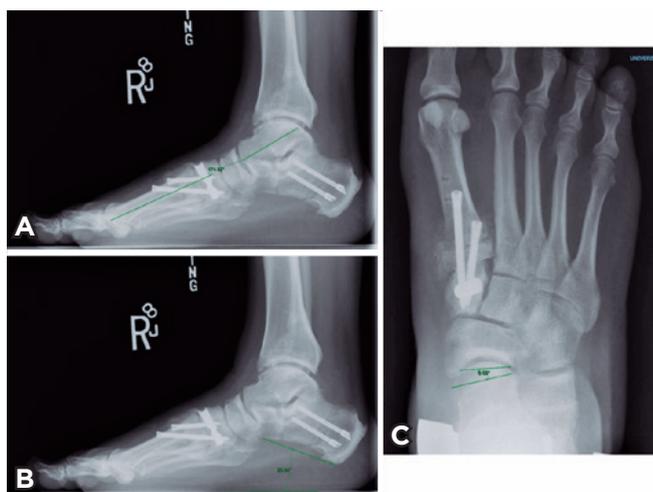
accessory navicular bone was then carved out of the tendon using a 15 blade, while protecting the spring ligament. The spring was completely intact with some stretching. After adequate preparation of the tuberosity, two anchors were inserted into the navicular tuberosity and used to reattach the posterior tibial tendon into the debrided navicular tuberosity as well as retain the spring ligament.

Patient was released in a non-weight bearing splint. This was replaced with a boot at the 14-day visit and non-weight bearing regime remained until the 6<sup>th</sup> week. After this period, physical therapy was introduced, and ankle range of motion slowly initiated. In the 7<sup>th</sup> week, progressive bearing was initiated, and the boot was removed by the 12<sup>th</sup> week. Gradual return to baseline activities occurred after the third postoperative month.

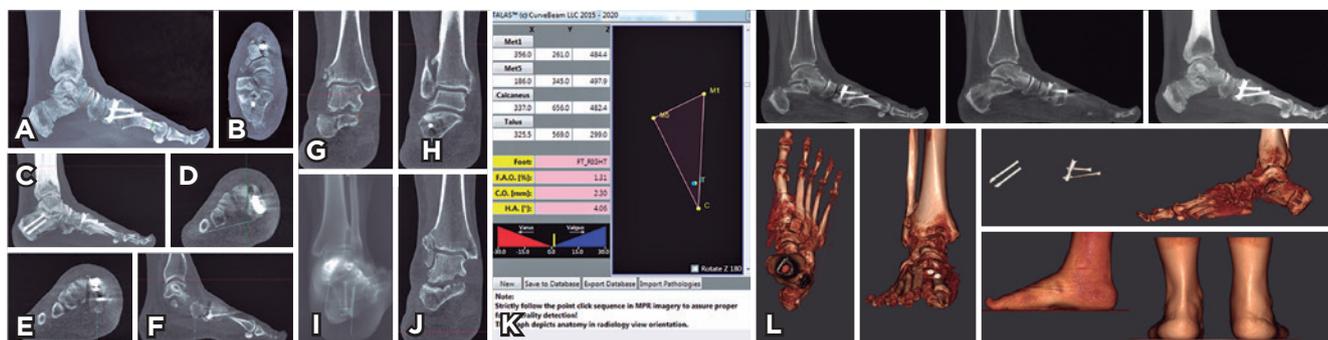
## Results

The presented outcomes assessment occurred in the three-month follow-up visit. Radiographic parameters showed the following postoperative values: 5.9° in Meary's angle, 20.8° in calcaneal pitch and 9.1° in talonavicular coverage angle (Figure 6). Cuneiform-metatarsal length was 93.82mm (AP) and 88.71mm (P). WBCT postoperative measurements were: 7.8° in Meary's angle, 26.4° in calcaneal pitch, 4.1° in talonavicular coverage angle, 13.3° in forefoot arch angle, 24.48mm in cuneiform-to-floor coronal distance, 33.34mm in navicular-to-floor sagittal distance, 22.2% in middle facet subluxation, 11.6° in subtalar horizontal angle (50%), -1.37mm in hindfoot moment arm, -3.4° in hindfoot alignment angle and absence of subtalar and subfibular impingement (Figure 7)<sup>(5)</sup>. Cuneiform-metatarsal length was 88.99mm in the WBCT. The postoperative Foot Ankle Offset (FAO) was 1.31.

Postoperative functional scores were 44 for Tampa Kinesiophobia Scale, 9 for Pain Clinic Scale, 70 for PROMIS Pain, 64.7 for FFI and 40.47 for the FAAM. The patient presents an excellent clinical alignment with no pain at the osteotomies' sites and at the TMT arthrodesis (Figure 8).



**Figure 6.** Postoperative radiographs obtained during the third-month follow-up visit, showing the Meary's angle (A), the talonavicular coverage angle (B) and the calcaneal pitch angle (C).



**Figure 7.** Postoperative WBCT acquisitions at 3-month follow-up displaying the Meary's angle (A), the talonavicular coverage angle (B), the calcaneal pitch angle (C), the forefoot arch angle (D), the navicular-to-floor distance (E), navicular-to-foot height (F), middle facet subluxation (G), subtalar horizontal angle (H), hindfoot alignment angle (I), absence of subtalar impingement (J) and the Foot and Ankle Offset (K). Fusion status and alignment are also depicted (L).



**Figure 8.** Clinical appearance at 3-months following PCFD reconstruction and LapiCotton.

## Discussion

PCFD treatment remains a challenge in terms of defining surgical strategies and assessing the proper necessary correction<sup>(12)</sup>. We demonstrated a surgical technique that uses a wedge structured graft in the TMT fusion site with the intention to potentialize alignment gain. Tripod reestablishment and good functional results were obtained with the use of this strategy in conjunction with other procedures.

Importance of first ray plantarflexion to restore the “static triangle of support” and to further ankle joint protection was established by other authors<sup>(10,26-28)</sup>. The Cotton has the advantage of being an extraarticular osteotomy that allows different wedge graft sizes to be inserted. Benthien et al. showed that inclusion of the Cotton osteotomy in cadavers reduced load over the lateral column, bringing the foot to a more plantigrade position<sup>(28)</sup>. De Cesar Netto et al. found a significant decrease in ankle pressures through a PCFD cadaveric model when the Cotton osteotomy was performed. Additional procedures enhanced this effect<sup>(26)</sup>. On the other hand, Conti et al. performed a retrospective evaluation of patients that underwent this cuneiform osteotomy and found that moderate postoperative plantarflexion provided lower functional results in comparison to a mild plantarflexion<sup>(29)</sup>. Our patient reached good functional results and an excellent alignment (evaluated by several measures) with the presented technique that aimed a proper plantarflexion of the first ray.

Tarsometatarsal arthrodesis is a traditional procedure for correction of forefoot varus in the setting of PCFD when severe medial column instability, TMT plantar gapping, local arthritis or hallux valgus is present<sup>(1,30,31)</sup>. Reliability of this technique and good functional results are usually the arguments that supports its indication<sup>(32,33)</sup>. Few studies analyzed the contribution of the Lapidus fusion in PCFD correction but

none tested the technique in isolation<sup>(34,35)</sup>. Greisberg et al. demonstrated a mean talometatarsal angle correction of 16° in patients that underwent tarsometatarsal and naviculocuneiform fusion for collapsing deformities<sup>(35)</sup>. Fuhrmann showed increase in the first metatarsal head load in all patients performing a Lapidus in the scenery of a PCFD associated with HV but did not quantify it<sup>(34)</sup>. The presented technique was able to recreate the arch, as shown by the improvement of the Meary’s angle, forefoot arch angle, cuneiform-to-floor distance, and the FAO.

Performing a TMT fusion in the PCFD context may be quite complex due the intrinsic necessity to restore the medial arch<sup>(21)</sup>. Joint preparation naturally shortens the ray which may prejudice final foot alignment and the patient’s gait. Previously, Greef et al. described a mean shortening of 4.1mm after TMT fusions for HV. Despite these findings, only one patient (from the 32 sampled) had symptoms of transfer metatarsalgia<sup>(20)</sup>. Dahlgren et al. showed in cadavers a mean metatarsalcuneiform length decrease of 3mm when using osteotomes in comparison to a mean of 6.9mm when the saw was used to prepare the site<sup>(36)</sup>. Plantarflexion of the first ray is also challenging. Incongruity among bone surfaces is usually noted when the metatarsal is placed in the desired plantarflexion position<sup>(37)</sup>. This may lead surgeons to resect more bone from the inferior region, intensifying ray shortening. Caudal metatarsal translation is a described strategy to bring the first ray downwards but effects in foot mechanics are still unknown<sup>(21)</sup>. In our case description, we were able to achieve first ray correction and maintain its length by using a trapezoidal wedge in the TMT joint.

The use of a bone block in a fusion site could theoretically increase the chance of non-union. The fact that two surfaces are expected to heal and the use of an allograft in this technique supports this concept. Still, no comparative data was produced regarding fusions rates in TMT joints to sustain the idea. Hamilton et al. found 18% of non-union in Lapidus arthrodesis using an autogenous bone block<sup>(38)</sup>. When using cadaveric donor bone to fill defects in metatarsophalangeals fusions, Luke et al. observed pseudoarthrosis in 13% of the sample and Malhotra et al. observed it in 12%<sup>(39,40)</sup>. Clinical and radiographical fusion was noted in this study’s patient at three months, with at least 80% of trabecular formation through each surface noted.

Procedures that may combine the advantages of a wedge osteotomy and a fusion while decreasing the detriments of both techniques are desired in the PCFD setting. This technical description study demonstrated an option for medial column stabilization and forefoot supination correction that may also provide an enhanced realignment outcome. By using a structured wedge at the tarsometatarsal joint combined with a pillar fixation implant we were able to provide a good functional and radiographic result. Foot alignment was reestablished, and fusion occurred at three months in both surfaces. We would recommend this technique modification as an adjuvant powerful procedure for patients with PCFD in the setting of a forefoot varus with tarsometatarsal arthrodesis indications.

**Authors' contributions:** Each author contributed individually and significantly to the development of this article: CCN \*(<https://orcid.org/0000-0001-6037-0685>) conceived and planned the activities that led to the study, participated in the review process, approved the final version, performed the surgeries; SJA \*(<https://orcid.org/0000-0002-5486-9858>) formatted the article, collected the data; CI \*(<https://orcid.org/0000-0003-1434-2725>) formatted the article, collected the data. VV \*(<https://orcid.org/0000-0002-1574-3793>) bibliographic review, data collection; ES \*(<https://orcid.org/0000-0002-6922-5238>) bibliographic review, data collection; HYL \*(<https://orcid.org/0000-0003-4179-9501>) bibliographic review, data collection; KND \*(<https://orcid.org/0000-0002-8061-4453>) participated in the review process, formatted the article, approved the final version; NSBM \*(<https://orcid.org/0000-0003-1067-727X>) wrote the manuscript. Participated in the review process, formatted the article, approved the final version. \*ORCID (Open Researcher and Contributor ID) 

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