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Case Report

Optimal Sequence of Corrective Surgeries for Concomitant Valgus Knee and Rigid Pes Planus Deformities: The Knee-First Approach

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ABSTRACT

In patients requiring surgical correction of ipsilateral valgus knee and rigid pes planovalgus deformities, the optimal operative sequence is controversial. Growing evidence suggests these 2 deformities are related in etiology and interrelated in disease course. We present the case of a 72-year-old female with concomitant valgus knee and rigid pes planovalgus deformities successfully treated with total knee arthroplasty followed by triple arthrodesis and Achilles lengthening. Surgical correction of these deformities must be carefully planned between the operating surgeons to avoid over- or under-correction of alignment that could further impact gait. In contrast with the limited available literature, the authors recommend correction at the knee first and the foot and ankle second. Further prospective studies are needed to elucidate the best operative sequence in these patients.

Introduction

Valgus knee and pes planus (flat foot) are 2 common deformities of the lower extremity. Valgus deformity is found in an estimated 10%-57% of the population and is correlated with obesity and knee pain. [1-5] Flexible pes planus is normal in infancy as development of the longitudinal plantar arch does not occur until roughly 3 years of age; it is estimated that 20% of adults have an acquired or persistent flat foot deformity, often also associated with obesity and pain in the foot, ankle, and knee. [1,2,6,7] Both of these common deformities, as well as their relationships to biomechanics, pain, and disease in the lower extremity joints, have been extensively studied. Several studies have linked valgus knee deformity to higher incidence of tricompartmental osteoarthritis, listing valgus malalignment as both a cause and a result of degenerative knee diseases. [8-12] Planus deformity of the foot has been independently associated with a higher incidence of injury, arthritis, and pain in all joints of the lower extremity and is most often caused by insufficiency of the posterior tibialis tendon. [13-17] While each of these conditions has the potential to cause pain and arthritis independent of the other, there is growing evidence that valgus knee and pes planus are both related in etiology and interrelated in disease progression.

There is some controversy over the best operative sequence for patients with both valgus knee and pes planus deformities requiring surgical correction. Joint-preserving surgeries, including distal femoral and high-tibial osteotomies, can be used in patients with lower extremity malalignment. In patients with both malalignment and moderate to severe tricompartmental osteoarthritis of the knee, total knee arthroplasty is often used as definitive treatment for both conditions. Several studies have demonstrated that valgus or varus knee deformity correction with total knee arthroplasty has the potential to correct concomitant hindfoot malalignment without the need for further foot and ankle realignment surgery, though the particular knee and hindfoot malalignment relationships (valgus knee-valgus hindfoot, varus knee-valgus hindfoot, etc.) that best respond to total knee arthroplasty alone are unclear and seemingly conflicting. [18-27] Furthermore, evidence suggests uncorrected hindfoot malalignment can affect the mechanical axis and subsequent longevity of knee prostheses after arthroplasty. [24] In patient cases where both total knee arthroplasty and flat foot realignment are indicated, the only other manuscript found regarding operative sequence suggests flat foot be corrected first and total knee arthroplasty be completed second. [23] In support of the alternate sequence, the

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authors present a case report of a 75-year-old Caucasian female patient with right leg valgus knee deformity, severe tricompartmental knee arthritis, and rigid pes planus deformity with arthritis of the hindfoot joints treated with first-stage total knee arthroplasty with correction of the knee alignment, followed by second-stage rigid flat foot reconstruction with triple arthrodesis.

Case history

J.J.M. is a Caucasian 72-year-old female who initially presented to the outpatient orthopaedic clinic for right knee and foot pain. She described the knee pain as aching and sharp with gradual onset that had been worsening over the last 5 years. It was now preventing her from performing her activities of daily living. The pain was worse with activity and improved slightly with rest. She had tried and failed conservative treatment including NSAIDs, physical therapy, and corticosteroid injections, which no longer provided significant relief. She had a history of left total knee arthroplasty 2 years prior without complications and a successful recovery. She was ambulating with a cane. Regarding her foot pain, she reported lateral (subfibular) ankle pain, posteromedial ankle pain, and anterior ankle pain. The pain was aggravated by walking, and she had failed conservative treatment with shoe inserts.

Physical exam of the right lower extremity demonstrated moderate valgus deformity of the right knee and severe pes planovalgus and abduction deformity. There was right knee medial and lateral joint line tenderness to palpation with crepitus. There was also lateral, posterior medial, and anterior ankle tenderness to palpation. Right knee range of motion (ROM) was from 5 degrees short of full extension to 110 degrees of flexion. The right ankle was unable to dorsiflex to neutral and demonstrated limited subtalar and 1st metatarsophalangeal joint ROM. The knee was stable to varus and valgus stress test with negative anterior drawer, posterior drawer, and Lachman's tests. There was no ankle laxity, and ankle anterior drawer and talar tilt tests were negative. Strength was 5/5 in all muscle groups except 3/5 in the tibialis posterior. Sensation was intact in all dermatomes. The knee extensor mechanism was intact. The Achilles tendon demonstrated tightness with a negative Silfverskiold test. The foot skin was intact without toe deformities or calluses. Distal pulses were full, and capillary refill was brisk throughout.

Long leg films taken at this visit demonstrated severe tricompartmental degenerative changes and a valgus deformity of the right knee (Fig. 1a-c). Mechanical and anatomic axis measurements taken from these films confirmed valgus malalignment (Table 1, Fig. 2a-h). Right foot and ankle radiographs demonstrated hindfoot arthritic changes, severe talar collapse with medial subluxation of the talus and talar uncoverage at the talonavicular joint, and evidence of early deltoid insufficiency with subtle talar tilt (Fig. 3a-c). In summation, this patient had severe right knee osteoarthritis with valgus deformity and ipsilateral rigid pes planovalgus deformity due to stage IV tibialis posterior tendon dysfunction. Given the patient's age, the severity of the symptoms, and failure of conservative treatments for both foot and knee pain, the patient opted for surgical treatment. The patient was offered and agreed to a comprehensive surgical plan with the first stage involving total knee arthroplasty by a joint replacement specialist, followed by second stage of triple arthrodesis with tendoachilles lengthening by an orthopaedic foot and ankle specialist.

The patient underwent right total knee arthroplasty using a standard anterior approach and medial parapatellar arthrotomy. There were significant arthritic changes and hypoplasia of the lateral femoral condyle. The iliotibial band was released due to a tight extension gap laterally. The joint was replaced with a Smith & Nephew Legion Total Knee System (Smith & Nephew, Memphis, TN). [28] The operation was performed without complication, and the postoperative course was uneventful. Postoperative radiographs showed the right knee hardware in proper alignment without any evidence of fracture (Fig. 4). By the 6-week postoperative visit, the patient was doing well with physical therapy and endorsed a significant improvement in her knee pain activity from 6/10 in severity before surgery to 1.5/10 in severity after surgery. Standing x-rays at this visit demonstrated prosthesis in good alignment with evidence of a small effusion (Fig. 5a-c). Knee alignment measures from these films demonstrated successful valgus deformity correction (anatomical lateral distal femoral angle = 88.9° postoperative from 81.8° preoperative; anatomical medial proximal tibial angle = 88.1° postoperative from 95.6° preoperative) (Fig. 5d-e). The patient continued to report significant foot and ankle pain secondary to her severe rigid flatfoot deformity.

Four months after her knee surgery, the patient underwent her second stage procedure: right foot triple arthrodesis and percutaneous Achilles tendon lengthening using the Hoke method [29] and bone grafting with a mixture of harvested autologous iliac crest bone marrow and Stryker Vitoss Synthetic Bone Graft Substitute

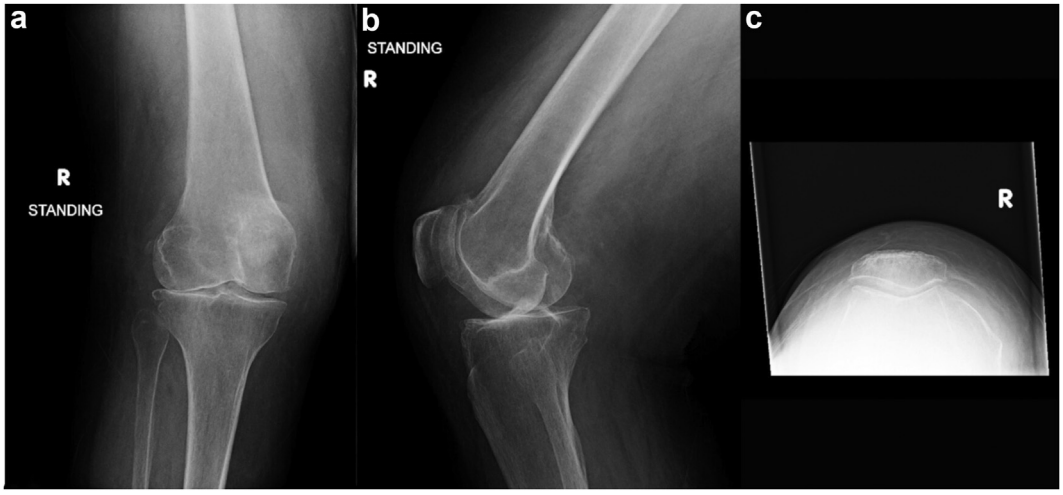

Figure 1. Initial right knee radiographs.

Table 1
Mechanical and anatomical axis measurements of the right leg.

Mechanical axis measurement	Angle(°)	Imaging	Anatomical axis measurement	Angle(°)	Imaging
mLPFA	88.6	Figure 2a	aMPFA	85.0	Figure 2e
mLDFA	87.4	Figure 2b	aLDFA	81.8	Figure 2f
mMPTA	95.3	Figure 2c	aMPTA	95.6	Figure 2g
mLDTA	94.2	Figure 2d	aLDTA	94.8	Figure 2h

mLPFA, mechanical lateral proximal femoral angle; mLDFA, mechanical lateral distal femoral angle; mMPTA, mechanical medial proximal tibial angle; mLDTA, mechanical lateral distal tibial angle; aMPFA, anatomical medial proximal femoral angle; aLDFA, anatomical lateral distal femoral angle; aMPTA, anatomical medial proximal tibial angle; aLDTA, anatomical lateral distal tibial angle.

(Stryker). [30] The hindfoot valgus was fully corrected, and the patient was kept nonweight-bearing for 8 weeks postoperatively. She was initially immobilized in a posterior splint for 2 weeks, then placed in a controlled ankle motion boot for 10 weeks. The patient was seen at 2, 4, and 8 weeks postoperatively with foot radiographs at each visit to monitor the progression of fusion.

At her 8-week postoperative follow-up visit, the patient reported no pain in the foot. X-rays of the foot demonstrated a completely healed triple arthrodesis (Fig. 6a-c). X-rays of the knee, now 6-month postoperation, demonstrated prosthesis in good alignment with no evidence of fracture or loosening (Fig. 7a-c). The patient's weight bearing was gradually advanced over the following

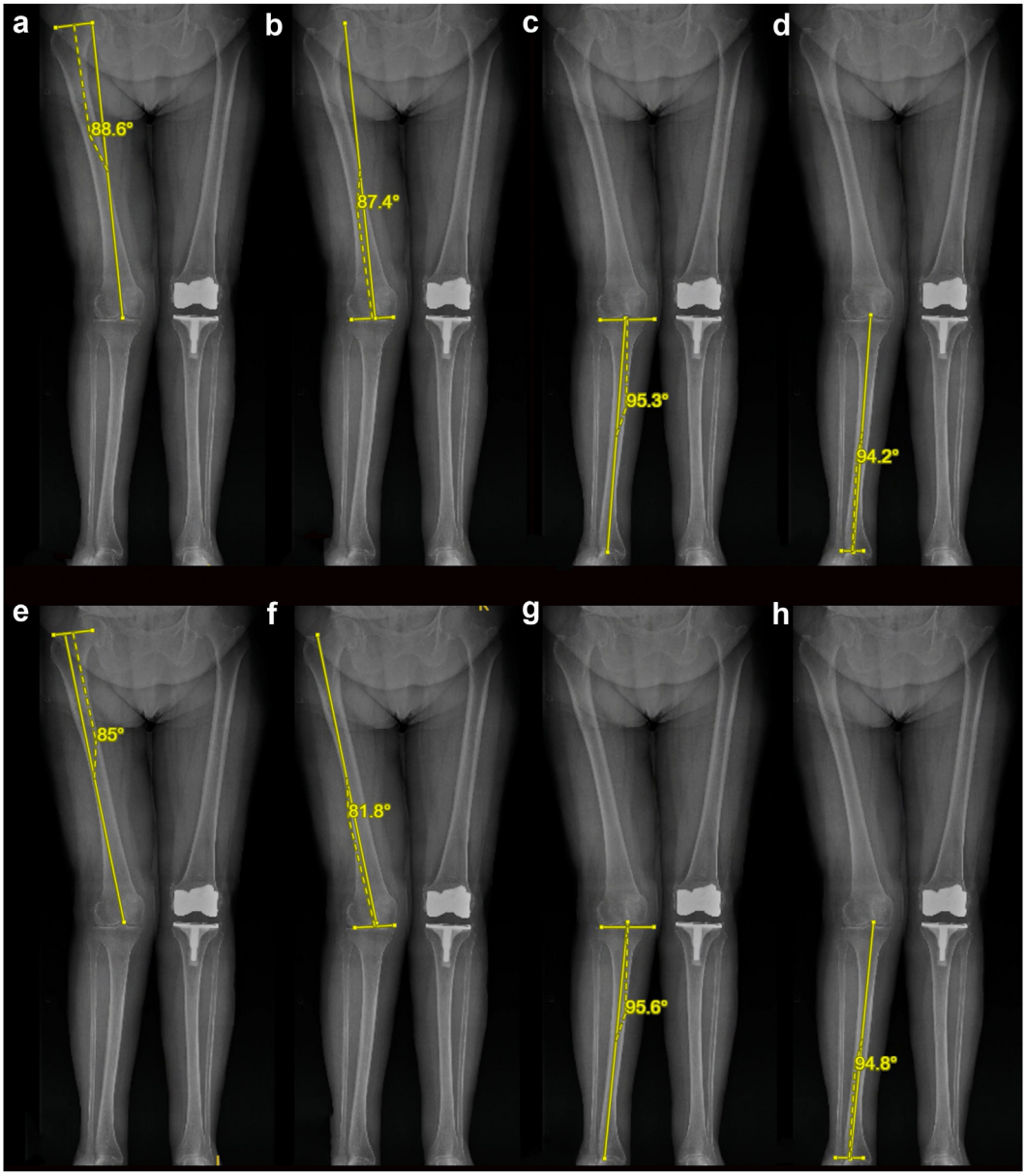

Figure 2. Long leg films with mechanical and anatomical knee axis measurements.

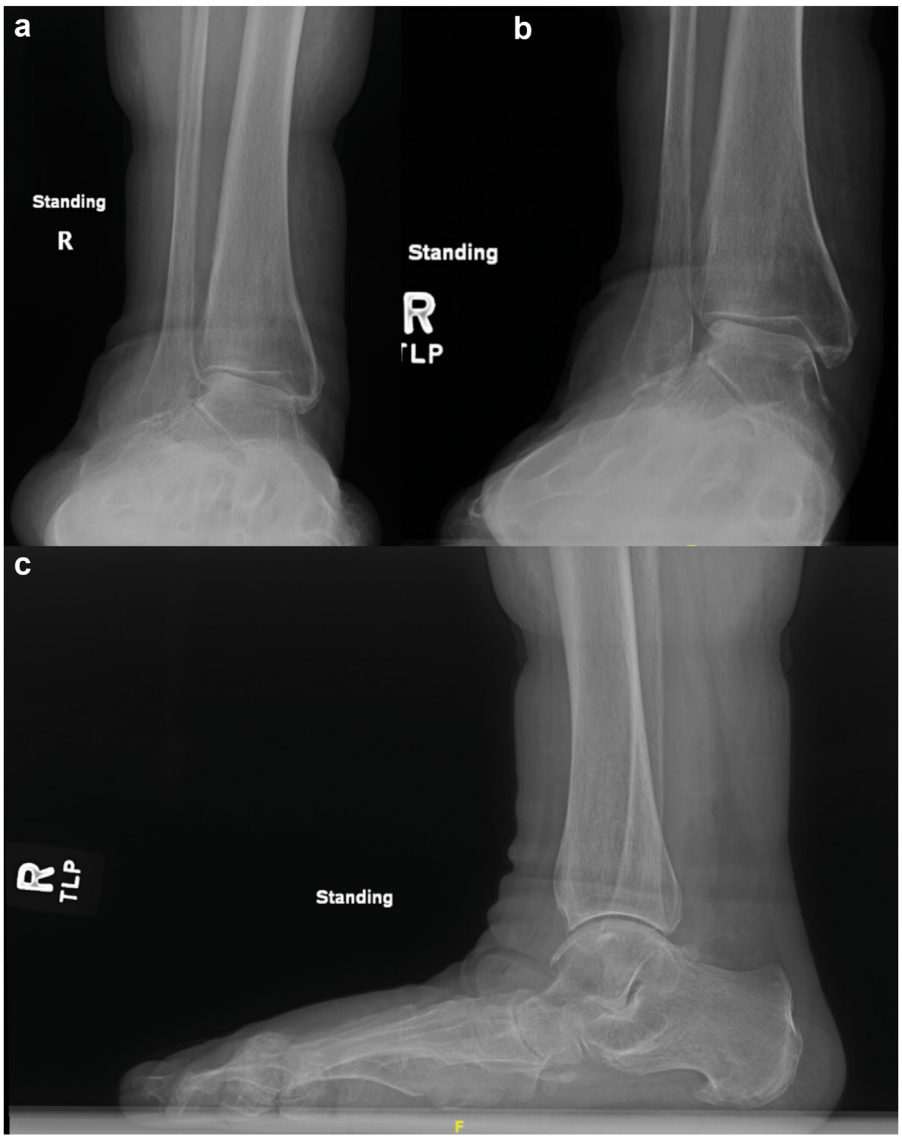

Figure 3. Initial right foot standing radiographs.

4 weeks to full weight bearing, and she was referred to physical therapy. At her 12-week postoperative visit, the patient was fully weight-bearing in controlled ankle motion boot and was transitioned to shoes. On exam, the right lower extremity was in good clinical alignment with full correction of the knee valgus, and the severe flat foot deformity with hindfoot valgus. At 6-month follow-up, the patient was progressing very well with no pain in the knee or the foot. She was fully weight-bearing in normal shoes and ambulating with a cane. Standing x-rays of the foot taken at this visit demonstrated a healed triple arthrodesis with stable and intact hardware (Fig. 8a-c). She was instructed to follow up again in 1 year or sooner if needed.

Discussion

Proper alignment of the lower extremity joints is crucial to normal leg function, especially in regards to gait. Throughout the normal gait cycle, the bones and joints of the lower extremity work in concert to facilitate stable weight transfer between the legs. This process involves many movements, including both internal and external rotation of the femur, tibia, ankle, and foot, and inversion and eversion of the subtalar joint. [31] The relationships and timing of these motions are crucial to maintaining a normal gait; weakness or decreased range of motion in any part of the leg can destabilize the entire gait cycle. Resulting motion abnormalities can lead to stress, inflammation, and eventually arthritis of the affected joints. The anatomy of the tibiotalar joint restricts tibial external rotation while the talus is everted, thus internally rotating the tibia when weight bearing on a pronated foot. [32,33] Tiberio hypothesized that excessive pronation of the subtalar joint - like that seen in flat foot deformities - causes a delayed tibial external rotation during midstance, necessitating compensatory internal rotation of the femur for proper knee extension in the swing phase. [34] Abnormal internal rotation of the femur and tibia both contribute to an increased Q angle, medializing the knee and leading to lateral patellar tracking, osteoarthritis, and valgus deformity of the knee. [34,35] Furthermore, weight bearing on a valgus knee has been shown to increase forces in the medial foot, contributing to ipsilateral posterior tibialis dysfun ction and further arch collapse. [25,36]

Figure 4. Right total knee arthroplasty postoperative radiographs.

This biomechanical model connecting valgus knee and pes planus deformities to gait impairment, subsequent injury, and arthritis is well supported by data in the available literature. [1,2,8,13-15,18,20,23,32,34-39]

Treatment options for knee pain secondary to valgus knee deformity in adults include conservative management with physical therapy and anti-inflammatory drugs as a first line, followed by intra-articular corticosteroid injections, and finally surgical modalities. Joint-preserving alignment surgeries, including distal femoral and proximal tibial wedge osteotomies, are good treatment options, especially in patients of younger age with high activity level and a lower severity of osteoarthritis [40-42]. In older patients with valgus knee malalignment and more severe knee osteoarthritis, it is often preferable to treat both conditions simultaneously with total knee arthroplasty [4,42-44]. Treatment for foot and ankle pain secondary to pes planus follows a similar path to that of knee pain. Conservative management with braces, physical therapy, and anti-inflammatory drugs are first line, followed by surgical reconstruction upon failure of other treatment modalities [45,46]. Surgical options for flat foot reconstruction vary depending on the severity of pes planus deformity. For stage 2 pes planovalgus, several reconstructive options are available, including flexor digitorum longus transfer, calcaneal osteotomy, Achilles tendon lengthening, forefoot osteotomy, spring ligament repair or reconstruction, lateral column lengthening, and medial column arthrodesis, as well as combinations of these [47-50]. In cases with a concomitant hypermobile first ray, a first tarsometatarsal arthrodesis is often required [51,52]. Stage 3 pes planovalgus due to posterior tibialis tendon insufficiency can be surgically treated with triple arthrodesis, while stage 4 disease requires additional ankle stabilization with deltoid ligament reconstruction and ankle replacement or tibiotalocalcaneal (triple) arthrodesis [46,53,54]. The goal of these surgical reconstructions is to restore the correct alignment of the lower extremity joints and reduce pain with ambulation.

Lower extremity joint dysfunction as a result of concomitant knee and foot malalignment can be challenging to treat. In patients with concomitant valgus knee and pes planovalgus requiring both total knee arthroplasty and flat foot reconstruction, proper

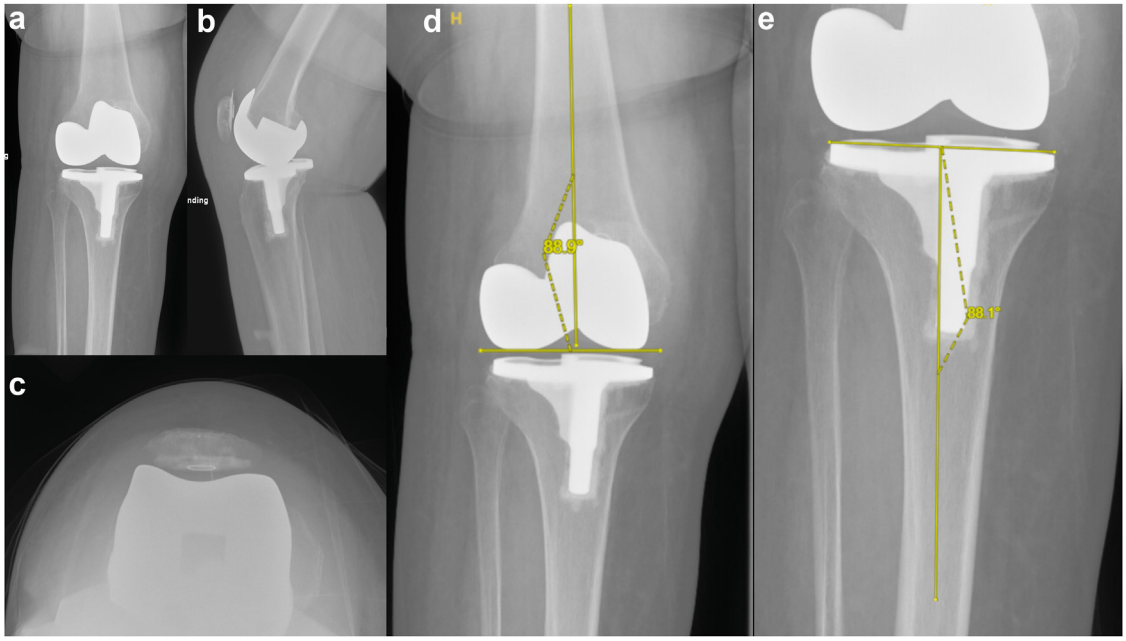

Figure 5. Right total knee arthroplasty postoperative radiographs with axis measurements.

Figure 6. Right ankle triple arthrodesis postoperative radiographs.

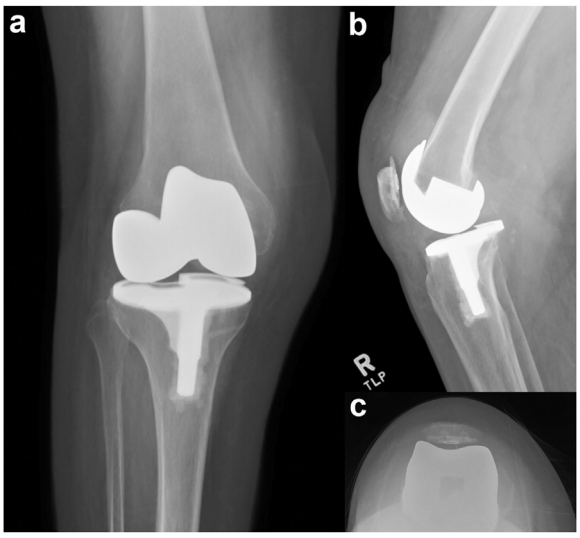

Figure 7. Six-month status post right total knee arthroplasty radiographs.

alignment can be difficult to achieve and requires careful planning and measurement before and during all procedures to ensure the proper alignment is achieved [42]. Overcorrection of a valgus knee deformity into varus alignment has been associated with higher rates of complications like pain and gait disturbance [55]. Some studies have shown varus knee malalignment greater than 3° to be associated with an increased risk of medial compartment tibiofemoral cartilage damage, with a higher incidence of postoperative varus malalignment in patients with more severe preoperative varus deformity, though the literature regarding optimal corrective models and safe angles of knee alignment after TKA is still controversial [12,42,56-58]. Overcorrection of pes planus has also been associated with poorer patient outcomes, including recurrent pain [59,60]. Thus, careful preoperative planning is required when carrying out these procedures on the same extremity, and surgeons may opt to err on the side of undercorrection to avoid symptomatic overcorrection.

Historically, the order of these 2 operations has been a matter of surgeon or patient preference. With some evidence that total knee arthroplasty can affect flexible hindfoot malalignment, surgeons may be inclined to offer knee correction first and later assess if foot correction is still necessary. [18-27,39] In our literature search, only Hooper et al. commented on operative sequence for correction of concomitant valgus knee deformity and rigid hindfoot deformity [23]. They suggested the hindfoot alignment be corrected before total knee arthroplasty in several scenarios: if hindfoot deformity appears to be the primary problem; if knee arthritis is not severe; and if knee deformity is comparatively mild. They also suggest this sequence may prevent abnormal loading through the knee prosthesis as the patient ambulates on a planovalgus foot between operative stages. While these concerns are understood, the case we present here demonstrates the standard technique employed by the authors for patients with severe tricompartmental knee arthritis, valgus knee, and rigid flat foot deformities, with good clinical outcomes. We believe the challenges of achieving near-perfect alignment of the knee and ankle are best addressed with the knee first in order to minimize risk of overcorrection. We also believe our patients' postoperative courses are better tolerated with knee surgery coming first, especially when pain and deformity are more severe in the knee than the foot, which could affect the patient's ability to engage in physical therapy and activities of daily living after foot surgery. We agree with Hooper et al. that future studies—specifically prospective studies—are needed to form guidelines for optimal operative sequence in these patients.

Summary

The case reported here demonstrates a successful strategy of correcting concomitant valgus knee deformity and rigid pes planovalgus by first addressing the knee with total knee arthroplasty and then addressing the foot with triple arthrodesis and achilles tendon lengthening. When treating concomitant rigid flat foot and valgus knee deformities, sparse evidence in the available literature suggests correcting the pes planus with reconstruction or arthrodesis before correcting the knee with total knee arthroplasty in order to maintain proper alignment; however, we illustrate a representative case in which we used the opposite sequence with good clinical outcomes. In either sequence, meticulous preoperative planning is critical to achieve proper alignment and avoid overcorrection. The authors advocate for a collaborative effort between orthopaedic knee, foot, and ankle surgeons while planning and carrying out valgus knee deformity correction before flexible or rigid pes planus correction in patients with these concomitant deformities. Future prospective studies are needed to better determine the optimal order of corrective procedures in these patients.

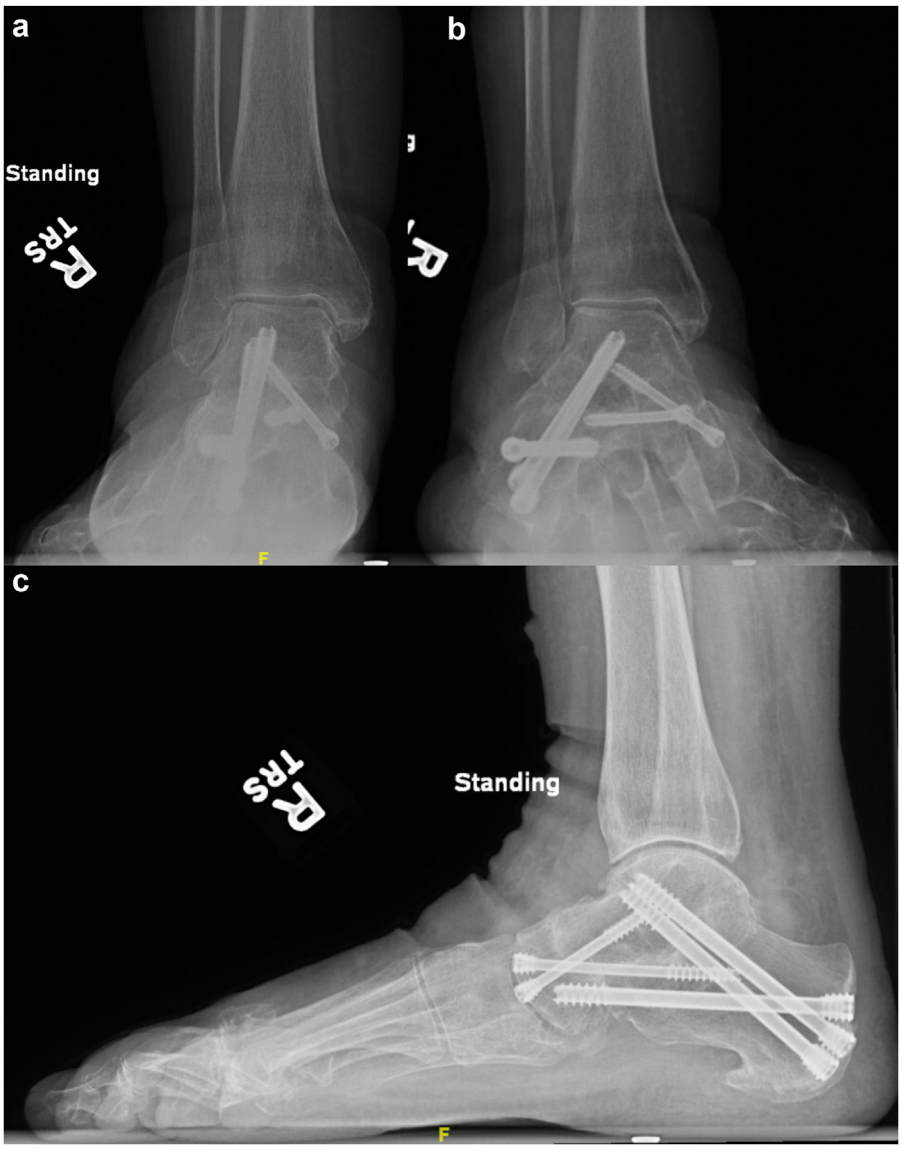

Figure 8. Six-month status post right ankle triple arthrodesis standing radiographs.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2023.101265.

Informed patient consent

The author(s) confirm that written informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they have given approval for this information to be published in this case report (series).

CRediT authorship contribution statement

Adam Pasquinelly: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Dalton Blood:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Osama Elattar:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – review & editing. **Maged Hanna:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – review & editing.

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