Progressive collapsing foot deformity: clinical presentation, diagnosis, and management options

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ABSTRACT

Progressive collapsing foot deformity (PCFD) is a prevalent musculoskeletal disease that can cause significant deformity and disability. This review article aimed to overview the clinical presentation, diagnosis, and management options for PCFD. Google Scholar and PubMed were searched specifically for publications published up until May 2023 through several keywords. Inclusion criteria were articles on PCFD and articles published in English. The exclusion criteria were related to flexible flatfoot, vertical talus condition, and non-English articles. PCFD can present with various symptoms and signs, including elongation of the tibialis posterior tendon, hindfoot valgus deformity, forefoot abduction, weakness on the single-heel-rise test, and too-many-toes signs. The footprint assessment can be used easily and effectively to detect PCFD. Diagnosis of PCFD must be according to a thorough history taking, physical check-up, and appropriate imaging studies. Treatment options for PCFD range from conservative measures such as orthotic devices and physical therapy to more aggressive measures such as tendon transfers, arthroereisis, and implant-based reconstructions. The therapeutic plan should be individualized to the patient’s requirements and comorbidities. Different surgical modalities are available to manage flat foot deformity, including arthroereisis, lateral column lengthening, medializing calcaneal osteotomy, dorsal opening wedge osteotomy, and cotton osteotomy. Each intervention has its benefits and disadvantages, and the most appropriate modality should be selected according to the kind and severity of the deformity, the patient’s features and risk factors, and the surgeon’s experience. Pre- and postoperative patient-reported outcomes measurement information system scores can help to evaluate treatment outcomes.

Keywords: Evaluation, flat foot, treatment, deformity, diagnosis.

Introduction

Progressive collapsing foot deformity (PCFD) is defined as a wide spectrum of insufficient ligaments and tendons, contributing to significant deformity and disability. This deformity, which is cited as pes planus, plano valgus foot, or merely as fallen arches, can be documented as congenital in childhood populations, or acquired in adult populations. The congenital flatfoot deformity is outside the scope of this review [1].

Adult-acquired flatfoot deformity (AAFD) is considered one of the most commonly prevalent musculoskeletal disorders among adults who present in any foot and ankle practice, and have a lot of concerns and misunderstandings from the patients about treatment modalities and their effect on their quality of life (QoL) [2]. Regarding its pathoanatomic etiology, it is categorized as either flexible or rigid flatfoot. The former is known as ligamentous laxity of the posterior tibial tendon, which is documented with a reduction in the medial longitudinal arch, a valgus...
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hindfoot, and forefoot abduction that occurs with weight bearing.

In contrast, a rigid flatfoot is presented with a flattened arch despite the foot’s position. Arche or pretibial pain can be a classical presentation in both types [3]. It is often insufficiently diagnosed, managed, and even neglected, given that many adults prefer to suffer silently without seeking medical care [4].

Orthopedic surgeons commonly encounter adults complaining of foot and ankle pain and hence play a significant role in the management required for optimizing the management outcomes of flatfoot [5]. This review aimed to focus on the prevalence and negative impact of acquired flatfoot on adults and to provide orthopedic surgeons with an updated evidence-based perspective on disease diagnosis and management.

Subjects and Methods

Google Scholar and PubMed were searched specifically for publications published up until May 2023. The keywords “progressive collapsing,” “flat foot,” “surgery,” “adult,” “conservative,” “flatfoot surgery,” “acquired,” “Complications,” “Diagnosis,” “Causes,” “Risk Factors,” and “Treatment” were used in the literature search. Inclusion criteria were articles on PCFD and articles published in English. The exclusion criteria were related to flexible flatfoot, vertical talus condition, and non-English articles.

Discussion

Risk factors and clinical presentation

Current evidence suggests that acquired flatfoot symptoms usually start secondary to multiple risk factors and can be considered modifiable and non-modifiable risk factors that are supposed to be stressed cautiously during the patient complaint [6].

The most recorded modifiable risk factors of PCFD are increased body mass index (BMI), diabetes mellitus, hypertension, and long-term use of corticosteroids. These factors can be prevented or managed appropriately to decrease the risk of flatfoot development [7]. On the contrary, non-modifiable risk factors, such as those of the female sex, increasing age, and seronegative inflammatory disorders, could never be eliminated and can seriously impact the patient’s QoL [7]. The typical PCFD patients are obese females in the sixth decade of life with either a history of type two diabetes, hypertension, or both [8].

Patients might primarily suffer from pain along the medial foot. In more severe cases, symptoms might involve lateral pain [9]. This frequently demonstrates subtalar arthritis, fibular impingement against the calcaneus, talocalcaneal impingement at the angle of Gissane, and peroneal tendinitis or tears as a result of subfibular impingement [10]. Aside from physical influence, acquired flatfoot disturbs the QoL and productivity of affected adults [11].

A study conducted in Cambre-Spain has shown that the impact of QoL in flatfoot patients is inked with BMI, age, foot size, and Charlson’s Comorbidity Index [12].

Examination

The step width, speed, stride length, and cadence are significantly lower in PCFD [13]. Also, PCFD can result in elongation of the tibialis posterior tendon (TPT), hindfoot valgus deformity, forefoot abduction, weakness on the single-heel-rise test, and too-many-toes signs [14]. The footprint assessment can be used easily and effectively to detect and diagnose PCFD [15].

Three important parameters can also be used to detect PCFD including Clarke’s angle, Chippaux-Smirak index, and Staheli index. Clarke’s angle is an angle that is measured by drawing two lines. The Staheli index is the ratio of the mid-foot’s lowest width to the rear foot’s highest width. The Chippaux-Smirak index is the ratio of the mid-foot’s lowest width to the forefoot’s greatest width [16]. That angle is highly accurate, followed by the Chippaux-Smirak, then the Staheli index. The cut-off point of such parameters for flatfoot diagnosis is Chippaux-Smirak index ≥45.75%, Clarke’s angle ≤30.5°, and Clarke’s angle ≤30.5° [17].

A patient with PCFD would exhibit some changes in the gait pattern and gait kinematics. The changes occur in the ankle, knee, hip, and pelvic joints with some range of motion (ROM) variations in all different planes [18].

Classification

PCFD can be classified into four stages based on the TPT condition, pathological changes, and clinical findings. In Stage 1, there is peri tendinitis with/without tendon degeneration in the TPT, normal hindfoot alignment, localized mild pain, mild weakness on a single heel rise test, negative too-many-toes sign, normal forefoot alignment, and degenerative changes.

In stage 2, there is elongation of the TPT, mobile hindfoot valgus position, moderate pain along the TPT, notable weakness on the single-heel-rise test, positive too-many-toes signs with forefoot abduction, and degenerative changes in the TPT.

In stage 3, there is elongation of the TPT, fixed hindfoot valgus position, moderate pain along the TPT, notable weakness on the single-heel-rise test, positive too-many-toes signs with forefoot abduction, and degenerative changes in the TPT [14].

In stage 4, there are degenerative changes of the TPT that lead to hindfoot valgus deformity with valgus deformity of the talus [19].

Investigation and imaging

Many tools are available to assist in the diagnosis of flat feet, including radiographs, ultrasound (US), magnetic resonance imaging (MRI), and computed tomography...
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Radiographs and their views

It is the first imaging used for lower foot deformity. It is always used as an anterior-posterior (AP) view and lateral weight-bearing view to assess the bone integrity and angles of lower foot bones [21]. Numerous angles can be used to establish the flat foot diagnosis and treatment. In the AP view, these angles can be measured [1,22,23]. Talar-first metatarsal angle; flatfoot: mild >4°; severe >30°, Talonavicular coverage angle; normal, <7°; flatfoot, >7°, Talonavicular uncoverage percentage, useful to estimate forefoot abduction (normal, 10% to 30%; flatfoot >30%), and Talar incongruency angle; normal, 5° = 26°; flatfoot >26°. In the lateral view: Talar-first metatarsal angle (Meary’s angle): the normal value is 0 ± 10 degrees and is elevated in flatfoot deformity. Calcaneal pitch; normal, 20°–30°; flatfoot, <20°. Talocalcaneal angle; normal, <45°, flatfoot >45°. Calcaneo-fifth metatarsal angle: normal <170°, flatfoot >170° [1,22,23].

In Saltzman’s view: The Saltzman view is also known as a hind foot alignment view. This view described by Saltzman and El-Khoury1 involves a 20°-angulation caudally towards the ankle joint from the posterior aspect, with the detector perpendicular to the anterior aspect of the foot. The hindfoot moment arm is normal, −3 mm to +10 [varus], and flatfoot, >+10 mm (valgus) Hindfoot alignment angle is normal, 5.6° ± 5.4°; and flatfoot, 22.5° ± 4.9° [24].

Using these traditional images alone is insufficient for clinical judgment in all cases. On the other hand, radiological imaging is crucial in the intraoperative; it guides the surgeon through the operation. Also, it is important to see the result postoperatively and compare it before and after [25].

MRI

It is the best imaging tool for identifying soft tissues, tendons, and muscles; it can be used to clearly understand the pathophysiology of flat feet. The most common incidental MRI finding is an injury of the lateral ankle ligament, which occurs due to the biomechanical alterations within the foot and raises stress on the surroundings of both subtalar joints and the ankle, resulting in pain [26]. Standard sequences for investigating the ankle, such as axial proton-density weighted, axial T2-weighted fast spin echo fat-saturated, coronal density-weighted fat-saturated, and sagittal T1-weighted spin-echo, should be included in MRI protocols [27].

Tibial posterior tendon: The best method for evaluating the TPT is MRI. This modality is highly sensitive in detecting tendon anomalies, with a sensitivity of up to 95% and a specificity of 100% in detecting TPT ruptures [28]. High intensity of T2 and T1 signals, tendon enlargement and defects, tendon linear fluid signal (longitudinal split tear), or a complete rupture of the tendon is indicative of a TPT tear [23].

Spring Ligament: The plantar calcaneal-navicular ligament, or spring ligament, is the medial arch’s principal static stabilizer, second only to the TPT in significance [22]. A plano-valgus deformity develops when it is wounded or released and cyclically loaded, weakening other components in the process [29].

MRI helps examine the extent of this ligament’s damage [30]. According to Ormsby et al., new MRI sequences, that comprise an axial oblique proton dense fat repress sequence with 3-mm (0.3 mm gap) slices at 30° to the axial plane along the tibia-navicular portion of the deltoid complex, can demonstrate the dorsal talonavicular component of the tibia-navicular ligament as injury related to PCFD progresses [31].

MRI allows for monitoring of infection, insufficiency fractures, soft-tissue reconstruction integrity, and osteotomy healing after surgery. Through MRI, the stability and remodeling of the graft in soft-tissue reconstructions might be observed, with the transposed tendon gradually becoming more distinct and hypointense [32].

US

US is a low-cost, operator-dependent test that evaluates TPT, the health of the spring ligaments, and the anatomical and functional alterations in the foot [33], with comparable accuracy to MRI [23]. Dynamic mode might be helpful for individuals who might have friction syndrome [22].

CT

CT offers a sophisticated and comprehensive view of the hindfoot and helps assess any abnormalities in the bone structure [34]. However, images can only be retrieved through offloading with a regular CT scan. During walking, hindfoot instability and alignment have been more clearly detected in patients with PCFD [35]. Cone-beam CT (CBCT), permits imaging of lower limbs in a normal upright WB. CBCT uses a pyramid-shaped and large-area detector X-ray beam, obtaining volumetric data from several projections without moving the patient in a single rotation through the scanner [36].

Conservative management

Before considering surgery, all individuals affected by PCFD, regardless of stage, should first receive nonsurgical treatment. Nielsen MD et al., described the treatment of 64 individuals who had been diagnosed with TPT tendinosis over some time using physical therapeutic techniques, drugs including nonsteroidal
anti-inflammatory drugs, corticosteroids, orthotics, or bracing [37]. According to researchers, 87% of surgeries succeeded and did not need further surgical intervention. Similar outcomes for nonoperative therapy of TPT insufficiency have been reported by other authors, with success rates between 67% and 90% [38,39]. Alvarez et al. [39] treated 47 individuals in a row who had stage I or stage II TPT impairment. Subjects received treatment with a short, articulated Articulated foot orthosis or foot orthosis, vigorous plantarflexion exercises, and a vigorous, high-repetition home exercise that involved extending the gastrocsoleus tendon. Success was determined by a 10% strength deficit (relative to the unaffected side), the capacity to ambulate 100 feet on the toes without significant pain, the ability to complete 50 single-support heel raises without significant pain, and the capability of tolerating 200 repetitions of exercises for each muscle category. About 89% of subjects were satisfied with this treatment prototype. However, the efficiency in relieving pain is counterbalanced by the braces’ cumbersome nature and the motion restriction [38]. For these causes, braces are rarely counseled for more than two months if they do not improve symptoms [40].

**Surgical management**

Repair, reconstruction, and salvage procedures might be used to treat patients who respond poorly to nonsurgical therapy. Selection should be made according to the kind and severity of the abnormality, the patient’s features and risk factors, the experience of the surgeon, and the body of accessible literature. Tendon debridement and repair are frequently performed during this surgical process to treat the TPT tendon inflammation and synovitis.

Stage II deformity is treated according to the severity of the malformation and talonavicular uncoverage. In stage III, treating the abnormality and producing a plantigrade foot using a double or triple arthrodesis is possible. Stage IV, PCFD surgical alternatives must concentrate on ankle stabilization before foot correction [40]. The surgeon must consider the following goals of surgery if it is thought of as definitive management: to reduce pain and enhance performance [41].

A pre-surgical patient-reported outcomes measurement information system physical function score >45.7 and <40.8 has 14.3% and 97.7%, respectively, probabilities of achieving the minimal clinically important differences (MCIDs). Only 23.1% of patients with a baseline PROMIS pain interference score of <54.1 (area under the curve = 0.799, p <.001) at two years postoperatively were likely to reach the MCID [42]. Neunteufel looked at the findings of 31 distal metaphyseal metatarsal osteotomies (DMMOs) in 30 patients, including pre- and post-surgical pedobarographic results and outcomes. The patient-reported scores increased (mean of American Orthopedic Foot and Ankle Society (AOFAS) increase of 31.87, AOFAS score mean increase of 16.29%), and pedobarographic profiles revealed lower peak pressures over problematic MTHs with better plantar pressure distribution (a mean drop of 14.15 N/cm²). They spoke of the general success of patient results. Complications included delayed union in four patients, hyperextension in 13 toes, and two instances of transfer metatarsalgia to the third and fourth MTH. Other case studies have also combined DMMOs and Weil osteotomies [43].

The most common surgical options for flatfoot deformity include arthroereisis, lateral column lengthening (LCL), and medializing calcaneal and dorsal opening wedge osteotomies. First, arthroereisis, by inserting an implant in the sinus tarsi to reduce subtalar joint pronation and improve the flatfoot’s position while carrying weight, the arthroereisis aims to treat flexible flatfoot. Flexible flatfoot can be successfully corrected by arthroereisis using combining mechanisms of dynamic, static, and proprioceptive. Endorthesis was successful in enhancing radiographic foot parameters in pediatric flexible flatfoot patients, providing acceptable long-term results after foot development. Additionally, the primary correction for lateral tarsometatarsal alignment and talonavicular congruency should be anticipated at skeletal maturity [44].

Superficial peroneal artery-related complications are remarkably uncommon. Painful peroneal muscle contracture appears to be a problem unique to subtalar extra-articular screw arthroereisis, whereas implant-related complications are more common in patients receiving sinus tarsi implants. When advising patients on STA, surgeons should be mindful of the various spectrums of complications [45]. The medical treatment for the talar valgus component of valgus flatfoot is medializing osteotomy. It attempts to realign the mechanical axis of the extremity with the calcaneal tuberosity and its insertions. The medial displacement calcaneal osteotomy is used to improve the mechanical leg alignment to the heel during weight-bearing, particularly to correct the deformity of the valgus hindfoot. Rigid progressive collapsing foot deformity (PCFD) and significant hindfoot arthritis are contraindications [46]. The procedure results in sural nerve injury in 7%–25% of patients and complications of wound in 5%–10% of patients. There is a substantial danger of sural nerve damage with a direct approach along the osteotomy line, according to other reports [47].

Mosca modified and further promoted the idea of LCL, which was first proposed in 1975. Since LCL has been shown to have positive outcomes, it has taken the lead among surgical alternatives for the management of symptomatic deformity of flexible flatfoot. However, drawbacks were noted, including insufficient or excessive corrections, loss of correction due to insufficient graft growth, migration, or improper placement [48]. The radiographic measurements of pediatric pes planovalgus and pes planus were greatly improved by lengthening the lateral column of Mosca with the progression of the TPT on the navicular bone.
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The likelihood of complications after this procedure is incredibly minimal. This makes it a viable option for the safe and efficient therapy of pediatric pes planus and pes planovalgus [49]. A plantar flexible opening wedge osteotomy of the medial cuneiform called Cotton osteotomy can treat residual forefoot varus. During this operation, an autologous (autograf) or homologous (allograf) wedge-shaped bone graft is inserted into the medial cuneiform [50]. Although there was a considerable correction loss between the early and late follow-up weight-bearing radiographs at a mean follow-up of 8.5 years, there was a remarkable increase in the angle of lateral talus-first metatarsal between the pre-surgical and final follow-up. Additionally, roughly 50% of subjects who had early and final follow-up radiography lost more than 50% of the correction that had been made. Prior research has shown good short-term and mid-term outcomes related to cotton osteotomy. Hirose and Johnson found that the calcaneal pitch, angle of lateral talus-first metatarsal, and the height of medial column improved statistically significantly (p-value=0.001) in 16 feet with a mean follow-up of 20 months for the adult subjects and 15 months for the young patient category. At an average of 7 months for pediatric patients and 12 months for adults, all of their patients had complete union without any complications [51] (Table 1).

**Conclusion**

PCFD is a common clinical condition that can present with various symptoms and signs. PCFD can result in elongation of the PT, hind-foot valgus deformity, forefoot abduction, weakness on the single-heel-rise test, and too many-toes signs. The footprint assessment can be used easily and effectively to detect PCFD. The diagnosis should be based on a thorough history taking, physical examination, and appropriate imaging studies. Treatment options range from conservative measures, such as orthotic devices and physical therapy to more aggressive measures such as tendon transfers, arthrodesis, and implant-based reconstructions. The treatment plan should be tailored to the patient’s individual needs and comorbidities.

There are a variety of surgical options available to treat flatfoot deformity, including arthroereisis, medializing calcaneal osteotomy, LCL, dorsal opening wedge osteotomy, and cotton osteotomy. Each procedure carries its own set of risks and benefits, and the selection of the most appropriate modality should be based on the kind and severity of the deformity, the patient’s characteristics and risk factors, and the surgeon’s experience. Additionally, pre-and post-operative PROMIS scores can help to evaluate treatment outcomes.

Furthermore, it is recommended that readers refer to additional articles encompassing a broader range of procedures beyond this review. These articles might address cases that necessitate multiple osteotomies or soft tissue procedures.

**List of Abbreviations**

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<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>AAFD</td>
<td>Adult-acquired flatfoot deformity (AAFD)</td>
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<td>AOFAS</td>
<td>American Orthopaedic Foot and Ankle Society (AOFAS)</td>
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<td>AP</td>
<td>Anterior-posterior (AP)</td>
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<td>BMI</td>
<td>Body mass index (BMI)</td>
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<td>CBCT</td>
<td>Cone-beam computed tomography (CBCT)</td>
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<td>CT</td>
<td>Computed tomography (CT)</td>
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<td>DMMOs</td>
<td>Distal metaphyseal metatarsal osteotomies (DMMOs)</td>
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<td>LCL</td>
<td>Lateral column lengthening</td>
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<td>LCL</td>
<td>Patient-Reported Outcomes Measurement Information System (PROMIS)</td>
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<td>MCID</td>
<td>Minimal clinically important differences (MCID)</td>
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<td>MRI</td>
<td>Magnetic resonance imaging (MRI)</td>
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<td>PCFD</td>
<td>Progressive collapsing foot deformity (PCFD)</td>
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<td>QoL</td>
<td>Quality of life (QoL)</td>
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<td>ROM</td>
<td>Range of motion (ROM)</td>
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<td>TPT</td>
<td>Tibialis posterior tendon (TPT)</td>
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<td>US</td>
<td>Ultrasound (US)</td>
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**Conflict of interest**
The authors declare that there is no conflict of interest regarding the publication of this article.

**Funding**
None.
Consent to participate
Not required.

Ethical approval
Not required.

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References

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