Progressive Collapsing Foot Deformity

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ABSTRACT
Adult-acquired flatfoot deformity is a complex orthopedic condition that was redefined with a new nomenclature and classification system published in 2020. In this article, we critically examine the newly introduced concepts, including the use of weightbearing computed tomography, detailing the changes in terminology and classification of the deformity and their clinical relevance. Additionally, we review current studies that support and refine this classification and identify areas for future research.
Keywords: Flatfoot; posterior tibial tendon; classification; collapsing deformity.
Level of Evidence: V

Deformidad colapsante progresiva del pie

RESUMEN
El pie plano del adulto es una entidad ortopédica compleja que ha sido objeto de una nomenclatura y clasificación nuevas publicadas en 2020. En este artículo, examinamos críticamente los nuevos conceptos introducidos, como la utilización de la tomografía computarizada con carga, analizando, en detalle, los cambios en la terminología y la categorización de la deformidad, así como su relevancia en la práctica clínica. Además, se revisan los estudios actuales que respaldan y refinan esta clasificación, y se identifican áreas para investigaciones futuras.
Palabras clave: Pie plano; tendón tibial posterior; clasificación; deformidad colapsante.
Nivel de Evidencia: V

INTRODUCTION

Adult flatfoot is a debilitating clinical condition characterized by a gradual loss of the medial longitudinal arch and foot function. It represents one of the most controversial and discussed disorders in the field of Orthopedics and Traumatology. The difficulty in understanding the disease may stem from its complex etiology, natural progression, varied clinical presentations, and diverse treatment approaches. Another obstacle to understanding this condition is the variety of names it has been given throughout history, such as adult-acquired flatfoot, posterior tibial tendon dysfunction (PTTD), tibialis posterior tendinopathy, lateral peritalar subluxation, or simply adult flatfoot. However, with the emergence of new anatomical concepts, imaging technologies, and surgical techniques, understanding the details of this complex disease has grown exponentially.[1,2]

In 2019, a group of expert surgeons with a significant number of publications on this condition met to reach a new consensus and redefine concepts regarding the terminology, classification, and treatment of the disease.[3]

The aim of this article is to provide a review of the current nomenclature and classification of this condition.

Selection of Experts

The original idea for the new consensus was developed by surgeons Cesar de Cesar Netto and Scott Ellis. They selected nine expert surgeons based on a minimum of 10 publications indexed in PubMed in high-impact journals covering various aspects of the diagnosis and treatment of adult flatfoot. The expert panel included Cesar de Cesar

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Netto (USA), Scott Ellis (USA), Lew Schon (USA), Mark Myerson (USA), Beat Hintermann (Switzerland), David Thordarson (USA), Jeffrey Johnson (USA), Jonathan Deland (USA), and Bruce Sangeorzan (USA). Each expert was asked to give a 10-minute presentation on a specific aspect of the diagnosis or treatment of adult flatfoot. From these presentations and subsequent discussions, additional aspect-specific consensus statements were formulated and voted on. Voting on each consensus statement consisted of agreement or disagreement. The strength of each statement was determined by the percentage of approval: unanimous (100%), strong (over 75%), or weak (between 50% and 75%). Following the final statements, each member was asked to write a manuscript summarizing the rationale for supporting the statements related to their talk, based on previous group discussions, clinical experience, and literature evidence.[3]

Consensus topics included: (a) new nomenclature and classification, (b) goals of surgical treatment, (c) evaluation of the amount of bony correction in surgical treatment, (d) use of weightbearing computed tomography (WBCT), (e) indication for medializing calcaneal osteotomy, (f) indication for lateral column lengthening, (g) indication for dorsal-opening wedge osteotomy of the medial cuneiform (Cotton osteotomy), (h) indication for isolated arthrodesis of the subtalar and cuneonavicular joints, and (i) indication for reconstruction of the deltoid and spring (plantar calcaneonavicular) ligaments.[4-12]

New Nomenclature

The consensus group recommended changing the term "adult-acquired flatfoot deformity" to Progressive Collapsing Foot Deformity (PCFD).

The term deformity is used because this is a complex, three-dimensional condition involving varying degrees of hindfoot valgus, forefoot abduction, midfoot varus, and medial ankle instability. The term collapsing emphasizes that the foot becomes globally dysmorphic, not just marked by isolated flattening of the medial arch. In addition, the term collapse is more objective and easier to describe and quantify than the more subjective term flat.

The word progressive reflects the natural history of the condition, indicating that it tends to worsen over time. It also clarifies that many patients may have painless flat feet initially, and it is only when progression toward collapse occurs that symptoms and dysfunction emerge.[4]

New Classification

The first classification for adult flatfoot was published by Johnson and Strom in 1989 (Table 1).[13.]

Table 1. Johnson and Strom classification.

Variable	Stage 1 Mild, medial pain	Stadium 2 Moderate, medial pain	Stage 3 Severe, medial and lateral pain
Physical examination	Mild swelling and tenderness along the PTT	Moderate swelling and tenderness along the PTT.	No swelling, but marked tenderness along the PTT
Single-leg heel raise	Mild weakness	Marked weakness	Marked weakness
Too many toes sign	Absent	Present	Present
Deformity	Absent	Present (flexible)	Present (fixed)
PTT	Normal tendon length, paratendinitis	Elongated with longitudinal tears	Disrupted
Images	No changes	Gross deformity	Deformity with osteoarthritis
Treatment	Nonoperative, tenosynovectomy	FDL Transfer	Triple arthrodesis

PTT = posterior tibial tendon; FDL = flexor digitorum longus.

The authors classified it into three stages, associated with dysfunction and eventual tear of the posterior tibial tendon (PTT), and referred to it as PTT dysfunction. Myerson, in 1997, added stage IV, referring to valgus ankle joint involvement: IV-A (flexible) and IV-B (rigid).[14] Recognizing instability of the medial column, forefoot abduction, and midfoot varus, Bluman et al., in 2007, modified all stages by subdividing them into different categories, with the most notable expansion in stage II (Table 2).[15]

Table 2. Bluman's classification.

Stage	Substage	Clinical findings	Radiographic findings	Treatment
I	A	Normal anatomy Tenderness along PTT	Normal	Immobilization, NSAIDs, Orthoses, Tenosynovectomy
	B	Normal anatomy Tenderness along PTT	Normal	Immobilization, NSAIDs, Orthoses, Tenosynovectomy
	C	Slight HF valgus Tenderness along PTT	Slight HF valgus	Immobilization, NSAIDs, Orthoses, Tenosynovectomy
II	A1	Supple HF valgus Flexible forefoot varus Possible pain along PTT	HF valgus Meary's line disruption Loss of calcaneal pitch	Orthoses Med. displ. calc. osteot. Achilles tendon lengthening or Strayer and FDL transf. if deformity corrects only with ankle plantarflexion
	A2	Supple HF valgus Fixed forefoot varus Possible pain along PTT	HF valgus Meary's line disruption Loss of calcaneal pitch	Orthoses Med. displ. calc. osteot. and FDL transf. Cotton osteotomy
	B	Supple HF valgus Forefoot abduction	HF valgus Talonavicular uncovering Forefoot abduction	Orthoses Med. displ. calc. osteot. and FDL transf. Lateral column lengthening
	C	Supple HF valgus Fixed forefoot varus Medial column instability Sinus tarsi pain	HF valgus First TMT plantar gapping	Med. displ. calc. osteot. and FDL transf. Cotton's osteotomy or medial column fusion
III	A	Rigid HF valgus Sinus tarsi pain	Subtalar joint space loss HF valgus Gissane's angle sclerosis	Custom bracing if not surgical candidate Triple arthrodesis
	B	Rigid HF valgus Sinus tarsi pain Forefoot abduction	Subtalar joint space loss HF valgus Gissane's angle sclerosis Forefoot abduction	Custom bracing if not surgical candidate Triple arthrodesis + lateral column lengthening
IV	A	Supple tibiotalar valgus	Tibiotalar valgus HF valgus	Surgery for HF valgus and associated deformity Deltoid reconstruction
	B	Rigid tibiotalar valgus	Tibiotalar valgus HF valgus	Tibiotalocalcaneal fusion or or pantalar fusion

NSAIDs = nonsteroidal anti-inflammatory drugs; FDL = flexor digitorum longus; Med. displ. calc. osteot.= medial displacement calcaneal osteotomy; HF = hindfoot ; TMT = tarsometatarsal joint; PTT = posterior tibial tendon.

This classification was widely used due to its added value as a guide for surgical indication and the type of procedure to be performed. However, it is recognized that this modification was also limited and did not sufficiently include the anatomical and radiographic details of the deformity. In 2012, Raikin et al. introduced a new classification more focused on the midfoot, called RAM, which divides the deformity into the individual components involved in the disease process (Table 3).[16] It retains the original classification of three stages, as well as the subclassifications introduced by Bluman et al., but applies them separately to the rearfoot (R), ankle (A), and midfoot (M).[16] In 2013, Richter and Zech published another clinical classification. They divided adult flatfoot disease into four stages according to PTT function, independent of joint flexibility. The authors' original intent was to differentiate PTT insufficiency and stiffness from deformity, suggesting that some patients with collapsed feet are not stiff, and others have stiff feet without any PTT lesion.[17]

Table 3. RAM classification.

	Rearfoot	Ankle	Midfoot
Ia	PTT tenosynovitis	Neutral alignment	Neutral alignment
Ib	PTT tendonitis without deformity	Mild valgus (<5º)	Mild flexible supination
IIa	Flexible planovalgus (<40% talar uncoverage, <30º of Meary angle, incongruency angle 20º-45º).	Valgus with deltoid ligament insufficiency (no osteoarthritis)	Supination without radiographic signs of instability
IIb	Flexible planovalgus (>40% talar uncoverage, >30º Meary angle, incongruency angle >45º)	Valgus with deltoid ligament insufficiency with tibiotalar osteoarthritis	Supination with instability without osteoarthritis
IIIa	Fixed/arthritic planovalgus (<40% talar uncoverage, <30º Meary angle, incongruency angle 20º-45º).	Valgus associated with lateral collapse of the tibial plafond (normal deltoid ligament).	Isolated osteoarthritis of the medial column (cuneonavicular joint or first tarsometatarsal joint).
IIIb	Fixed/arthritic planovalgus (>40% talar uncoverage, >30º Meary angle, incongruency angle >45º) - not correctable through triple arthrodesis	Valgus associated with lateral collapse of the tibial plafond with deltoid ligament insufficiency.	Medial and middle column with osteoarthritis (in general, with supination or abduction of the midfoot).

PTT = posterior tibial tendon.

While these classifications are still in use, the expert group had three main goals for incorporating a new classification: 1) to explicitly remove PTT as the primary cause of the disease; 2) to emphasize the fact that multiple deformities can occur simultaneously, in different anatomical sectors (multifocal) of the foot and ankle; and 3) to abandon the concept of sequential development of deformity by anatomical sectors (i.e., first PTT injury, and eventually ankle involvement), asserting instead that there is temporal progression—first the deformities are flexible and then they become rigid.

The new classification proposed by the expert group covers both anatomical and functional aspects. It is based solely on the flexibility or stiffness of the affected anatomical segment, and on the type and location of the deformity as determined by physical examination. The classification includes five classes of deformities that may occur in isolation or simultaneously (combined). Each class can be subdivided into stage I (flexible) or stage II (rigid). The five types of deformity (classes) are: (A) rearfoot valgus, (B) midfoot/forefoot abduction, (C) forefoot varus

or medial column instability, (D) peritalar subluxation, and (E) ankle instability.[4] Experts proposed using different letters for the classes to highlight that the patient may present with one or more elements of the deformity simultaneously. For example, if a patient has PTT dysfunction with stage and class 1AB, this refers to flexible deformities with marked hindfoot valgus and increased midfoot abduction. Another example could be a patient classified as stage 1ABE 2D, indicating a clinical case with hindfoot valgus, midfoot abduction, ankle valgus deformity (all flexible deformities), plus a rigid forefoot in supination or medial instability of the medial column.

Lee et al. studied the intra- and interobserver reliability of the new PCFD classification. They evaluated 94 feet with three independent observers. The findings demonstrated high intraobserver and moderate interobserver agreement. Only 5.8% of patients had isolated deformities, and the most frequent combinations were 1ABC, 1AC, and 1ABCD.[18] Li et al. evaluated the diagnostic accuracy of the classification. They prospectively studied 20 patients with 13 observers. The results yielded overall, class-specific, and stage-specific diagnostic accuracies of 71%, 78.3%, and 81.7%, respectively.[19]

Computed Tomography (Weight-bearing)

Many of the classes can be easily diagnosed clinically and through radiographs, such as class A (hindfoot valgus) and class E (ankle instability). However, class D (peritalar subluxation), which presents with external rotation, valgus, and lateral translation of the calcaneus in relation to the talus, is best diagnosed with cone-beam computed tomography (CBCT). Although experts highlight the broad benefits of CBCT, its inclusion in the new classification system received a weak recommendation.[7] One of the reasons is its limited availability. In South America, there are only two of these devices. Experts suggest that, when available, CBCT should be used for preoperative planning. They unanimously agreed that the signs to be evaluated on imaging include: sinus tarsi impingement, increased valgus tilt of the posterolateral facet of the subtalar joint, subluxation of the posterolateral or medial facet of the subtalar joint, and subfibular impingement.[7] CBCT not only allows confirmation of the diagnosis but also helps predict prognosis and disease progression. de Cesar Netto et al. retrospectively studied CBCT (coronal slices) in patients with PCFD and a control group. They reported that patients with PCFD had higher values of joint uncoverage and incongruity of the medial facet of the subtalar joint ($p < 0.0001$), which served as an isolated marker of peritalar subluxation. In addition, they found that joint uncoverage and incongruity in that facet had high diagnostic accuracy (>17.9%, with 100% specificity and 96.7% sensitivity; >8.4° with 100% specificity and 100% sensitivity, respectively) and represented an early marker of peritalar subluxation (medial facet vs. posterior facet: 17.7%) in PCFD.[20,21] Despite the advancements in CBCT, conventional anteroposterior and lateral weight-bearing radiographs of the foot, as well as forefoot or ankle mortise views, remain essential.

Stage I

A key aspect of this new consensus is the abandonment of Stage I (patients with pain but no deformity) from older classifications. The consensus states that there is no valid description for this stage, and only 5 of the 9 experts (56%) believe that surgery may be indicated. Experts suggest that at this stage, the condition reflects tendinitis or tendinosis of the posterior tibial tendon (PTT), but without deformity, describing it as a stable process. They argue that PTT failure occurs secondary to ligamentous attenuation in patients with underlying bony deformities.[4] Despite this, some authors argue that Stage I should continue to be used for patients with a subtle hindfoot valgus deformity (not visible on weight-bearing radiographs but detectable on CBCT), with medial soft tissue pain and inflammation (involving the PTT, calcaneonavicular, or deltoid ligament), and the presence of risk factors for disease progression (such as obesity, ligamentous laxity, chronic inflammatory disease, or gastrocnemius contracture).[22]

During the consensus discussions and voting, the most important finding in former Stage I was reported to be PTT pain (5/9, 56%), followed by gastrocnemius contracture and moderate hindfoot valgus (2/9, 22%). The surgeries considered potentially beneficial in this stage were gastrocnemius recession, PTT tenolysis and debridement, and medializing calcaneal osteotomy (5/9, 56%), followed by Cotton osteotomy, PTT tenolysis and debridement, and arthroeresis (1/9, 11%).[4]

Over the past 30 years, numerous classifications have been published, mainly based on flexibility and the site of deformity, emphasizing PTT injury as the primary cause. Perhaps due to this reasoning, progress in understand-

ing the disease's causes was limited. However, new studies in anatomy, biomechanics, and imaging have led to better insights into underlying deformities—such as joint positioning, angulation, and bone morphology—which may explain disease onset and even predict which patients may develop PCFD. Perhaps the key to resolving the controversy surrounding adult flatfoot lies in moving away from the idea of PTT failure as the cause of the condition.

Strengths

The change in terminology from adult acquired flatfoot to PCFD reflects a more comprehensive understanding of the condition as a progressive entity. This is significant, as the term "flatfoot" is often associated with a static and benign clinical picture, whereas "collapsing deformity" implies a dynamic and progressive process that can result in pain and functional impairment. The new terminology incorporates the use of CBCT, which enables assessment of foot alignment under partial weight-bearing conditions, providing a more realistic and accurate visualization of bony and articular architecture. It also offers a more detailed description of the stages and categories, which facilitates treatment planning and improves communication among surgeons.

Weaknesses

As with previous classifications, the current system includes several classes that may be difficult to memorize and apply in clinical settings. The subdivision into multiple classes may seem excessive and overly complex for quick application in everyday practice. The inclusion of only 2 stages and 5 classes results in up to 242 possible combinations. Classifications should be simple and easy to use.

As suggested by Boakye et al., to enhance usability, the classification should follow a more intuitive structure. Although the expert group based the classification on anatomical organization, it does not follow a linear pattern: it begins with hindfoot valgus deformity as Class A and moves distally to Class C (forefoot varus), then retrogresses to peritalar subluxation as Class D, and finally to ankle instability as Class E. A linear progression from ankle to forefoot would be easier to remember.

Another limitation is the lack of specification on whether flexible deformities are stable or unstable, and some joints may exhibit flexibility alongside arthritic changes.[23] PCFD is not a rare condition; therefore, the new classification may not align with the terminology and criteria used in prior studies and clinical registries on adult flatfoot, potentially hindering longitudinal comparisons and evaluations of treatment efficacy over time.

As with any shift in medical terminology, there may be resistance from clinicians accustomed to previous terms and classifications. This reluctance can delay adoption and limit implementation. In many cases, the most enduring classifications are those that withstand the test of time, even amid the development of new treatments.

CBCT represents a major advance in the assessment of PCFD. However, its limited availability in some countries may restrict its utility. It is essential for new classifications based on this imaging to remain adaptable and usable alongside traditional diagnostic methods in areas where CBCT is not accessible.

These criticisms highlight common concerns when transitioning to new medical terminologies, where the challenge lies in balancing accuracy and relevance with clinical practicality. While the intent behind updating nomenclature and classification is to improve clinical and surgical management of patients with PCFD, there are notable challenges in implementation, comprehension, and consistency.

CONCLUSIONS

Advances in the understanding of foot deformities and associated findings arising from new research eventually lead to revisions or updates in classification systems.

Staging systems are often developed to classify the severity of a condition according to various criteria, such as clinical features, imaging findings, and functional impairment. The proposed new staging for PCFD could provide surgeons with a more standardized approach to assessing and managing the condition, which may lead to improved patient outcomes. It would be valuable to further evaluate this new staging system in terms of its validation, reliability, and clinical utility to determine its effectiveness in guiding treatment decisions and predicting prognosis.

The new nomenclature aims to improve the clarity, accuracy, and consistency of terminology applied to PCFD. If this new nomenclature is to be adopted, it would be beneficial to assess its acceptance and implementation within the trauma and orthopedic medical community to understand its potential impact on clinical practice and future research.

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