

Review Article:

The Current Literature on Clubfoot Deformity:

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Abstract

Background: Idiopathic Clubfoot (CF) deformity is a musculo-skeletal deformity affecting children with a high prevalence. Regrettably, management of the CF deformity is complicated, especially in severe and neglected cases.

Aim of Study: This narrative review aimed to explore the published articles concerning the CF deformity and its available therapeutic options.

Material and Methods: A meticulous search of the updated published articles using keywords related to CF deformity. The current search included the published articles since the late twenties. The extracted data were stratified in the same order as the used keywords.

Results: Early management of CF deformity is advocated to get the best results. Conservative management is efficient but carries a high risk of relapse. The patient's compliance with the brace is a major determinant of the treatment outcome and predisposition to relapse. Timely diagnosis of relapse is crucial, and its management is mandatory.

Conclusion: Conservative management is appropriate and effective, especially for selected cases. Generally, recurrent deformity after conservative treatment accounts for a high incidence rate. Additionally, surgical interventions are the last resort for management of relapsed cases and as initial management for severe and neglected cases.

Key Words: Clubfoot deformity – Ponseti Management – Soft-tissue release surgeries – Osteotomies.

Introduction

IDIOPATHIC congenital talipes equinovarus (CTEV), or Clubfoot (CF) deformity, is a Muscu-

lo-skeletal deformity that affects children. Clubfoot deformity globally affects 1.2 in 1000 live births [1]. Geographically, the prevalence rate of CF deformity varies, reaching up to about 2 in 1000% in the United States [2].

The management of the CF deformity is complicated, especially in severe and neglected cases. Despite the availability of multiple treatment methods, still no consensus on the best treatment, the ideal surgical approach, or the best fixation hardware available [3]. CF treatment is challenging, particularly in low- and middle-income localities, where treatment is limited secondary to low resources, weak healthcare systems, and a shortage of trained providers [1].

Kites developed the early nonsurgical method for congenital CF treatment. However, the Ponseti method is more popular and has been proven to be highly effective in achieving functional correction in these children [4]. Despite the effectiveness of the Ponseti method, recurrence of CF is common secondary to nonadherence or delayed treatment. The incidence of the relapsed clubfoot deformity after the Ponseti treatment and how to manage are challenges; thus, the earlier recognition of the relapsed deformity may allow the application of less invasive treatment and improve the outcomes with subsequent improved patient welfare [5]. Gait analysis using GDI score and individual kinematic parameters, particularly of the forefoot, may have a potential role in aiding the detection of relapse [6].

The occurrence and the treatment of a relapsed clubfoot are a challenge in clubfoot care. Early recognition of relapse is important to minimize the invasiveness of treatment and the impact of recurrence and its management on foot functionality later in life.

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Aim of work:

This narrative review aimed to explore the published articles concerning the classification of CF deformity and the radiologic workup for diagnosis. Also, the review searched for the various therapeutic options for CF deformity.

Material and Methods

A meticulous search in the updated published articles using frequent keywords concerning the following points was performed through PubMed and Google Scholar. The keywords applied in this search included “clubfoot”, “developmental factors”, “genetics”, “anatomy”, “classification”, “treatment” or “management”, “relapse” or “recurrence”, “Ponseti method”, “surgery”, and “outcomes”. The current search included the full-text articles published since the late twenties. The extracted data were stratified in the same order as the used keywords.

Results

Developmental Background:

During early development, the morphology of the foot and the ankle joint is distinctly different from their morphology observed in adults, and physiological clubfoot is a well-documented phenomenon [7].

Continuous supination of the hindfoot, pronation of the forefoot along the foot axis, and the reduced plantar flexion of the ankle joint contribute to the development of physiological clubfoot during the late embryonic period. The obliquity of the tibia-talus joint resulted in twisting between the forefoot and hindfoot and the abduction of the ankle joint. These changes in the shape of the tarsal bones, especially the calcaneus and talus, and the

affected relative bone positions, indicate that the concept of “differential growth” for ankle-joint and foot morphogenesis may enhance understanding of the pathogenesis and mechanisms underlying CF and facilitate fetal diagnosis via morphological assessments [7].

Karyotyping and chromosomal microarray analysis (CMA) indicated a total detection rate of genetic factors in 16.2% of fetuses diagnosed with talipes equinovarus using prenatal ultrasound. Furthermore, pathogenic single-nucleotide variants associated with the RIT1, GNPAT1, PEX1, RYR1, ASCC1, and GDAP1 genes were identified in 33.3% of fetuses with normal karyotyping and CMA results [8].

Cerebral palsy (CP) is the most common motor disability of childhood, predominantly characterized by spasticity. Equinovarus deformity is a frequent complication of spastic CP and results in pain, instability, and altered gait, which significantly affects ambulation. Surgical intervention, particularly the split posterior tibialis tendon transfer (SPOTT), is often required to correct deformity when conservative management fails [9].

Further, a positive relationship exists between CTEV and developmental dysplasia of the hip (DDH), with a 5-10 times higher relative risk of DDH in patients who had idiopathic CTEV compared to the general population; thus, hip ultrasound screening of CTEV patients is mandatory [10].

Anatomical Considerations:

Foot and ankle joints bear the entire body weight and facilitate easy transfer of the patient anywhere (11). The calcaneocuboid ligament, and the inferior calcaneonavicular ligament form the calcaneopedal unit (CPU) (Fig. 1) [12].

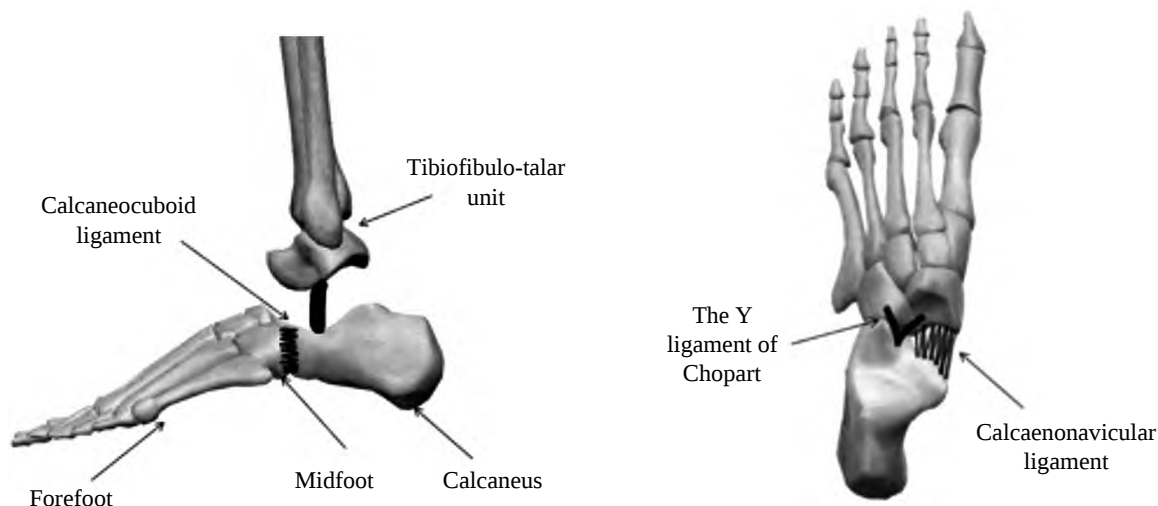


Fig. (1): The constituents of the CPU. Quoted from [12].

The CPU is a functional unit that articulates through four articular components with the talus. The talus belongs to the functional unit “The talo-tibiofibular complex”, not to the CPU. The movement of the CPU is complex because it rotates under the talus and around the axis of Henke. In the standing position, the CPU can adapt to achieve a plantigrade position [13].

The CPU moves three-dimensionally, 41° dorsiflexion and 23° internal rotation, around “The Henke axis”. The Henke axis is an oblique imaginary axis passing from the upper-medial aspect of the neck of the talus, traversing the ligament to come out the lateral calcaneal aspect (Fig. 2) [14].

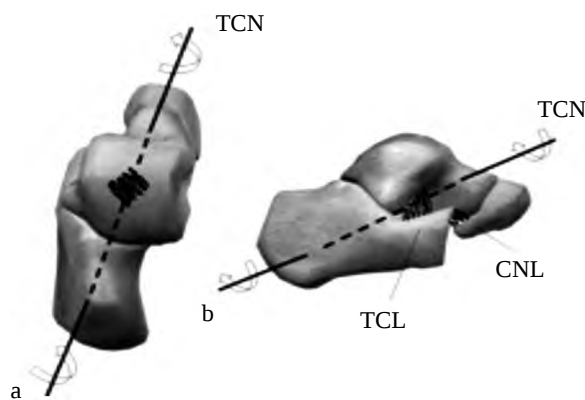


Fig. (2): Transverse and lateral views of the talocalcaneonavicular joint showing the TCN axis as it traverses the interosseous talocalcaneal ligament. Quoted from [12].

Classification and Assessment:

Types of CC:

The CF deformity was categorized as idiopathic, which is the commonest, and the syndromic, and the neurogenic clubfoot, which is the more severe type, and the fourth, less severe type is the postural. Idiopathic CC is characterized by a wide range of severity and rigidity. Rigidity is its main feature and requires manipulation and plaster immobilization. The Ponseti method succeeded in treating most idiopathic CC cases. For the prevention of recurrence, and maintenance of the correction with castings the tenotomy of the Achilles tendon tenotomy is required for most patients with idiopathic CF.

Classifications:

Diméglio classification:

Diméglio CC classification scores four main parameters: Equinus, varus, rotation, and adduction, by one to four according to reducibility. On the existence of secondary parameters, one point was added for each of these parameters for a total score range of 0 to 20, and these scores were graded based on the severity and flexibility into five grades

Grade I (0–5 points): Mild, flexible, and benign CC [15].

Pirani Classification:

Pirani's classification scores three parameters for the assessment of the hindfoot and another three for the evaluation of the midfoot. These parameters included the posterior and medial creases, calcaneal palpation and talus coverage, and the reducibility of the equinus and lateral edge of the feet. Scoring of these parameters was based on the presence of abnormality; none was scored by zero, and present was scored by 0.5, and if severe, it was scored by 1 [16]. The total Pirani score ranges from zero to 6 and the resultant total score was used to assess the progress of the provided treatment [17].

Diagnostic Approaches:

X-ray:

Anteroposterior and lateral views that were obtained in the standing position were examined to measure the angle created between the axes of the talus and calcaneus in the two planes. Moreover, the relation between the calcaneal equinus and the longitudinal axis of the tibial bone was also assessed. Additionally, to evaluate the forefoot cavus, the angle created in-between the talus and the long-axis of the 1st metatarsal bone was defined [18]. Evaluating the talar head flattening and subluxation of the navicular bone is an essential issue during the assessment of CF deformity [19].

Ultrasonography (US):

Ultrasound allows real-time visualization of dynamic foot movements, allows the evaluation of the flexibility and reducibility of the deformity through assessment of soft tissues, ligaments, and joint structures. The US can also identify associated anomalies, which may impact treatment planning as tendon abnormalities or joint contractures [20]. Additionally, Achilles tenotomy can be performed under real-time US guidance [21]. Pre-natal US could identify CP and accurately distinguish structural from positional deformities, and this allows early psychological parental preparation and treatment planning [22].

Magnetic Resonance Imaging (MRI):

MRI is the best diagnostic approach whenever soft tissue abnormalities are suspected. The detailed cross-sectional images of foot soft tissue that were provided by MRI are essential for management planning. Additionally, assessment of the integrity of the tendons and the bulk of the foot muscles that is provided by MRI aid the surgical-decision making [19]. MRI can provide a more precise char-

acterization of clubfoot deformities and has the potential to identify recurrences and complications of clubfoot earlier than traditional X-ray imaging [23].

Treatment of CC deformity:

The main option for congenital clubfoot deformity is to reduce the deformity and to achieve a flexible, plantigrade, and painless foot to facilitate the child's mobilization and development [24].

Procedures for Conservative Management:

Kite Procedure:

Conservative methods initially aim to resolve the problem. In the early twenties, Kite's conservative approach involving manipulations and serial casting was used. The Kite procedure was criticized for its correction fulcrum, which was in the calcaneocuboid bone; this fulcrum limited varus correction and resulted in most cases requiring soft-tissue release surgery [25].

Ponseti Method:

Ponseti attributed the high failure rate of the Kite's approach for the correction of the CC to the misunderstanding of the anatomy and biomechanics of the deformity and used the fulcrum on the lateral surface of the head of the talus, which is palpable on the lateral dorsum of the midfoot, with pressing the first metatarsal bone (FMT), and supinating the foot to unlock the subtalar as a sequence of manipulation for CC treatment. The approach innovated by Ponseti allowed global application for CC treatment, and was considered by most orthopedic surgeons to be the gold standard for conservative management [26].

The international prominence of the Ponseti method is due to its effectiveness and reduction in the need for surgical procedures. The Ponseti method is superior for its improvement of the prognosis hand-by-hand with the long-term therapeutic outcomes [27].

The Ponseti method consists of weeks of manipulation and serial casting with correct manipulation, and years of orthotic wear, thereby resulting in lengthening of the posteromedial contracture structures with sequential effective deformity reduction [28]. The Ponseti method is also advantageous for allowing weekly assessment using the Pirani scale [29].

The duration of management with the Ponseti method varies. Considering that the genetically altered growth of type III collagen is the main underlying pathogenic factor for the development of clubfoot deformity, which ends by the age of four years, the Ponseti serial casting must continue for

these four years to maintain the achieved reduction of the deformity and guard against recurrence [30].

When to start the Ponseti management: One study detected meaningless differences in cast numbers, skin lesion incidence, treatment adherence, or recurrence according to the age of initiation of treatment [31]. However, taking advantage of the neonatal higher flexibility [32], treatment was suggested to start in the first week of life to allow for family adaptation, the establishment of breastfeeding, and defining the rate of effective weight gain; however, a delay in the start of treatment was inadvisable [33].

The rationale and sequences of the Ponseti approach to correct the CC deformity entailed the following:

- Initially, the cavus deformity is corrected, with support on the neck of the FMT bone, and a forefoot supination to place it in adequate alignment with the rearfoot [33]. Pronation is unnecessary because it enlarges the cavus, leading to an iatrogenic deformity [25].
- Correction of adduction, varus, and equinus using an abduction maneuver was the next step, and must be simultaneous because tarsal joints have a strict mechanical interdependence and cannot sustain correction in isolation. During the abduction maneuver, thumb counterpressure on the talar head is applied to prevent its rotation in the ankle clamp [32].
- Correction of equinus deformity is the last step and requires 4-6 serial castings. Forced manipulation during equinus correction may precipitate the development of inkblot deformity because the Achilles tendon consists of thick, non-distensible collagen fibers with few cells; thus, tenotomy is required in approximately 90% of cases [32].

The French Functional Method (FFM):

The FFM is a conservative management involving daily physiotherapy sessions of stretching the triceps surae to enhance tibio-talar joint function, aiming for a gradual and painless correction. The FFM starts with talonavicular joint reduction, and then lateral de-rotation of the calcaneo-forefoot unit [34]. Several modifications were incorporated in the FFM protocol; percutaneous Achilles tenotomy is performed to improve the range of motion for patients who have tibio-talar dorsiflexion of $<10^\circ$ at walking age. Above-knee casts with semi-rigid tapes and night bracing for mild residual deformities to prevent recurrence. Additionally, supportive immobilization techniques are used to maintain the achieved correction between sessions [35].



Fig. (3): The initial correction step by the Ponseti approach for cavus correction. Quoted from [33].

The Hybrid Method:

Both the Ponseti and the FFM techniques provide highly efficient, reliable, and durable outcomes aimed to achieve a pain-free, flexible, and plantigrade foot while minimizing the need for surgical intervention. Regretfully, these techniques could not completely spare surgery for all cases [35]. The hybrid method integrated the serial-casting of the Ponseti method with the manipulative assessments of the FFM to achieve long-term correction with full foot functionality and pain-free mobility [19]. The surgical rate among newborns with congenital clubfoot treated between 2010 and 2014 was 8.7%, and dropped to 6% in the later cohort from 2015 to 2020 [36]. The hybrid method reduced the need for surgery and minimized the extent of surgical interventions, and the decrease in the surgical rate indicates growing experience with the hybrid method [18].

Follow-up after conservative management:

Follow-up care is pivotal for improving the outcomes of CF conservative management through monitoring growth with strict observation for the development of residual deformities or complications. Assessment of patient compliance with the applied protocol, and the correct use of orthoses and braces through scheduled follow-up appointments, is recommended [19].

A foot clinical assessment should include an evaluation of the overall foot morphology, the identification of any deformities, the mobility of the subtalar joint, plantar and dorsal flexion of the ankle, calf muscle atrophy, and the anatomical alignment of the lower limb. Functionally, the patient's ability to perform activities such as toe and heel walking, descending stairs, standing on one leg, rope jumping, and walking on uneven surfaces, and the presence and severity of abnormal gait [19].

Patients should be evaluated every 3 to 4 months, especially within the rapid growth phase of the foot, the first two years, to get early identification of relapses [37].

Relapse after Conservative Management:

Relapse is defined as the recurrence of clubfoot deformities in a patient after initial treatment and correction. It has been reported in more than 40% of patients treated with the Ponseti method. Equinus and/or adduction with or without dynamic supination are the most prevalent presentations of relapse [38]. The discomfort associated with braces or lack of cooperation from parents is the most common reason for poor compliance, particularly with brace wear, and is one of the most significant reasons for relapses [39]. Early stopping of brace use, the severity of clubfoot, soft tissue contractures, muscle imbalance, genetic predisposition, and undiagnosed neuromuscular conditions are also important factors [40].

The management of relapsed clubfoot is based on the clinical presentation, the severity of the relapse, previous treatment history, time interval since initiation of the conservative management, the method used for correction, the adherence to the follow-up instructions, and underlying risk factors [41]. Management of relapse ranges from non-operative interventions, such as brace wear, physiotherapy, and serial casting, to surgical options, including soft tissue releases, osteotomies, or tendon transfers [42].

Management of Relapsed CF Deformity:

Non-operative Management of relapsed CF deformity:

Recasting is a desirable approach for treating relapses after the Ponseti method that results in more flexibility and less stiffness in these feet than in feet

initially treated with surgery. The use of braces during nighttime is crucial after recasting is essential, considering that non-compliance with orthoses and braces is a major cause of relapse; educating parents about the importance of brace use and close follow-ups must be integral to the treatment plan [43].

Operative Management of relapsed CF deformity: Soft Tissue Release:

There are two surgical techniques used for soft tissue release: The a la Carte Procedure as a selective approach, only the tight structures that impede proper alignment are released to preserve as much functionality and mobility as possible [44]. The One-Size-Fits-All Procedure involves a complete soft tissue release through a circumferential incision, aiming to correct all aspects of the deformity in a single surgery. The a la carte procedure is usually preferred for its fewer postoperative complications over the one-size-fits-all procedure. Further, the a la carte procedure preserves greater muscle strength and provides better radiological outcomes [45].

Tibialis Anterior Tendon Transfer (TATT) is most frequently indicated for patients initially treated with the Ponseti method who have relapsed deformity exhibiting dynamic supination during the swing phase of gait. The optimal approach is to use casting to align the deformity, and then the foot is reassessed. If dorsiflexion without supination is achieved after casting, surgery might be omitted. If equinus contracture is present alongside dynamic supination, Achilles tendon lengthening or gastrocnemius recession may also be performed during surgery [43]. TATT is mostly indicated for stopping the use of the splint in children older than three years to guard against relapse if the lateral cuneiform is inadequately ossified, which increases the risk of relapse [46]. The recurrence rate after the TATT procedure is approximately 15% [43]. Comparison of three techniques for fixation of the transferred tibialis anterior tendon ensured the effectiveness of the three methods, but the suture anchor technique is the safest [47].

Achilles tenotomy is indicated for patients with equinus deformity unresponsive to casting, particularly in early relapses. The decision is age-dependent; for patients younger than two years, tenotomy is sufficient, while Z-plasty lengthening of the Achilles tendon is indicated for older patients. For patients presenting with cavus deformity, which can accentuate the appearance of equinus, casting is a useful option. If plantar fascia tightness persists despite casting, a plantar fascia release may be per-

formed during the tenotomy [45]. Achilles tendon lengthening and limited posterior release, followed by a reduced period of splinting of 2.1 years, provides similar results to the original Ponseti method but is advantageous for the reduced duration of casting [48].

Bony Osteotomies:

Midfoot Osteotomies are typically indicated for CF patients beyond the optimal age for soft tissue release or not old enough for arthrodesis, usually within the age range of 4 to 8 years, and exhibiting residual adduction deformity [49]. Hindfoot Osteotomies were applied for varus heel deformities, but had a high complication rate. Lateralization slide osteotomy is the commonly used approach to correct varus heel deformities in adolescents and young adults [50]. Supramalleolar Osteotomies might correct rigid deformities of the midfoot and hindfoot, wherever soft tissue interventions are not applicable [51].

Ilizarov Correction:

Severe and persistent clubfoot deformities require a combination of osteotomies and soft tissue release to facilitate a gradual correction using Ilizarov techniques into a plantigrade position [52]. Older children with rigid congenital CF deformity could be managed safely using the Ilizarov technique combined with limited soft tissue release or V-shaped osteotomy that resulted in significant orthopedic effectiveness [53].

Conclusion:

Conservative management is appropriate and effective, especially for selected cases. Generally, recurrent deformity after conservative treatment accounts for a high incidence rate. Additionally, surgical interventions are the last resort for management of relapsed cases and as initial management for severe and neglected cases.

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دراسة مراجعة : سرديّة للقدم الحنفاء

الخلفية: تشوه القدم الحنفاء عند الأطفال مجهول السبب هو يتمثل في تشوه عظمي يصيب الأطفال بنسبة عالية. وللأسف، فإن علاج تشوه القدم الحنفاء معقد، خاصة في الحالات الشديدة والمتأخرة.

الهدف من العمل: هدفت هذه الدراسة المراجعة السردية إلى استكشاف المقالات المنشورة بشأن تشوه القدم الحنفاء والخيارات العلاجية المتاحة.

المواد والطرق: بحث دقيق في المقالات المنشورة الحديثة باستخدام الكلمات الرئيسية المتعلقة بتشوه القدم الحنفاء. شمل البحث الحالي المقالات المنشورة منذ أواخر العشرينات. تم تقسيم البيانات المستخرجة بنفس ترتيب كلمات البحث المستخدمة.

النتائج: يُنصح بالعناية المبكرة بتشوه القدم الحنفاء للحصول على أفضل النتائج. التدبير التحفظي فعال ولكنه يحمل مخاطر عالية للانتكاس. يعد سوء الانتظام في ارتداء الدعامة سبباً رئيسياً للانتكاس. يعتبر تشخيص الانتكاس في الوقت المناسب أمراً بالغ الأهمية، كما أن علاجه إلزامي.

الاستنتاج: التدبير التحفظي مناسب وفعال، خاصة للحالات الخاصة. وبصفة عامة، يمثل التشوه المتكرر بعد العلاج التحفظي نسبة عالية من الحالات. بالإضافة إلى ذلك، فإن التدخلات الجراحية هي الحل الأخير لعلاج الحالات المنتكسة وكعلاج أولى للحالات الشديدة والمتأخرة.