

Review Article

Current conservative management and classification of club foot: A review

Ganesan Balasankar^a, Luximon Ameersing^{b,*} and Adel Al-Jumaily^a

^a*Department of FEIT, University of Technology Sydney, NSW, Australia*

^b*The Hong Kong Polytechnic University, Hong Kong, China*

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Abstract. Clubfoot, known as congenital talipes equinovarus, is one of the complex paediatric foot deformity with the incidence of 1 in every 1000 live births. It consists of four complex foot abnormalities such as forefoot adductus, midfoot cavus, and hindfoot varus and ankle equinus. There are a number of surgical techniques (soft tissue releases, arthrodesis) used to correct clubfoot. However currently the conservative management (manipulation, serial casting, and braces) of clubfoot is considered as the best choice and it is widely accepted among orthopaedists. Clubfoot treated with surgical techniques might suffer various complications such as soft tissues contractures, neurovascular complications, infections, and shortening of the limbs. Although conservative method is generally considered as an effective method, it is still challenging to cure clubfoot in advance stages. Also, the classification of the initial severity of clubfoot is essential to evaluate the outcome of the treatment. In this review, the aim is to review the different types of conservative method and the assessment of clubfoot severity.

Keywords: Clubfoot conservative management, clubfoot, Ponseti method, Copenhagen method, French functional or physiotherapist method

1. Introduction

Congenital talipes equinovarus (CTEV) is a complex foot deformity in children that affects 150,000–200,000 newborn babies every year around the world and eighty percentages of clubfoot occurring in developing countries [1]. It is characterized by the following four structural deformities in foot and ankle: midfoot cavus, forefoot adductus, hindfoot varus, and ankle equinus – CAVE [2] (Fig. 1). The structural deformities of clubfoot might be caused by the subluxation of talocalcaneonavicular joint, dislocation of talus bone, abnormalities of peroneus and calf muscles, and contractures of soft tissues on the medial

side of the foot [3–5]. Children with untreated clubfoot, also known as neglected clubfoot, will suffer in their daily life such as difficulties in gait pattern, mobility, daily living skills, and social activities. In addition, neglected clubfoot children walk on the dorsal side of the foot leading to complications such as callus formation, injuries, and infections on the dorsum of the foot [6]. For many years, there are a number of treatment methods either surgical or conservative procedures that have been proposed and debated to treat clubfoot. However, surgical methods have its own limitations due to post-surgical complications such as soft tissues contractures, neurovascular complications, infections, and shortening of the limbs. Recently, almost all of the orthopedicians agreed that the conservative treatment would be the best choice to correct the clubfoot. The goal of all conservative treatment methods is to obtain the plantigrade, pain-free

*Corresponding author: Luximon Ameersing, The Hong Kong Polytechnic University, Hong Kong, China. Tel.: +852 27666449; E-mail: tcshyam@polyu.edu.hk



Fig. 1. Clubfoot (Source and approved by [67]).

and functional foot without any mobility problems [7]. Initially, around 400 BC, Hippocrates discussed about the manipulation and casting in a medical literature. In this literature, he suggested that management of clubfoot should be started as early as possible after the birth with manipulation method [8]. Subsequently, in 1782, the first surgical procedure (subcutaneous tenotomy) was developed by Lorenz [9]. Followed by, in 1930s, Kite developed a gentle progressive manipulation and followed by plaster casting techniques. Then, in 1948, Ponseti developed his own method of manipulation and casting techniques after several years of observation of different conservative and surgical methods. It consists of weekly serial manipulations, casting, Achilles tendon tenotomy, and using foot abduction orthosis to avoid the recurrences of the clubfoot. Many of the researchers reported that Ponseti method achieved higher success rate than other conservative methods. Also, they reported that success rate of the conservative method for clubfoot is higher than surgical procedures [10–14]. Based on the literature review, many studies explain the use of Ponseti method more than other conservative methods. This study is an attempt to review the different types of conservative methods and its techniques, and the principles of those procedures for correction of clubfoot deformities. Also, this review tried to address the different method of classification and assessment of clubfoot.

2. Prevalence of clubfoot

The prevalence rate of clubfoot varies from 0.9 to 7 per 1000 live births in different populations [15–18]. The highest incidence of clubfoot occurs in the Polynesian population and lowest incidence in the Chinese population [15,19,20]. Most of the studies reported that the incidence of clubfoot is higher in male than in female (2:1), and this ratio is consistent in all ethnic population [2,6,21–25]. Fifty percentage of the cases

are either bilateral or unilateral clubfoot, and the involvement of right foot is higher than unilateral clubfoot [24].

2.1. Normal development of children foot

A basic knowledge of lower extremity development is essential to understand the infant's foot. Lower limb buds appear at the 4th weeks of the gestational period, and foot can be noted on the 4.5 weeks. At the 6 weeks, foot looks paddle shaped in an equinus and inverted position. Feet turns into equinus, and hindfoot, forefoot in a adducted position and notches is very clear between the toes during the 8 weeks. During 12th weeks of the prenatal period, the foot rotates into supinated position. All digits are well developed in the period of the 9th week, and 1st and 5th metatarsal head drop downward, and form the transverse arch of the foot. In addition, talus and calcaneus together are developing the subtalar joint. Moreover, tibia and fibula are articulated with the talus during this period. At the period between 13 to 16th weeks, lower extremity increases in size, foot equinus level decreases, and foot will be in a perpendicular position to the lower leg. Finally, 28th weeks, the foot will achieve the neutral position [26].

2.2. Anatomy and biomechanics of the clubfoot

Knowledge of foot anatomy and its biomechanics is helpful to identify and treat the foot deformities well. Biomechanically, clubfoot deformities occur due to abnormalities of the tarsal bones (talus, calcaneus, cuboid, and navicular), ligaments, joints, and atrophy of the calf muscles [27]. In the hindfoot region, due to the misalignment of the navicular, cuboid, calcaneus bone, it leads to medial displacement and inverted position in relation to the talus [28]. In addition to the medial displacement of bones, the hind foot turns into firm position, where the calcaneus and talus are in equines position; especially, head and neck of the talus is turned into severe planter flexion and medially displaced, and calcaneus medially rotated under the talus [29]. In some cases of clubfoot, the talus neck will be absent or shortened [30]. In the case of severe clubfoot deformity, the navicular bone will be displaced medially towards the head of the talus and it articulates with the medial side of the head of the talus [31–33]. Also, retraction and atrophy of calf muscles, the calcaneus bone will also be displaced into adducted and inverted position under the talus [13,34]. In the midfoot region, metatarsal joints are deformed and narrowed



Fig. 2. Anatomical dissection of clubfoot (Source and thanks to [62]).

and in the forefoot region, the forefoot turns towards to the other side of the foot with a supinated position. It is referred as forefoot adduction and supinated position of the clubfoot. In relation to the hindfoot, it is in a more supinated position than forefoot; it develops a cavus deformity at the forefoot with medial and posterior skin crease [13]. Based on the literature review, one of the anatomical dissection studies shows that talus and calcaneus are displaced into medially and develops varus deformity in the hind foot (Fig. 2). Moreover, soft tissue contractures will also develop on the posterior, medial side of the ankle and sub-talar joint region of the foot, it leads to shortening of the medial and posterior tarsal ligaments, and medial displacement of the tibialis posterior, flexor hallucis longus and flexor digitorum longus tendon occur. These contractures of the soft tissue structures limit the motion of the sub-talar joint [13,33]. Sometimes, there is a deficiency or absence of anterior tibial artery and dorsalis pedis artery in the clubfoot condition. One of the magnetic angiography studies revealed that diminished size of the peronial artery on the affected extremity of the leg [35].

3. Etiology

The causes of clubfoot are still not clearly known and it remains controversial. Previous studies have reported a number of theories to describe the causes of club foot. The causes of clubfoot are vascular, environmental, genetic, abnormal position in the utero, and anatomical factors [27]. Some of the studies have reported observed abnormalities in the intracellular structure of the muscles of the clubfoot [36]. Mostly clubfoot present as a birth defect (idiopathic congenital club foot), and around 20% of the clubfoot deformities are associated with other conditions such as arthrogryposis, myelodysplasia, Down syndrome,

Classification	Types/Features
Grade I	Benign: Reducible without any resistance
Grade II	Moderate: Reducible with certain degree of resistance
Grade III	Severe: Reducible with certain degree of resistance
Grade IV	Very severe: Not reducible

Larsen's Syndrome, freeman-Sheldon syndrome, and multiple congenital abnormalities [2,24,27,37]. Especially, club foot associated with distal arthrogryposis, meningomyelocele, and is considered a main etiological factor among the involvement of nervous system disorders [38]. In addition, the causes of clubfoot are also associated with some risk factors such as male gender, smoking during the maternal period, and diabetes on the maternal stage, maternal age, marital status, and parity [39].

3.1. Classification of clubfoot

Clubfoot can be classified into four types based on the causes and treatment responses: 1) Postural, 2) Idiopathic, 3) Neurogenic, 4) Syndromic. Generally, the postural clubfoot can be resolved by stretching and casting. Another type of clubfoot, called idiopathic clubfoot, is 'true' clubfoot and can be classified by various grades of severity. Neurogenic clubfoot is usually associated with neurological conditions such as spina bifida. Syndromic clubfoot are rigid type, and are associated with other anomalies [40]. Also, there are numbers of classification available to measure the severity of the clubfoot based on the physical aspects of the clubfoot such as Pirani score and Dimeglio scale [41,42]. Dimeglio et al. introduced clubfoot classification in 1995, and it is classified into four types: Grade I–Grade IV [43–46]. In this method, four types of parameters, in a sagittal and horizontal plane, has been used to measure the clubfoot severity: Sagittal plane – 1) evaluation of equinus; 2) evaluation of varus; and horizontal plane – 3) evaluation of derotation; 4) evaluation of forefoot adduction relative to the hindfoot. The each item of the scale starts from 0–4 points and maximum score is 20 points. It can also be graded as benign, moderate, severe, and very severe (Table 1 and Fig. 3). Another method of classification of clubfoot severity is, Pirani scoring system, which is commonly used to assess the severity, and progress of clubfoot treatment by Ponseti method. It is a simple scoring system based on the physical appearance of the foot, and it consist of 3 clinical signs in the hindfoot (three

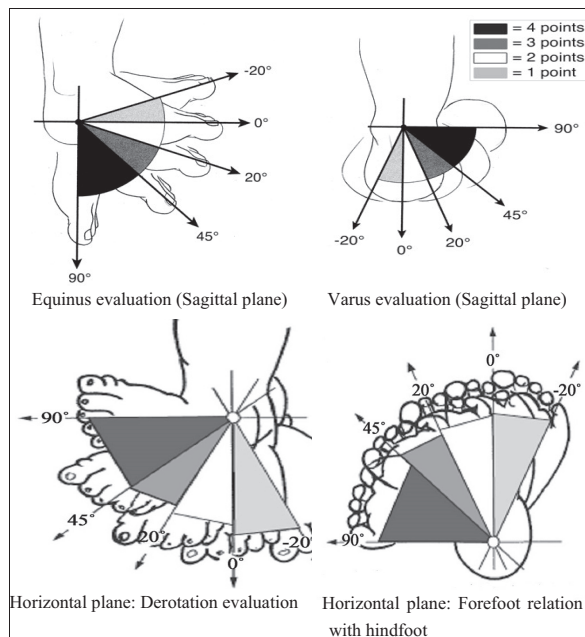


Fig. 3. Dimeglio et al. clubfoot classification system (Source and thanks to [63]).

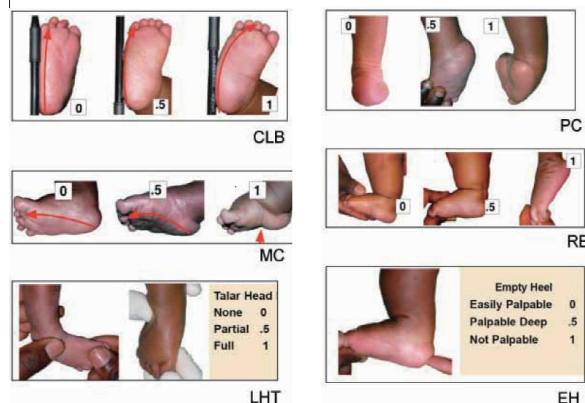


Fig. 4. Pirani Scoring system (Source and approved by [62]).

morphological changes sign: posterior crease, emptiness of the heel, rigid equinus) and 3 clinical signs in the midfoot (three morphological changes signs: lateral curvature of the foot, medial crease, position of the head of the talus on the lateral border (Fig. 4). The maximum score will be one for each item of the scale (0-normal, 0.5-mildly abnormal, 1-severe abnormal), and the total score is six [42].

3.2. Management of clubfoot

Clubfoot can be corrected by either conservative or surgical methods [46]. Historically, in 400 BC,

the conservative management of clubfoot with manipulation and immobilization techniques was introduced by Hippocrates. Based on Hippocrates's principles of clubfoot management, there are number of conservative methods (Kite method, French method, Ponseti method – “manipulation, casting, tenotomy, foot abduction brace”, other physical methods such as kinesio-therapy, thermo-therapy, electro-therapy, splinting, shoe modification and orthotic devices) developed recently to correct clubfoot [6,47]. In 1930s, at first, Dr. Kite developed a conservative method for treating clubfoot after facing poor results of surgical method [48,49]. In this method, the correction of clubfoot deformity components (adductus, varus, and equinus) was performed separately with progressive manipulation and serial casting [5,50]. Especially, correction of heel varus was performed by everting the calcaneus. In this method, when performing the manipulation, midfoot was used as fulcrum and pressure was applied on the calcaneo-cuboid joint (mid-tarsal joint area) to abduct the foot. The adducted deformity is corrected by foot abduction with applying pressure on the calcaneo-cuboid joint, and eversion of the hindfoot, which is done by casting or edges, used to correct the varus deformity of the foot. Finally, the equinus deformities will be corrected by progressive dorsiflexion of the foot after correction of other components [33]. In addition, night splint has been used to maintain the foot in dorsiflexion and mild abducted position to avoid the recurrences of the clubfoot. Initially, Kite reported that this method was successful in correcting the clubfoot however other researchers did not achieve the successful correction as mentioned by Dr. Kite [51,52]. In addition, one of the previous studies reported that approximately ninety percentages of the cases required surgical and soft releases in Kite's method [53,54]. Poor success rate of the Kite methods may be because of inaccurate method of manipulation, and below knee or short leg casting. Generally, short leg or below knee casting has disadvantages because it will not provide adequate position to maintain the corrected clubfoot [6,54]. At the same time, in this method, it will also make some complications due to inaccurate manipulation such as rocker bottom feet, subluxation of the navicular bone, rigidity of ligaments and capsule, torsion of the ankle (lateral side) and talar body [13].

Initially, the conservative management failed due to the poor understanding of functional anatomy of clubfoot. However, clubfoot has been treated by conservative methods for more than 40 years. Later, due to the



Fig. 5. Stages of casting intervention (Source and thanks to: [42]).

development of advanced surgical procedures, clubfoot was successfully corrected by “posteromedial release” techniques at the age of one year. Then, for the past decade, conservative treatment such as Ponseti method achieved high success rate due to the understanding of the functional anatomy of the clubfoot as compared to the surgical methods [2]. Recently, most of the studies stated that Ponseti method is considered as more effective method to correct the clubfoot without further complications such as stiffness and pain [55].

4. Current conservative methods for clubfoot

4.1. Ponseti method

Over the past decade, conservative management has been widely used to correct the clubfoot deformity than surgical management. Ponseti method consists of weekly gentle manipulation and followed by application of serial long leg casting [56]. In this method, casting should be changed every 5 to 7 days (Fig. 5). Before the final casting, if there is still equinus deformity persists, Achilles tendon percutaneous tenotomy should be done to correct the equinus deformity fully. Approximately ninety percent of the cases requires tenotomy. Then, the foot will be immobilized for 21 days with 60° abduction and maximum dorsiflexion [42,56,57]. Once the clubfoot is corrected, the child needs to wear full-time foot abduction brace for twelve weeks (23 hours per day). After 3 months, foot abduction brace are used at night and nap time until the age of four to prevent the relapse of club foot. Foot abduction orthosis or brace are used after the foot achieves about 60°–70° abduction and 20° dorsiflexion range of motion. The goal of treatment of Ponseti method aims to correct four basic deformities: ankle equinus, hindfoot varus, forefoot adductus and

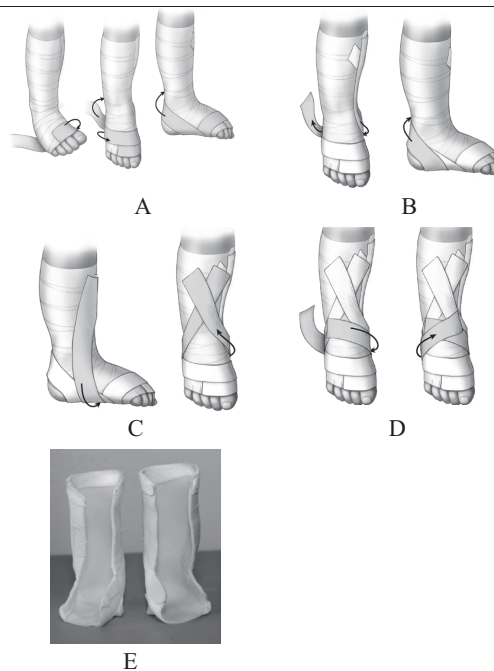


Fig. 6. A–D: Steps of taping techniques. E: Ankle foot orthosis (Source and thanks to: [58] – Picture is adapted and formatted).

cavus. Initially, during the application of the first casting, cavus deformity is corrected by supination of the forefoot with providing pressure in the first metatarsal head of the forefoot. Mostly, the cavus deformity correction will be achieved in the first casting. During the next 3 or 4 casting application, simultaneously adduction and varus, equinus deformity will be corrected by providing counter pressure on the talar head with positioning the foot in the abduction and external rotation [42,57].

4.2. French functional or physiotherapist method

The principle of French functional conservative method stated that clubfoot deformity occurs due to the contracture of the following foot structures: tendon of the posterior tibialis muscles and fibrotic tissues, weakness of peroneus longus and peroneus previous muscles, and deviation of mid-tarsal joints. Therefore, this method is mainly focused on stretching of medial side of the foot. In this method, treatment techniques such as stretching, daily corrective manipulations have been used to correct the deformity. The corrected foot are maintained by elastic taping and splints until the next day of treatment as shown in Fig. 6 [58]. The total duration of treatment is 1–3 months, and therapist sees the patients five days per week. Then, the

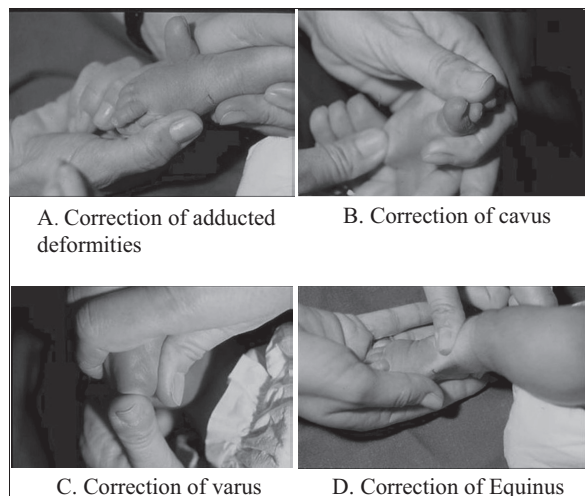


Fig. 7. Manipulation of clubfoot by Copenhagen method (Thanks to [47]).

family members need to help the child to do the exercise regularly at home. This method has two phases of treatment: corrective phase and maintenance phase. Corrective phases of the treatments include calf massage, forefoot stretch, distraction, derotation, stimulation of evertors, hindfoot valgus, and dorsiflexion. In the maintenance phase, splints are used to maintain the correction [58].

4.3. Copenhagen method

In 1976, another conservative clubfoot treatment technique, Copenhagen method was developed in Copenhagen orthopaedic hospital. The following technique has been used to treat the clubfoot problems: flexion and manipulation, stimulation of muscles of the foot, using plaster of cast. These techniques need to be practiced daily until the foot become as 'normal' and it might be achieved in 6 weeks period of treatment [59]. The corrected foot are maintained by bandage instead of using braces until the child gets to start to walk. Also, the corrected clubfoot is inspected periodically until the skeletal maturity [47,59]. According to the modified Copenhagen method, to correct the clubfoot adduction, varus, and cavus deformities, the following principles of "correction rule" is applied in a sequential order: correcting the adducted deformity first, then other deformities such as cavus, varus, and equinus are performed.

The adducted deformity is corrected by holding hind foot by one hand, and the tibial epiphysis and cuboid bone should be between the index finger and thumb

of the same hand. Subsequently, the forefoot adduction is corrected by distraction movement applied by the thumb of another hand on the first metatarsophalangeal joint (Fig. 7A). Cavus is corrected by supination of forefoot while performing the dorsiflexion motion at the first metatarsal area of the foot (Fig. 7B). The varus deformity is corrected by holding the heel of the feet (posterior side) by one hand, and pressure provided on the neck of the talus bone to push the inwards while thumb of the same hand used to give pressure on the calcaneal bone towards outside. At the same time, pressure is applied to the metatarsal bones (sole of the foot) by using another hand to obtain the everted position of the forefoot (Fig. 7C). Equinus deformity correction is achieved by gentle traction of Achilles tendon by one hand while performing dorsiflexion of the forefoot by another hand (Fig. 7D) [47,60]. Finally, lateral side of the muscles (Peroneal muscles and anterolateral area of the foot) will be stimulated by brush after the manipulation of the foot [47]. Once the clubfoot is corrected, Larsen Active T splint are used to maintain the foot until 7 to 8 months, after that it is used at night time. At the same time, this method recommends regularly exercises 5 times per day.

5. Discussion

Although there are a number of conservative method used to treat the clubfoot problems, the outcome varies from one method to another. The purpose of this review was aimed to provide the various method of conservative treatment and classification the of clubfoot severity to predict the outcome of the intervention. Previous studies have reported that clubfoot can be treated by less casting and duration by Ponseti method compared to other method to achieve the full correction of the clubfoot with good mobility of the foot [61]. The manipulation and casting techniques were described in both Kite method and Ponseti method, however the success rate varied about ten to eighty percentages in Kite method. Serial casting has been followed as stretching techniques in the both method to achieve normal and functional foot but it differs in their manipulation techniques. Forty two years of experience of Ponseti, he stated that he achieved ninety percentages of successful outcomes of clubfoot correction by practicing his own regime method. Ponseti method is mostly used in USA, some part of Europe and developing countries such as India and Bangladesh. Ponseti method is widely used in the developing and de-

veloped countries, with the ninety percentages of successful correction rates, while those who used Kite method have stated that fifty percentages of the cases required surgical correction and around forty percentages persisted with residual deformity [33]. In contrast, one of the author reported that they achieved successful correction of clubfoot but they performed about ninety one percentages of percutaneous tenotomy of the Achilles tendon in their study [12]. Another study, Morcuende et al., stated that they performed Achilles tenotomy in the eighty six percentages of the cases to obtain the stated correction [65]. Other method, French functional physiotherapy method is also practiced in some centres of America and Europe. Few studies have reported that French functional physical therapy method is equally effective as the Ponseti method. In addition, one of the studies have reported that French functional physical therapy and Ponseti method achieved about ninety percentages of successful outcomes in the initial correction of the clubfoot. Though, thirty-seven percentage of relapses occurred in the Ponseti method and twenty nine percentages in the French functional physiotherapy method in the follow-up [66]. Very few studies reported and published about Copenhagen method as a conservative method for clubfoot correction. Peroneal muscle stimulation was performed in this method to strengthen the hypotonic muscles in addition to the physical manipulation and physical therapy exercises. In their studies, the author has reported that thirty-four percentages of feet did not require any surgeries and sixty percentage had posterior release, and two percentage had tenotomy of the Achilles tendon [47]. In conclusion, this literature review discussed several conservative methods of clubfoot treatment such as Kite method, Ponseti method, French physical therapy method, and Copenhagen method. After several decades of debates of surgical treatment for clubfoot, now-a-days, conservative management, especially Ponseti method, has been considered as best choice for clubfoot treatment in terms of low cost, low technology and effective outcome. However, further research is required to reduce the relapses rate by considering the combination approaches of casting, physical therapy, and stimulation of hypotonic muscles.

Conflict of interest

The authors have no conflict of interest to report.

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