Current Concepts Review

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Treatment of relapsed, residual and neglected clubfoot: adjunctive surgery

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Abstract

Over the past two decades, the Ponseti 'conservative' (non-surgical) method of clubfoot treatment has been almost universally adopted worldwide. As a result, the need for operative treatment for clubfoot has decreased dramatically. However, even Ponseti himself routinely used surgery for certain patients: at least 90% of feet need percutaneous tenotomy, and 15% to 40% may require tibialis anterior tendon transfer. Additionally, relapses are common, sometimes necessitating further surgical intervention. Relapses are recurrent deformities in previously well corrected feet. Residual deformities may be defined as persistent deformities in incompletely corrected feet. In addition, in many parts of the developing world, neglected clubfoot is still a major challenge. Many neglected feet can be treated with Ponseti principles, particularly in younger children. However, in older children and adults, surgical approaches are more likely to be needed. Major reasons for relapsed/residual clubfoot include incomplete application of the Ponseti principles, inability to adhere to the foot abduction brace protocol, failure to recommend a complete course of bracing and inadequate follow-up. Sometimes, despite excellent treatment, and perfect adherence to the bracing protocols, there are still relapses, related to intrinsic muscle imbalance. We describe several solutions that include reinstitution of Ponseti casting and 'á la carte' operative treatment. As an alternative for particularly stubborn cases, application of a hexapod external fixator can be a powerful tool. In order to be a full-service clubfoot specialist, and not only a Ponseti practitioner, one must have in their toolbox the full gamut of adjunctive surgical options.

Level of Evidence: V

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Introduction

Since ancient times, the initial treatment of congenital idiopathic clubfoot has been manipulations and strapping, eventually replaced by casting.[1] Prolonged casting followed by extensive soft-tissue releases became the mainstay of treatment in the latter half of the 20th century.[1,2] However, many feet that underwent extensive soft-tissue release suffered from deep scarring, joint stiffness and muscle weakness.[2-5] For many years, nonoperative treatment of idiopathic clubfoot was successful only for the mildest deformities. A revival of nonoperative treatment took place in the beginning of the 21st century, when the Ponseti method became popular. Ironically, Ponseti had described and used his technique for nearly 40 years before it actually started to spread worldwide. Nearly all feet that were treated using the Ponseti method became functional, pain-free, normal looking and mobile; all without the need for extensive operative treatment.[3-10] Results of the Ponseti treatment became self-evident, which led to its wide adoption. In 1963, Ponseti described that 71% of patients had good results, while 28% remained with slight residual deformity.[3] In his later work he described a success rate of 85% to 90%.[5,6] Herzenberg et al[7] found that 96% of children avoided open soft-tissue release. With 30 years follow-up following Ponseti treatment, Cooper and Dietz[8] found that 78% of patients treated with the Ponseti method for idiopathic congenital clubfoot had excellent or good functional and clinical outcomes, compared with 85% of aged matched controls. While the Ponseti method is often described as 'nonoperative' or 'conservative', even the most ardent Ponseti loyalist will admit that some surgery is often required: tenotomy (~90%), tibialis anterior tendon transfer (TATT) (~15% to 40%) and also repeat tendo Achilles lengthening (TAL) and sometimes plantar fasciotomy for certain relapses. However, it is the hypothesis of this paper, that the Ponseti practitioner in the field need not restrict his/her surgical options to these few listed procedures. Indeed, a wide array of surgical

procedures may need to be called upon to solve vexing, stubborn problems in previously Ponseti-treated feet.

Despite the excellent results now widely documented as being reproduced worldwide, the problem of relapses remains problematic. A 'relapse' can be defined as recurrence of deformity in a previously well-corrected foot. This is distinguished from a 'residual' clubfoot, in which the foot was never fully corrected, but rather partially corrected, hence the term residual. Finally, for the foot (in older patients) that was never treated at all, we refer to this situation as a 'neglected' clubfoot.

Relapses following Ponseti treatment still occur for several reasons. Nosologically, we divide all relapses into three groups: early relapse (from six months to 30 months), relapse in older children (between 30 months and eight years) and relapse in adolescents (9 years and older).

Early relapse group

The basic Ponseti protocol consists of weekly casting for four to eight weeks, depending on how rapidly the foot responds, Achilles tenotomy and additional casting for three weeks (~90%), followed by the foot abduction brace (FAB) protocol full time for three months, followed by nighttime/nap bracing for up to age four to six years. From the moment that the last cast is removed and the FAB begun (typically nine to 12 weeks of age), the parents become responsible for the continuation of treatment. Noncompliance with the FAB leads to relapse, the signs of which include progressive loss of dorsiflexion, with the foot slipping out of the FAB as a result. Hence, it is important for the clinician to measure and document dorsiflexion when the last cast is removed and during subsequent visits.

For success of the treatment, the parents' education is crucial. Frequent follow-ups are also very important. Parents must understand that relapses are directly related with noncompliance with the FAB. In 2004, Morcuende et al[9] found that relapses occurred in 11% of cases. In nearly all patients, FAB noncompliance was the reason for relapses. In case of early loss of dorsiflexion, it is recommended to repeat a short course of casting to regain correction, followed by reinstitution of the FAB. Repeated casting generally restores the correct alignment of the foot. It is important to re-emphasize to the parents the need for the FAB. It is incumbent on the clinician to explore with the parent what, if any, barriers exist to their use of the FAB. In this patient population of early relapses, extra time needs to be spent by the physician and physician extenders to educate the family, to identify barriers to adherence and to propose solutions to overcome those barriers.

In rare situations when relapses are diagnosed relatively late (after 12 months), and an attempt to achieve more than 10° of dorsiflexion with casting has not been not successful, repeated Achilles tenotomy should be considered. We do not recommend a repeat tenotomy in the clinic environment. Instead, repeat tenotomy should take place in the operating theatre, as a mini-open procedure, under general anaesthesia, as the tendon may be scarred, and is in dangerously close proximity to the posterior tibial neurovascular bundle. Indeed, we have seen neuromas in continuity (of the posterior tibial nerve) from overly aggressive percutaneous tenotomies. It can be sobering to see how close in proximity the posterior tibial neurovascular bundle can be to a previously tenotomized Achilles tendon.

In addition to a TAL, there may be forefoot equinus (cavus) contributing to the overall appearance of equinus. In such cases, the plantar fascia will feel tight under forced dorsiflexion. A stressed lateral dorsiflexion view of the foot, or standing view of the foot, will show an increased Meary angle, which should normally be 0°. Plantar fasciotomy followed by serial casting using the so-called Ponseti II manoeuvre (upward pushing on the metatarsal heads with counter pressure on the dorsum of the neck of the talus) can help in this situation. For milder cases, it is enough to cut the superficial plantar fascia in the arch of the foot. In more severe cases, a proximal transection of the entire origin of the short flexors of the foot off the calcaneus (Steindler stripping) can help decrease the cavus.

In walking age children, equinus can be a sign of relapse, along with hindfoot varus and supination due to over-activity of the tibialis anterior tendon.[10] In the majority of relapsed feet younger than 2.5 years, recasting using Ponseti principles is usually sufficient to restore the correction. The goal of recasting is to regain the 60° to 70° of thigh foot angle which was achieved in the initial treatment, and also to get maximum dorsiflexion. Once again, it is imperative to reinstitute a vigorous FAB programme to maintain the correction achieved. Relapses should be considered as 'teachable moments', to help emphasize the importance of FAB to the parents.

Late relapse group

Distinct from the early relapse group, there are children who present with relapses in the 2.5- to eight-year-old period. Many children in this group stopped FAB use, had atypical clubfoot or were lost to follow-up (Fig. 1). Relapses in this group range from mild dynamic forefoot supination during walking, all the way to multiple components of clubfoot deformity (cavus, adductus, varus and equinus). Ponseti recommended TATT in children over 2.5 years, with transfer of the tendon to third (lateral) cuneiform. If the foot is supple and passively correctable, then no preoperative casting is required. However, the

Fig. 1 (a) Four-year-old boy with relapsed clubfoot, lost to follow-up and noncompliant with foot abduction brace (printed with permission); **(b)** foot after four Ponseti casts and before tibialis anterior transfer.

majority of children who present in this age group with relapses have stiff feet that are not fully passively correctable. They require preoperative Ponseti serial casting (ideally long-leg casts) to regain correction. No tendon transfer is capable of correcting a non-passively correctible foot. Tendon transfers are only capable of maintaining correction. Therefore, the goal is to first *obtain* correction with casting, and then *maintain* this correction with the tendon transfer. In all children with stiff deformities, casting should be done first (Fig. 1). The majority of these patients also have loss of dorsiflexion, requiring TAL or gastrocsoleus recession, in addition to TATT. No consensus exists regarding the use of the FAB after TATT, though we believe it should be encouraged. Some surgeons regard the TATT as a 'biologic brace'. Most children probably do not use the FAB after tendon transfer. In cases where the preoperative casting does not achieve a passively correctable foot, then other methods must be considered: open release, osteotomy or gradual distraction with an external fixator. TATT for relapsed feet has been well described in many publications.

When doing the TAL for relapses in this 2.5- to eight-year-old group, many children will not show any improvement in their equinus following a TAL. Therefore, the authors recommend intraoperative stress lateral dorsiflexion views of the foot/ankle before and after making the open 'Z' cut in the Achilles tendon. If there is no improvement, then the surgeon should consider immediately proceeding to a formal open ankle and/or subtalar arthrotomy. This requires careful anatomical dissection under loupe magnification and tourniquet control, identifying in order, the peroneals, flexor hallucis longus (FHL), neurovascular bundle and flexor digitorum longus (FDL). Once these structures are exposed and retracted, the posterior capsulotomy can be done. This capsular release begins laterally from the deep peroneal tendon sheath and posterolateral corner, headed medially to the deltoid, stopping at the FDL tendon sheath. If required, the subtalar joint is released from the posterolateral corner to the FHL tendon sheath.

If posterior arthrotomy is necessary, then it may be unadvisable to also do a TATT at the same sitting. This is because the TATT requires immobilization for six weeks, while the open posterior arthrotomy should be mobilized at three weeks to prevent stiffness. For this reason, we advise starting (if needed) with the TAL, then proceeding, if necessary, to the posterior ankle release and postponing the TATT for another sitting. If the TAL is adequate, and no capsulotomy is needed, then a TATT can be done simultaneously. It has been shown that ankle range of movement (ROM) achieved after capsulotomy is preserved, provided that the foot is immobilized for less than one month, and physiotherapy instituted early.[11]

In more severe relapse cases, a full, classic posteromedial soft-tissue release might be required. However, we prefer not to use extensive soft tissue release, because it may lead to deep scaring, muscle weakness and permanent foot stiffness. The exception may be for the initially very stiff, arthrogrypotic foot, in which overall stiffness is the norm. If preoperative casting, TATT and lengthening

of gastrocsoleus are not successful, or not an option, then we may consider soft-tissue distraction with a hexapod external fixator to correct rigid deformities. Usually patients that need external fixation are relatively older and have rigid feet. Most of them have non-idiopathic clubfoot. Ilizarov principles of foot correction in children are based on soft-tissue distraction in children less than about eight years of age, and various hindfoot/tarsal/supramalleolar osteotomies with gradual correction of deformities in older children.[12-14]

Many authors have used classic circular Ilizarov style frames for soft-tissue distraction or modifications such as the Joshi fixator. We prefer computer-guided hexapod correction. The original hexapod frame widely available in the United States and Europe was the Taylor Spatial Frame (TSF) (Smith & Nephew, Memphis, Tennessee), so we coined the term 'Ponse-Taylor method' of clubfoot correction, in dual homage to Dr Taylor (fixator) and Dr Ponseti (sequential method of clubfoot correction) (Figs 2 to 4).

The Ponse-Taylor method of correction is a specific soft-tissue distraction method that attempts to recapitulate the Ponseti sequence, composed of two stages. The first stage includes correction of internal torsion and hindfoot varus. In order to allow foot derotation, a talar olive wire is at this stage attached to the proximal ring (Fig. 2). It is important to programme some lengthening to distract the joints during this process. Once the foot has been derotated through the subtalar joint, the second stage can begin. The second stage recapitulates the Ponseti 'tenotomy' to gain dorsiflexion. First, the talar wire must be disconnected from the tibial ring, and repositioned and tensioned onto the foot ring, so that the talus can dorsiflex together with the entire foot. This manipulation of the frame is typically done in the operating room under anaesthesia, but in an insensate foot (e.g. myelodysplasia)

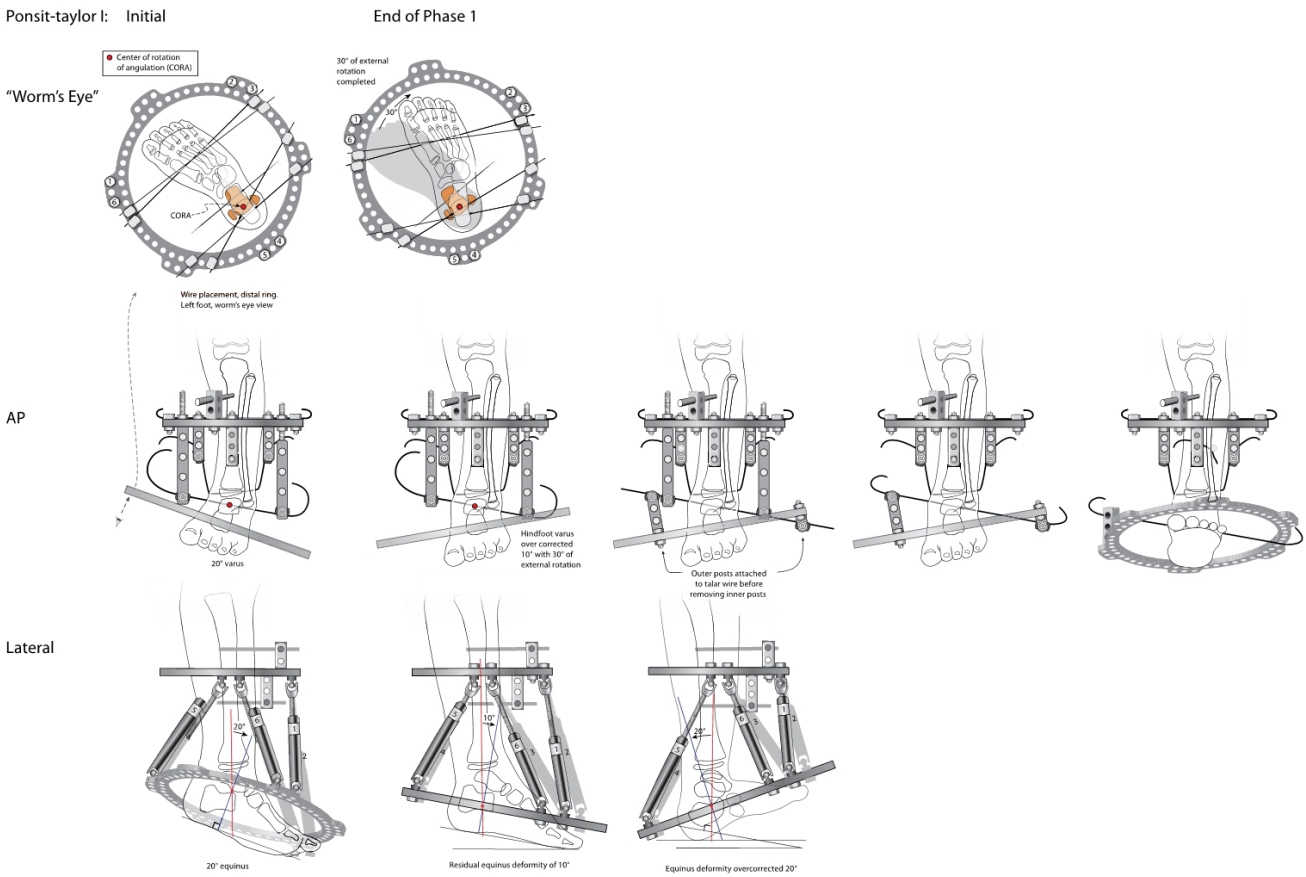

Fig. 2 The 'Ponse-Taylor' hexapod strategy to correct residual/relapsed clubfoot (used with permission, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore). Worm's eye view: before and after derotation to correct the internal spin through the subtalar joint. Anteroposterior (AP) view: during the initial varus to valgus correction and derotation, the talar neck wire is attached to the tibial ring with step down plates, to focus the correction through the subtalar joint. Next the talar neck wire is transferred to the foot ring, and then the equinus correction is focused on the ankle joint. Lateral view: the gradual correction of the equinus to neutral, and then additional over correction into approximately 20° dorsiflexion, anticipating some rebound.

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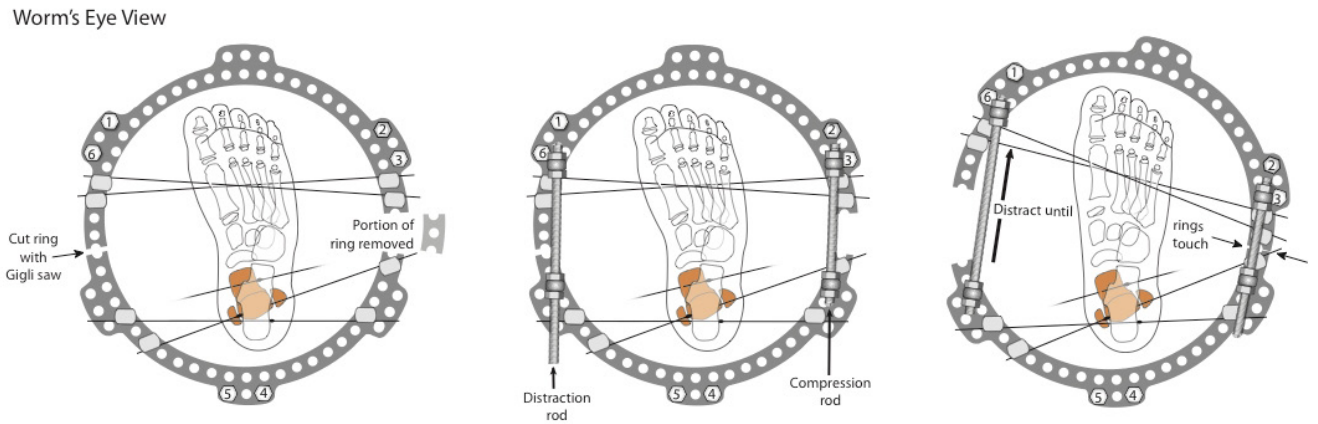

Fig. 3 Ponse-Taylor II: used for cases in which there is also a forefoot adductus or cavus (used with permission, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore). This is the last step, after the internal rotation, varus and hindfoot equinus have been corrected. The foot ring is cut on both sides, removing a segment from the lateral side in order to allow the cut ends to shorten. Threaded rods are applied over one-hole posts to act as a distractor on the medial side, and to allow compression (neutralization) on the lateral side, to correct adductus. For pure cavus, both sides may be distracted.

it can be done in the clinic. The next step is to programme dorsiflexion above the neutral position. We recommend going to at least 20° above neutral, to avoid rebound equinus. Adding 5 mm of length in the programme prevents joint compression (Fig. 2). The foot is held in the corrected position for four to six weeks, and the frame is then removed, and splints applied. Postoperative physiotherapy and splinting is recommended. For feet that include forefoot adductus or cavus, then a third stage can be added (Fig. 3) in which the foot ring is cut medially, and a segment of the foot ring is removed laterally. The rents in the ring are bridged by threaded rods suspended off one-hole posts and used to distract medially and compress laterally (for adductus) or to distract on both sides (for cavus).

Adolescent group

Many patients in this group are from the 'pre-Ponseti' era and were treated in the past with various methods. They usually have significant rigid deformities.

Thanks to the worldwide spread of the Ponseti method, relapses in this age group nowadays are uncommon. Most of the patients in this group have loss of dorsiflexion and residual supination due to overactivity of the tibialis anterior. These patients might be treated as in the younger group with recasting, tibialis anterior transfer and lengthening of the Achilles tendon or gastrocsoleus complex. However, some patients that came after loss of follow-up can present with all the components of severe clubfoot.

In older children and adolescents with significant and rigid deformities, we prefer osteotomies and gradual correction using a hexapod frame. Most of these patients already had at least one soft-tissue release, therefore, there is little hope that another soft-tissue release will dramatically improve the situation.[15,16] Although the classic Ilizarov frame is still a popular and powerful solution for deformity correction in clubfoot,[17] it requires frequent frame adjustments, building multiple hinges for multiplanar correction, and requires years of experience for mastering the method.[15,17,18] Our preferred hexapod is the TSF.[18] The TSF is a circular frame that uses a virtual hinge that allows correction of six-axis deformities simultaneously.

A variety of TSF foot frames for correction of different types of foot deformities are available today. We use two types of frames:

1. Standard frame configuration that consists of two rings connected with six struts. This mode is our preferred option for the Ponse-Taylor method and equinus correction in younger children (Figs 2 and 3).
2. The Butt frame (Fig. 4) consists of a vertically aligned U-plate on the foot connected to standard rings over the tibia and the forefoot. This configuration allows correction of midfoot and forefoot deformities alone or in combination with corrections of more proximal (supramalleolar) level. We found that the most effective osteotomy is percutaneous midfoot osteotomy using a Gigli saw through cuneiforms and cuboid bones.

The Gigli saw is ideal for correction of midfoot deformities using external fixation: completion of the osteotomy

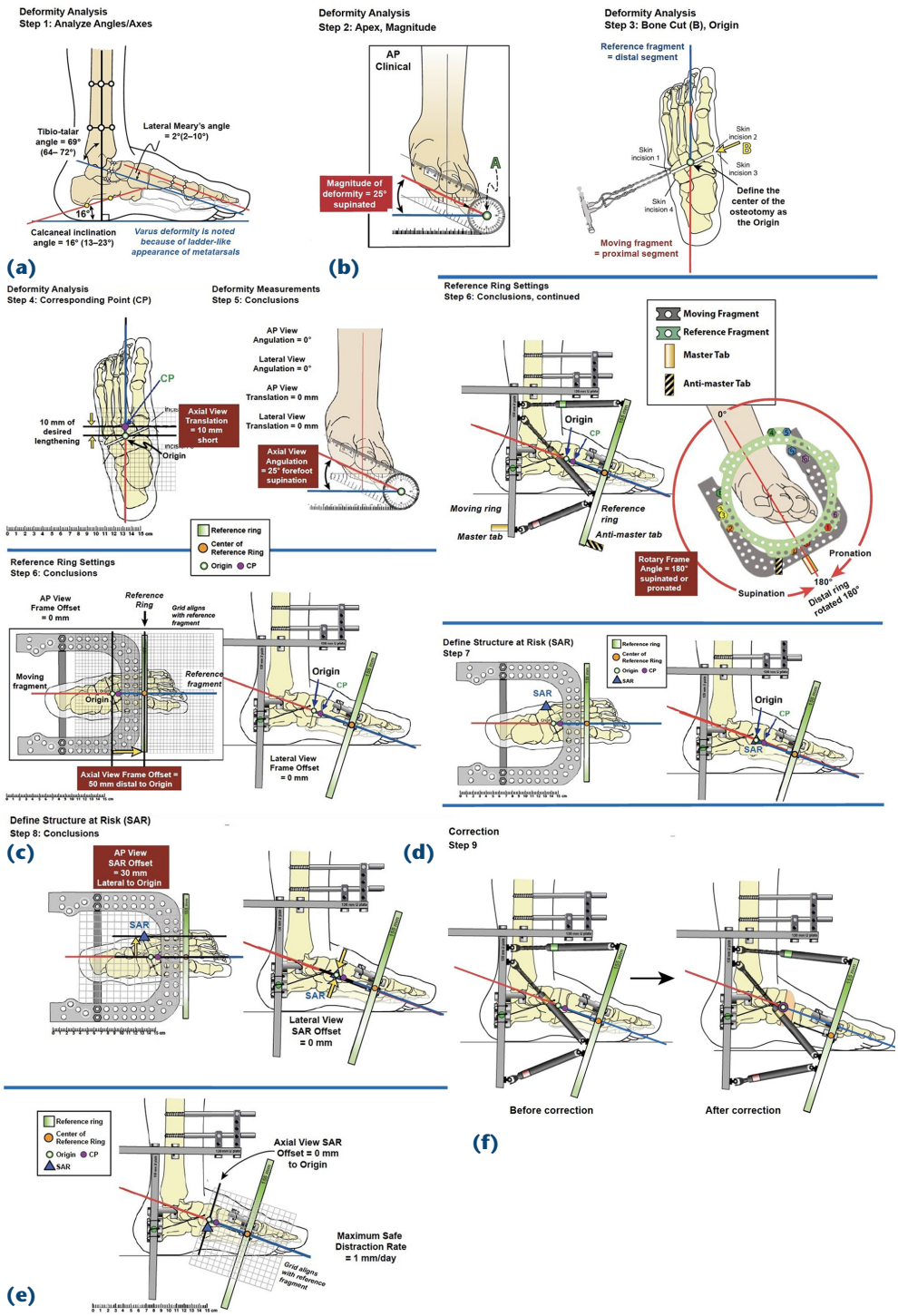

Fig. 4 Hexapod 'Butt' frame to correct residual forefoot supinatus/adductus. This assumes that the hindfoot is well aligned (neutral) (used with permission, Rubin Institute for Advanced Orthopedics, Sinai Hospital of Baltimore): **(a)** lateral view of foot showing normal hindfoot orientation, but supinatus of the forefoot; **(b)** anteroposterior (AP) view of foot demonstrates forefoot supinatus. Percutaneous Gigli saw cut through the cuneiforms and cuboid; **(c)** the forefoot is designated as the reference segment, and the (green) ring applied perpendicular to that segment but rotated to reflect the supinatus (25°). The designated origin and corresponding point which are about 10 mm apart to permit disengagement of the osteotomy, to make it easier to rotate, can correct the deformity; **(d)** the forefoot is the reference segment, so it is depicted parallel to the floor, and the rest of foot (the proximal portion) is offset in an angular fashion. The structure at risk (SAR) is shown as the lateral edge of the osteotomy which is the farthest point from the centre of rotation (middle of the foot); **(e)** the offsets of the SAR are shown measured on the different views; **(f)** lateral view of the foot before and after correction. The foot is initially supinated, and then flat.

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should be performed before applying the frame, as it is much easier to accomplish the osteotomy without the interference of the frame. The surrounding ligaments provide stability of the osteotomy during frame application. When using a Butt frame, supination, cavus and forefoot adduction can be effectively corrected. This is relatively easy frame to apply. The disadvantage of this frame is the inability to simultaneously perform correction of any hindfoot varus or equinus. In the presence of a hindfoot varus, a calcaneal shift osteotomy (Dwyer) may be done simultaneously or as a secondary procedure.[15]

After completion of correction we are using cast immobilization for six weeks, followed by ankle-foot orthosis (AFO) bracing. Frequent follow-ups are needed to monitor for recurrences.

Neglected clubfoot

Neglected clubfoot by definition is untreated equino-cavo-adducto-varus in older children, adolescents or even adults (Fig. 5). Untreated severe clubfoot rarely exists today in developed countries, except in some migrants from low- and middle-income countries (LMIC). However, in LMIC countries where there is incomplete access to modern medical care, as many as 50% of children worldwide with clubfeet receive no treatment.[19] The feet look bizarre with forefoot pronation, adduction of the midfoot, varus/inversion of the hindfoot and the ankle is in fixed severe plantar flexion (equinus). Children and adolescents are unable to wear normal shoes and have functional problems. Nonetheless, treatment of children less than ten years old may still start with a regular Ponseti protocol, as many of these previously untouched feet can be surprisingly supple. Despite some success achieved with this type of late casting, the majority of patients in this group will need some kind of operative intervention. Success of treatment is inversely proportional to the age at the time of treatment.[20] The first line of treatment should be a course of casting independent of the severity and age.[21] External fixation using a hexapod Miter frame that may simultaneously correct all components of clubfoot deformities might be an effective solution. However, this is a very sophisticated and technically demanding frame (Fig. 6), which may particularly be unavailable in LMIC situations.

In severe neglected clubfoot in older children, a modified triple arthrodesis has also described. Penny[22] spent many years treating neglected clubfoot in Uganda. He recommended a modification of modified Lambrinudi triple arthrodesis that may correct the most severe clubfoot deformities (Fig. 5c). In our experience, even this procedure can be challenging in cases of severe hindfoot equinus to gain a full correction. Feet treated with Penny's procedure often have small residual deformities but are generally much more serviceable than the neglected state.

Adjunctive procedures (soft tissue)

Adjunctive procedures can be divided into soft-tissue and bone procedures (Tables 1 and 2). As previously described, one can do a TAL with or without posterior ankle capsulotomy. The primary indication is for hindfoot equinus but it should be mentioned that hindfoot varus is often also simultaneously corrected by allowing dorsiflexion. The normal ROM of the ankle and subtalar complex goes from 'down and in' (equinus and varus) to 'up and out' (dorsiflexion and valgus) because these movements are linked.

Equinus is a clinical description in which the foot is pointed downward. In fact, there can be isolated equinus of the hindfoot, the forefoot or they can be combined. Equinus of the forefoot is also called 'cavus' and can be defined as a plantarflexed first metatarsal. It is easy to distinguish between forefoot and hindfoot equinus using a stress dorsiflexion lateral radiograph of the foot. If the Meary angle is greater than 0°, then there is an element of forefoot equinus. This can be improved by plantar fasciotomy. Plantar fasciotomy can be simple (superficial) or complex (deep). The deep release can be just the plantar origins of the short flexor muscles (Steindler) or can include a deep dissection of the foot to include the ligaments of the talonavicular joint and the calcaneocuoid joint. In all cases, consider postoperative stretching serial casting to get further correction and to prevent rescarring into the preoperative state.

Along with the plantar fascia, it is also possible to release the abductor hallucis tendon distally in an intramuscular slide style, to lessen forefoot adductus deformity. A more aggressive treatment for the adductus is to do a classic open medial release of the talo-navicular joint. Some would argue for a complete midfoot release, to include the calcaneocuboid release. Carroll has described a method to release the calcaneocuboid joint from the medial plantar approach.[23]

The TATT has been well described, first by Garceau[24] and then by Ponseti[4]. In addition to the TATT, we sometimes add transfer of the peroneus longus tendon to the peroneus brevis tendon. The indications are for a cavus foot in which you are doing a TATT. The rationale is that when you remove the tibialis anterior tendon from the first metatarsal, you get unopposed pull of the peroneus longus, which causes further plantarflexion of the first ray, increasing the cavus and leading to excessive prominence of the first metatarsal head on the plantar surface of the foot. The peroneus longus to brevis transfer can be done through a short incision laterally, above the lateral

Fig. 5 A 16-year-old boy with neglected clubfoot. Printed courtesy of Dr Scott Nelson, Port au Prince, Haiti.

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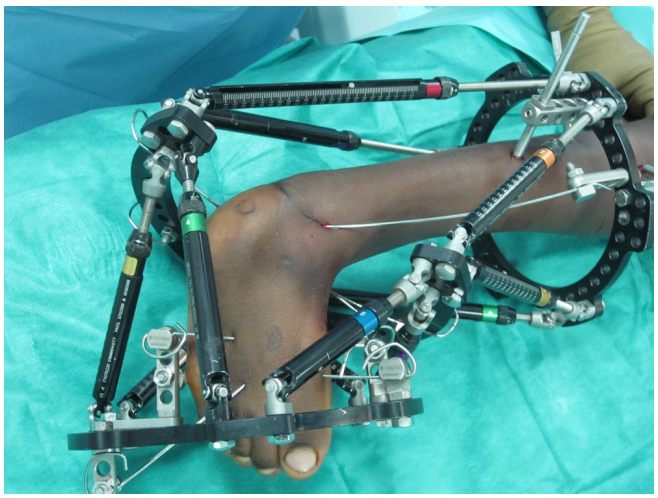

Fig. 6 Miter Taylor Spatial Frame correction of neglected clubfoot.

Table 1 Soft-tissue adjunctive procedures

Open tendo Achilles lengthening (TAL)
Open TAL + posterior ankle/subtalar capsulotomy
Plantar fasciotomy (superficial or complete)
Abductor hallucis tenotomy
Medial release
Medial plantar release
Tibialis anterior tendon transfer
Peroneus longus to brevis transfer
Terminal toe flexor tenotomies
Joint distraction with external fixator

Table 2 Bone adjunctive procedures

Calcaneal osteotomy (Dwyer)
Cuboid closing wedge osteotomy
Medial cuneiform opening wedge osteotomy
Naviculectomy + calcaneocuboid fusion
Guided growth (distal tibia)
Triple arthrodesis
Midfoot osteotomy
Supramalleolar osteotomy
Ilizarov U osteotomy
Ilizarov V osteotomy
Talectomy + calcaneocuboid fusion

malleolus, detaching the peroneus longus, and weaving it into the peroneus brevis, in the style of Pulvertaft.

After correcting a clubfoot with combinations of the above soft-tissue procedures, you may find that the toes are tightly curled when the foot is in the neutral or dorsiflexed position. This may be despite doing open Z-lengthenings of the FHL and FDL. In such cases, we do a simple percutaneous release of the long flexors at the plantar-digital creases with a 64 Beaver blade scalpel.

Finally, the ultimate soft-tissue procedure is joint distraction with external fixation, as described above. Whenever distracting joints with external fixation, it is very important to overcorrect and maintain the over corrected position for four to six weeks, as the myofibroblasts in the collagen tissue have 'memory' that will lead to rapid relapses. Long-term splinting is also advised.

Adjunctive procedures (bone)

The orthopaedic literature is full of an entire panoply of bone surgery options that can help treat a residual or relapsed situation after Ponseti treatment. These should be reserved for cases in which repeat casting and simpler procedures (TAL, TATT) are not effective. In general, the older a patient is, the more likely they are to need bone procedures.

Heel varus can be treated with a translational, closing wedge Dwyer osteotomy fixed internally. Adductus can be addressed by combined medial opening wedge (medial cuneiform) and lateral closing wedge (cuboid) as described by McHale and Lenhart.[25] For more severe cases of cavoadductus, in children older than about seven years of age, a naviculectomy combined with lateral calcaneocuboid shortening as described by Mubarak and Dimeglio[26] can remarkably loosen up a stiff foot and allow proper positioning.

Guided growth for ankle equinus is a good alternative in school age children to supramalleolar osteotomy for equinus and varus, as osteotomy corrections can get 'undone' by physeal remodelling in a growing child.[27]

In the Ilizarov world, multiple osteotomies have been described to correct various combinations of varus, valgus, equinus and supinatus.[28] A full description of these is beyond the scope of this review article. For purposes of illustration, we have included the midfoot Gigli osteotomy with gradual correction using the TSF butt frame (Fig. 4).

As a final salvage procedure, talectomy combined with lateral column shortening and fusion is an effective procedure, especially for arthrogrypotic feet, although long-term results are mixed.[29]

Summary

The Ponseti method has been a true revolution over the past more than 20 years and has changed our way of treatment of clubfoot deformities. Nonetheless, relapses still happen, but are mainly related to incorrect treatment protocol or noncompliance with the FAB. An age-related algorithm helps to tailor the correct treatment for most relapses. Neglected clubfoot may still be treated using the Ponseti principles, however, in older patients with severe deformities, more radical treatment might be required. As the Ponseti method becomes more universally adopted, experience with older, more invasive surgical procedures will necessarily become less necessary. However, there are still many children and adults with relapses and residuals, and indeed untreated natural history feet, in whom the classic Ponseti

principles will be found wanting. Therefore, it is important for the clubfoot specialist surgeon to maintain his/her familiarity with the full pantheon of classical surgical procedures that have been used effectively by many generations of orthopaedic surgeons for treating challenging clubfoot. Not all feet can be successfully treated with plaster and a tenotomy, so it behoves us to keep our surgical toolbox in order, and to judiciously apply our classical skills as needed.

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AUTHOR CONTRIBUTIONS
All authors have been actively involved in the drafting and revisions of this manuscript. All authors approved this final version of the manuscript.

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