

The Ponseti method for the treatment of congenital club foot: review of the current literature and treatment recommendations

Christof Radler

Received: 7 July 2013 / Accepted: 10 July 2013 / Published online: 9 August 2013
© Springer-Verlag Berlin Heidelberg 2013

Abstract The Ponseti method has become the gold standard of care for the treatment of congenital club foot. Despite numerous articles in MEDLINE reporting results from around the globe there are still crucial details of the Ponseti method which seem to be less commonly known or considered. The Ponseti method is not only a detailed method of manipulation and casting but also of preventing and treating relapse. Recommendations on how to correct complex club foot have resulted in an almost 100 % initial correction rate. The foot abduction brace is crucial for preventing relapse and is still a challenge for families and sometimes doctors alike. Experience and knowledge on how to support the parents, how to set and apply the brace in the best possible way and how to solve problems that can be encountered during the bracing period are essential to ensure compliance. Regular follow-up visits are necessary to be able to detect early signs of recurrence and prevent full relapse by enforcing abduction bracing, recasting or performing tibialis anterior tendon transfer. Recent midterm outcome studies have shown that by following the Ponseti treatment regime in all aspects it is possible to prevent open joint surgery in almost all cases. The body of literature of the last decade has evaluated many steps and aspects of the Ponseti method and gives valuable answers to questions encountered in daily practice. This review of the current literature and recommendations on the different aspects of the Ponseti method aims to promote understanding of the treatment regime and its' details.

Keywords Ponseti treatment · Congenital club foot · Abduction bracing · Tibialis tendon transfer · Club foot casting · Foot abduction brace · Manipulation

C. Radler (✉)
Paediatric Orthopaedic Unit, Department of Paediatric Orthopaedics and Adult Foot and Ankle Surgery, Orthopaedic Hospital Speising, Speisinger Strasse 109, 1130 Vienna, Austria
e-mail: cradler@chello.at

Introduction

Treatment of congenital club foot has changed radically with the introduction of the Ponseti method in most paediatric orthopaedic centres worldwide during the last ten to 15 years. Ponseti first described his treatment regime including abduction bracing and tibialis anterior tendon transfer for the treatment of relapse in 1963 [1] and published a further detailed description in 1972 [2]. All recommendations are still valid today and only minor adjustments have been made over the decades by Ponseti and his colleagues. The superior results of his method were reported by Ponseti and his colleagues in different long-term studies [3–6].

Forty-seven years after Ponseti's first article on his method [1] an analysis of data from the Centers for Disease Control and Prevention and the Nationwide Inpatient Sample in the USA revealed that the estimated number of surgical releases performed in patients less than 12 months of age decreased from 1,641 releases in 1996 to 230 releases in 2006 with the percentage of club feet treated with surgical release dropping from 72 % in 1996 to 12 % in 2006 [7]. Members of the Pediatric Orthopaedic Society of North America (POSNA) were surveyed and 96.7 % stated that they use the Ponseti treatment method as their current treatment of idiopathic club foot [8].

But not only in the USA has the Ponseti method become established but also in Europe and other parts of the world with early reports on superior initial results from many different centres [9–19]. A review performed in 2011 showed that there is clear evidence that the Ponseti method is the most successful treatment regime for congenital club foot available and reported an initial correction rate of around 90 % in most studies [20].

The Ponseti method is described in many books and literature and a search for the keyword "Ponseti with club foot" generates 278 articles starting from 1972. Nevertheless, in the

literature as well as in routine clinical practice when evaluating cases from different centres and in teaching in courses and workshops it seems that crucial details of the treatment regime are less commonly known, considered or understood. A review of the current literature on the different aspects of the Ponseti method aims to promote understanding of the treatment regime and the rationales for the many detailed recommendations.

Manipulation and casting

The method of manipulation and casting has been described by Ponseti in great detail [1, 2] and he published a manuscript on common errors which he observed when his method was applied by others [21]. Short and gentle manipulation has been recommended before casting which is important to stretch the structures and additionally to get a feeling for the flexibility of the foot and the amount of correction which can be achieved with the cast. Serial casting is performed with above the knee casts as short leg casts cannot hold the abduction and would frequently slip off. In the first cast the first metatarsal must be raised which means supinating the forefoot to align the forefoot with the hindfoot and to decrease cavus. The foot should never be pronated. In the following casts a pure abduction with counter pressure on the neck of the talus is performed. Thereby the talus is stabilised and cannot rotate in the ankle mortise, while the rest of the foot is abducted underneath it. The calcaneus must not be touched as this might block the motion of the calcaneus which must be free to swing out from underneath the talus and thereby abducts, everts and dorsiflexes. Active dorsiflexion must not be performed before the subtalar joint is fully corrected and/or until after tenotomy.

A common error is that the counter pressure is not perfectly on the talus. The talus is very small in the infant foot and is more anterior and superior than commonly expected. When the counter pressure is applied too low or on too big an area the calcaneus is blocked and cannot swing out from underneath the talus. If this happens the abducting force acts on the Chopart and Lisfranc joints, abduction occurs in the midfoot and a lateral crease may develop. This should be regarded as a red flag in Ponseti casting.

With the counter pressure on the talus the foot must be abducted to 60–70° as only this manoeuvre results in full correction of the subtalar joint and sufficient stretching of the medial structures. Ponseti recommended a thin cast with only little padding which should be very well moulded onto the foot. Additionally, the crease above the heel must be well moulded to prevent slipping of the cast. Slipping of the cast has been recognised to be a major factor in the development of complex club foot [22]. Slipping of the cast is most dangerous in the second and/or third casts, especially in cases with severe equinus and cavus. At this time the foot is in a more or less straight line with the calf and can retract easily. To prevent

slipping the heel must be well moulded, the cast must reach high enough to the groin with the knee in at least 90° of flexion and with the cast moulded well around and behind the knee.

To correct a complex club foot which may be a result of improper casting or due to the non-idiopathic nature of the foot Ponseti has proposed a modification of his technique of casting and manipulation [22]. Very gentle abduction is performed while the thumb applies counter pressure over the lateral aspect of the head of the talus with the index finger of the same hand over the posterior aspect of the lateral malleolus. This index finger can feel the motion of the calcaneus during abduction and abduction should be stopped as soon as the calcaneus stops abducting. The foot might not be hyper-abducted as this again leads to abduction in the midfoot and a lateral crease, as the hindfoot is so contracted that the calcaneus cannot follow the abduction. Correcting the hyperflexion of the metatarsals and rigid equinus was recommended to be performed simultaneously by grasping the foot by the ankle with both hands while the thumbs under the metatarsals push the foot into dorsiflexion as an assistant stabilises the knee in flexion. The knee should be fixed in up to 110° of flexion in these cases to further minimise the risk of the cast slipping. A tenotomy should be performed early with about 30–40° of abduction and foot abduction bracing should be started in the same abduction as achieved in the last cast.

In all cases cast removal should only be performed just before a new cast is applied as it has been shown that removing the cast the night before results in a higher number of casts being necessary for correction [23].

Cast changes are typically done once a week but accelerated protocols have been reported. Morcuende et al. described similar results with cast changes every five days [5]. Another study group reported cast changes three times per week and again found similar results compared to a standard weekly cast change group [24].

Nevertheless, intervals that are too short between cast changes might not be preferable. Pirani et al. [25] showed that Ponseti casting resulted in correction of the abnormal shapes of the individual tarsal osteochondral anlagen and suggested these changes to be a result of the changes in growth resulting from the changes in mechanical loading of fast-growing tissues. This would suggest that the tissue might need some time in the corrected position in the cast to be able to adapt through this growth and change [25]. One could speculate if the age of the patient at the time of casting might make a difference in the ability and speed of adaptation.

Alves et al. reported on the influence of age at the beginning of treatment on the correction with one treatment group being over and a second under six months of age [26]. They did not find any difference regarding number of casts, tenotomies, success in terms of rate of initial correction, rate of recurrence and rate of tibialis anterior tendon transfer.

Others suggested that casting should be postponed until after the first four weeks of life or until the foot reaches a length of at least 8 cm to make casting easier [27]. Nevertheless, there seems to be a consensus that treatment for club foot should start not later than within the first month of life [28]. The mother should be well enough to travel and come for the regular cast changes. In premature babies it was recommended not to start treatment in the neonatal intensive care unit and to defer treatment for several weeks [28] until the infant has stabilised and the foot has grown.

To monitor the treatment progress and to help in finding the right time for the percutaneous Achilles tenotomy as well as for scoring the foot at presentation the Pirani score has been introduced with very good interobserver reliability and ease of use [29–31]. Although a study found only a low correlation of the score at presentation with the number of Ponseti casts required for correction [32] significant correlation was reported between initial severity of the foot and outcomes [33, 34].

Percutaneous Achilles tenotomy

Percutaneous Achilles tenotomy (pAT) is one of the major components of the Ponseti method and was originally reported to be necessary to complete correction in 79 % [1], with many series reporting a rate between 80 and 90 % [5, 9]. Ponseti recommended performing pAT under local anaesthesia [3]. One study reported pAT under local anaesthesia as an office procedure to be safe and effective [35]. The tenotomies in this patient series were performed at a mean age of 9.5 weeks (range four to 12 weeks) and the authors pointed out that performance of incomplete tenotomy in the more hectic environment of the outpatient clinic might be a substantial problem. Bor et al. reported a light sedation protocol offering a safe alternative to general anaesthesia and recommended it be used when treating older infants who might struggle while under local anaesthesia [36]. A different study group found propofol sedation without the need for airway instrumentation to be safe and effective [37]. Yet another study looked at general anaesthesia for 182 tenotomies in 89 patients under three months of age [38]. Only three patients were admitted overnight because of a maternal history of drug abuse with all other patients having been discharged on the day of surgery. No complications related to anaesthesia were identified [38].

It seems that pAT can be safely performed under different anaesthesia protocols with the choice being mostly dependent on the setting and experience of the anaesthesiologists and the surgeon. General anaesthesia should only be performed with the ability for proper monitoring, and Parada et al. recommended post-operative monitoring for at least four hours in infants less than 44 weeks post-conceptual age (PCA) at time of surgery or with a history of gestational age (GA) less than 37 weeks [38].

One of the crucial steps of the Ponseti method is the timing of tenotomy. Ponseti recommended tenotomy after the foot

had been adducted to at least 60° and when there was less than 15–20° of dorsiflexion [21]. Abduction to 60° is necessary for the calcaneus to be able to swing out completely from underneath the talus which corrects subtalar malalignment. Attempts to correct the equinus before the heel varus and foot supination are corrected will result in a rocker bottom deformity [21]. If the pAT is performed before 60–70° of abduction and before correction of the subtalar alignment the hindfoot will most likely stay uncorrected. It was shown in a radiographic study that the anteroposterior and lateral talocalcaneal angles, which describe the subtalar derotation between the talus and the calcaneus, are not influenced by the tenotomy [39] and must be corrected before pAT. The foot must be palpated to assess the correction before tenotomy. The talar head must be covered, the heel should be in slight valgus and it should be possible to abduct the foot to 60°. Due to the risk of pseudocorrection, describing mild midfoot rockering with false dorsiflexion in the midfoot, a lateral maximum dorsiflexion view radiograph has been recommended in cases where pAT is believed not to be necessary [39]. Sufficient correction before pAT can also be assessed using the Pirani score. When the midfoot score (MFS) reaches values below 1 and the hindfoot score (HFS) is still above 1 tenotomy can be indicated [30].

The technique for pAT has been described in detail, mostly in papers reporting complications of pAT [40, 41]. Dobbs et al. reported on four patients out of 200 feet (2 %) having a serious bleeding complication following pAT with bleeding presumably due to injuries to the peroneal vessels [40]. Another paper reported development of a pseudoaneurysm in one patient after undergoing pAT at the age of eight weeks [41], and damage to the neurovascular bundle necessitating open exploration, ligation of the artery and primary repair of the nerve was reported in one case in another study [42]. In daily practice the correct level of the pAT seems important. The tenotomy should neither be performed too high, as this may result in incomplete tenotomy due to fanning of the tendon, nor too low, as this would increase the risk of cutting the cartilage anlage. Careful palpation of the tendon and marking of the insertion site of the blade with the gloved fingernail can be performed. Completion of the tenotomy is usually confirmed by a gentle pop of the cut tendon, by sudden increase of dorsiflexion or by palpation of the gap. However, even with the gap being palpable, parts of the tendon might still be intact. Care should be taken never to start cutting too medial and too close to the posterior tibial vessels and nerve and not to go too lateral with the tip of the blade to prevent injury to the peroneal vessels.

The post tenotomy cast should be moulded in maximum abduction and dorsiflexion to achieve good correction. Failure to dorsiflex the foot in the cast after tenotomy may result in insufficient dorsiflexion after cast removal. However, care should be taken not to perform too vigorous or forceful dorsiflexion as not to damage the talar dome.

Multiple studies have demonstrated the phases of healing of the tendon after tenotomy with a continuity of the tendon in all cases after three weeks [43–45]. It has been shown that leg muscular atrophy is a primary component of club foot already present in the early stages of fetal club foot development before treatment or tenotomy of the Achilles tendon [46].

Bracing

In Ponseti's first case series he described the use of the foot abduction orthosis (FAO) after 3 months of full time bracing for an additional mean duration of 21 months (ranging from ten to 30 months) with a recurrence found in 56 % of cases [1]. Due to the high rate of recurrence in this first series he recommended the FAO to be used at night for at least five or six years in his second paper on club foot treatment [2]. Non-compliance has been recognised as a significant risk factor for the recurrence of club foot after correction with the Ponseti method with the parental educational level being an important factor [47]. Since abduction bracing is one of the most important factors for long-term outcome and since compliance with the FAO seems to depend on the type of brace, various studies have evaluated different braces and protocols. Attempts were made to improve compliance by improving acceptance of the brace by the child. The first flexible brace which had a flexible bar between the shoes was introduced by Kessler [48]. Garg and Porter reported on a dynamic orthosis introduced by M.B. Dobbs [49]. With the use of this dynamic brace they found improved compliance, fewer recurrences, fewer skin complications and reduced rates of surgery compared to traditional braces [49]. Other researchers focused on strategies that might promote adherence to brace treatment, which included educating the family, making encouraging calls and providing written instructions [50]. Additionally they found a strong physician-family partnership to be an important factor in adherence to bracing [50].

As traditional abduction bracing is based on a bar connecting both feet for bilateral and also for unilateral cases doctors as well as patients wished for unilateral braces. However, it was found that recurrence rates in patients using unilateral ankle foot orthoses were higher compared to those reported by others using FAOs after Ponseti treatment [51]. Recurrence requiring additional treatment was found in 83 % of cases (25 of 30 feet) in a group using an ankle foot orthosis versus only in 31 % (12 of 39 ft) in a group using a FAO [52]. There are different kinds of FAO available and while studies found new and more expensive brace designs not necessarily providing better clinical results [53] the newer braces might be easier to use [54], especially in more severe club foot.

While long-term results are available for the use of non-dynamic standard FAO [1–6] there are no long-term outcome studies available for braces with different biomechanical

properties. Recently a surrogate model was introduced to test muscle-tendon tensions in resting and braced positions [55] which might give insight into the biomechanical properties and effects of different brace designs.

Despite all technical aspects the most important factors for bracing and brace compliance seem to be education of the parents on the importance but also on the correct use of the brace. A study on the educational needs for parents of children with club foot identified understanding the process of treatment and problems concerning the bracing portion of treatment to be the two major categories [56].

However, no study ever looked at the educational need of doctors regarding the correct use of the brace. Frequently parents present with braces being set to the wrong size or position and have never been shown how to use the brace effectively. Foot abduction bracing cannot correct the club foot deformity but only prevent loss of correction. Therefore the prerequisite for bracing is a well-corrected foot with sufficient dorsiflexion. The abduction in the first brace must not be more than in the last cast, which is why in complex club foot the FAO is often started at only 40° of abduction. The brace must be ready quite immediately when the last cast comes off to prevent recurrence even before the first brace is applied. If initial problems with the brace are reported, it is mostly due to failure to put on the shoes correctly, insufficient correction of the foot, the wrong size shoes or not enough instructions given to the caregivers of the child. A follow-up one or two weeks after starting the FAO is necessary to detect and solve early problems. Slipping out of the heel with subsequent loss of correction of the hindfoot, or midfoot instability with rockering, might be due to insufficient dorsiflexion or the wrong brace size or design. Blisters on the heel are usually found with the middle front strap of the brace being too loose or the shoes too big, while bruises on the anterior part of foot are sometimes found if this strap is pulled too tight. A well-functioning and well-fitting brace is very important especially in the beginning, to get the infant as well as the parents used to the brace and to create a positive attitude towards bracing. Some mothers fear a negative influence of the brace on the motor and psychological development of their child. They can be assured that only minimal delays in gross motor milestone achievement are found in children with idiopathic club foot treated with the Ponseti method including bracing [57]. Additionally it was shown that foot abduction bracing does not result in pathological changes of the torsion of the femur or tibia [58].

Limits of the Ponseti method?

In Dr. Ponseti's first series of patients reported in 1963 the oldest patient was six months and he excluded cases treated in other clinics and referred for further correction, patients with arthrogyposis and patients with other syndromic or

neurological affection. Since then many papers have looked at the treatment of older children, of patients after failed surgical correction and patients with secondary and syndromic club foot.

Bor et al. reported the results of 36 club feet in 23 patients after failed casting or presenting after three months of age and achieved a correction without open joint surgery in 97 % of the cases (35 of 36 feet) [59]. Lourenço and Morcuende reported on patients with 24 neglected club feet with a mean age of 3.9 years treated with the Ponseti method and found a good correction in 67 % of cases [60]. Equally encouraging results were found by Spiegel et al. who analysed correction using the Ponseti method in 171 patients (260 feet) presenting between the ages of one and six years [61]. While 79 % required pAT to complete correction only 14 % needed open joint surgery.

Additionally to older and neglected club feet, relapses after posteromedial release have been successfully treated with the Ponseti method. Nogueira et al. obtained plantigrade and fully corrected feet in 86 % of cases (71 of 83 feet) which presented with relapse after posteromedial release at a mean age of five years two months (range seven months–14 years) [62].

The Ponseti method has been applied to non-idiopathic club feet and Boehm et al. reported the first results in 12 patients with 24 club feet with distal arthrogyposis. They achieved initial correction in all feet with two of six feet (8 %) relapsing and requiring open joint surgery. They suggested longer follow-up to assess the risk of recurrence [63]. Quite similar results were found by van Bosse et al. in the treatment of club foot with arthrogyposis at a minimum follow-up of 13 months (mean 38.5 months). They reported a need for open joint surgery in 10 % (two of 19 feet) which had an initial pAT before casting with 53 % having a second pAT before application of the last cast [64]. Morcuende et al. followed patients with club foot associated with arthrogyposis after correction with the Ponseti method for an average duration of 4.6 years and found that 16 % required open joint surgery in the midterm follow-up [65].

In club foot associated with myelomeningocele comparable results regarding initial correction were reported. However, a relapse was observed in 68 % (19 of 28 feet) after a mean of 7.1 months mostly treated with reapplication of the Ponseti method [66]. Higher relapse rates in non-idiopathic club foot compared to idiopathic club foot following Ponseti treatment have also been observed by others [67].

Results of treatment

The longest follow-up outcome studies are available for Dr. Ponseti's case series. Laaveg and Ponseti published the results of 104 club feet after ten to 27 years of follow-up with excellent or good results in 74 % of feet [3]. Cooper and Dietz reported on 71 club feet in 45 patients with a mean age of 34 years treated with the Ponseti method and with 78 % having excellent or good outcome [4]. Midterm follow-up studies from outside

of Iowa with minimum follow-up over three years are still rare. In the few studies available open joint surgery was avoided in 91–96 % of all cases with good outcome reported at the last follow-up [68–70]. Tibialis anterior tendon transfer was performed in about 20 % of feet in these case series [68, 69]. Tibialis anterior tendon transfer is recommended to treat relapse with mostly dynamic supination and adduction. Casting must be performed prior to tibialis anterior tendon transfer in cases with non-flexible deformities. A full transfer to the third cuneiform is recommended [1, 2] paying attention to the structures in the plantar side of the foot [71]. However, relapse may occur even after tibialis anterior tendon transfer. Masrouha and Morcuende reviewed 66 patients with 102 club feet treated by tibialis anterior tendon transfer for club foot relapses after successful initial treatment by the Ponseti method [72]. They found a subsequent relapse after tibialis anterior tendon transfer in 15 % of feet (ten patients with 15 club feet) [72]. The results of the treatment of relapse were evaluated in another study and it was observed that at an average age at final follow-up of 23.3 years (range eight to 50.6 years) 90 % of patients wore regular shoes, 41 % had pain with activities, but only 18 % were limited in function by their feet [73].

Conclusion

The Ponseti method enables us to correct most club feet with gentle manipulation and casting and pAT. Experience with the Ponseti method and great attention to the details of manipulation and moulding of the cast are necessary to achieve an initial correction rate of over 98 % as reported in the literature [5]. Especially complex club foot can be a challenge and often can only be managed after a significant learning curve. Non-idiopathic club feet can be managed well with the Ponseti method; however, a very close follow-up is recommended as recasting due to relapse is necessary in many cases. Patience is important or required in those cases and a dedication to the method as at certain times neither we nor the parents are thrilled when looking at the prospect of another set of casts. Bracing is the key to long-term success of the Ponseti method and the level of education of the parents on the brace and brace wear directly reflects on the quality and quantity of information we provide. The Ponseti treatment regime as a detailed method of manipulation and casting, preventing and treating relapse is the most successful treatment regime for congenital club foot to date.

References

1. Ponseti IV, Smoley EN (1963) Congenital club foot: the results of treatment. *J Bone Joint Surg Am* 45-A:261–344
2. Ponseti IV, Campos J (1972) Observations on pathogenesis and treatment of congenital club foot. *Clin Orthop Relat Res* 84:50–60

3. Laaveg SJ, Ponseti IV (1980) Long-term results of treatment of congenital club foot. *J Bone Joint Surg Am* 62(1):23–31
4. Cooper DM, Dietz FR (1995) Treatment of idiopathic club foot: a thirty-year follow-up note. *J Bone Joint Surg Am* 77-A:1477–1489
5. Morcuende JA, Abbasi D, Dolan LA, Ponseti IV (2005) Results of an accelerated Ponseti protocol for club foot. *J Pediatr Orthop* 25:623–626
6. Morcuende JA, Dolan LA, Dietz FR, Ponseti IV (2004) Radical reduction in the rate of extensive corrective surgery for club foot using the Ponseti method. *Pediatrics* 113(2):376–380
7. Zions LE, Zhao G, Hitchcock K, Maewal J, Ebrahimzadeh E (2010) Has the rate of extensive surgery to treat idiopathic club foot declined in the United States? *J Bone Joint Surg Am* 92(4):882–889
8. Zions LE, Sangiorgio SN, Ebrahimzadeh E, Morcuende JA (2012) The current management of idiopathic club foot revisited: results of a survey of the POSNA membership. *J Pediatr Orthop* 32(5):515–520
9. Herzenberg JE, Radler C, Bor N (2002) Ponseti versus traditional methods of casting for idiopathic club foot. *J Pediatr Orthop* 22(4):517–521
10. Chotel F, Parot R, Durand JM, Garnier E, Hodgkinson I, Bérard J (2002) Initial management of congenital varus equinus club foot by Ponseti's method. *Rev Chir Orthop Reparatrice Appar Mot* 88(7):710–717
11. Colburn M, Williams M (2003) Evaluation of the treatment of idiopathic club foot by using the Ponseti method. *J Foot Ankle Surg* 42(5):259–267
12. Tindall AJ, Steinlechner CW, Lavy CB, Mannion S, Mkandawire N (2005) Results of manipulation of idiopathic club foot deformity in Malawi by orthopaedic clinical officers using the Ponseti method: a realistic alternative for the developing world? *J Pediatr Orthop* 25(5):627–629
13. Aurell Y, Andriess H, Johansson A, Jonsson K (2005) Ultrasound assessment of early club foot treatment: a comparison of the Ponseti method and a modified Copenhagen method. *J Pediatr Orthop B* 14(5):347–357
14. Segev E, Keret D, Lokiec F, Yavor A, Wientroub S, Ezra E, Hayek S (2005) Early experience with the Ponseti method for the treatment of congenital idiopathic club foot. *Isr Med Assoc J* 7(5):307–310
15. Göksan SB, Bursali A, Bilgili F, Sivacioğlu S, Ayanoğlu S (2006) Ponseti technique for the correction of idiopathic club feet presenting up to 1 year of age. A preliminary study in children with untreated or complex deformities. *Arch Orthop Trauma Surg* 126(1):15–21
16. Thacker MM, Scher DM, Sala DA, van Bosse HJ, Feldman DS, Lehman WB (2005) Use of the foot abduction orthosis following Ponseti casts: is it essential? *J Pediatr Orthop* 25(2):225–228
17. Radler C, Suda R, Manner HM, Grill F (2006) Early results of the Ponseti method for the treatment of idiopathic club foot. *Z Orthop Ihre Grenzgeb* 144(1):80–86
18. Gupta A, Singh S, Patel P, Patel J, Varshney MK (2008) Evaluation of the utility of the Ponseti method of correction of club foot deformity in a developing nation. *Int Orthop* 32(1):75–79
19. Pirani S, Naddumba E, Mathias R, Konde-Lule J, Penny JN, Beyeza T, Mbonye B, Amone J, Franceschi F (2009) Towards effective Ponseti club foot care: the Uganda Sustainable club foot Care Project. *Clin Orthop Relat Res* 467(5):1154–1163
20. Jowett CR, Morcuende JA, Ramachandran M (2011) Management of congenital talipes equinovarus using the Ponseti method: a systematic review. *J Bone Joint Surg Br* 93(9):1160–1164
21. Ponseti IV (1997) Common errors in the treatment of congenital club foot. *Int Orthop* 21(2):137–141
22. Ponseti IV, Zhivkov M, Davis N, Sinclair M, Dobbs MB, Morcuende JA (2006) Treatment of the complex idiopathic club foot. *Clin Orthop Relat Res* 451:171–176
23. Terrazas-Lafargue G, Morcuende JA (2007) Effect of cast removal timing in the correction of idiopathic club foot by the Ponseti method. *Iowa Orthop J* 27:24–27
24. Harnett P, Freeman R, Harrison WJ, Brown LC, Beckles V (2011) An accelerated Ponseti versus the standard Ponseti method: a prospective randomised controlled trial. *J Bone Joint Surg Br* 93(3):404–408
25. Pirani S, Zeznik L, Hodges D (2001) Magnetic resonance imaging study of the congenital club foot treated with the Ponseti method. *J Pediatr Orthop* 21(6):719–726
26. Alves C, Escalda C, Fernandes P, Tavares D, Neves MC (2009) Ponseti method: does age at the beginning of treatment make a difference? *Clin Orthop Relat Res* 467(5):1271–1277
27. Iltar S, Uysal M, Alemdaroğlu KB, Aydoğan NH, Kara T, Atlihan D (2010) Treatment of club foot with the Ponseti method: should we begin casting in the newborn period or later? *J Foot Ankle Surg* 49(5):426–431
28. Böhm S, Sinclair M (2013) Report of the 1st European consensus meeting on Ponseti club foot treatment. *J Child Orthop* 7(3):251–254
29. Flynn JM, Donohoe M, Mackenzie WG (1998) An independent assessment of two club foot-classification systems. *J Pediatr Orthop* 18(3):323–327
30. Shaheen S, Jaiballa H, Pirani S (2012) Interobserver reliability in Pirani club foot severity scoring between a paediatric orthopaedic surgeon and a physiotherapy assistant. *J Pediatr Orthop B* 21(4):366–368
31. Dyer PJ, Davis N (2006) The role of the Pirani scoring system in the management of club foot by the Ponseti method. *J Bone Joint Surg Br* 88(8):1082–1084
32. Chu A, Labar AS, Sala DA, van Bosse HJ, Lehman WB (2010) club foot classification: correlation with Ponseti cast treatment. *J Pediatr Orthop* 30(7):695–699
33. Zhang W, Richards BS, Faulks ST, Karol LA, Rathjen KA, Browne RH (2012) Initial severity rating of idiopathic club feet is an outcome predictor at age two years. *J Pediatr Orthop B* 21(1):16–19
34. Goriainov V, Judd J, Uglow M (2010) Does the Pirani score predict relapse in club foot? *J Child Orthop* 4(5):439–444
35. Lebel E, Karasik M, Bernstein-Weyel M, Mishukov Y, Peyser A (2012) Achilles tenotomy as an office procedure: safety and efficacy as part of the Ponseti serial casting protocol for club foot. *J Pediatr Orthop* 32(4):412–415
36. Bor N, Katz Y, Vofsi O, Herzenberg JE, Zuckerberg AL (2007) Sedation protocols for Ponseti club foot Achilles tenotomy. *J Child Orthop* 1(6):333–335
37. Iravani M, Chalabi J, Kim R, Ebrahimzadeh E, Zions LE (2013) Propofol sedation for infants with idiopathic club foot undergoing percutaneous tendoachilles tenotomy. *J Pediatr Orthop* 33(1):59–62
38. Parada SA, Baird GO, Auffant RA, Tompkins BJ, Caskey PM (2009) Safety of percutaneous tendoachilles tenotomy performed under general anesthesia on infants with idiopathic club foot. *J Pediatr Orthop* 29(8):916–919
39. Radler C, Manner HM, Suda R, Burghardt R, Herzenberg JE, Ganger R, Grill F (2007) Radiographic evaluation of idiopathic club feet undergoing Ponseti treatment. *J Bone Joint Surg Am* 89(6):1177–1183
40. Dobbs MB, Gordon JE, Walton T, Schoenecker PL (2004) Bleeding complications following percutaneous tendoachilles tenotomy in the treatment of club foot deformity. *J Pediatr Orthop* 24(4):353–357
41. Burghardt RD, Herzenberg JE, Ranade A (2008) Pseudoaneurysm after Ponseti percutaneous Achilles tenotomy: a case report. *J Pediatr Orthop* 28(3):366–369
42. Changulani M, Garg NK, Rajagopal TS, Bass A, Nayagam SN, Sampath J, Bruce CE (2006) Treatment of idiopathic club foot using the Ponseti method. Initial experience. *J Bone Joint Surg Br* 88(10):1385–1387
43. Barker SL, Lavy CB (2006) Correlation of clinical and ultrasonographic findings after Achilles tenotomy in idiopathic club foot. *J Bone Joint Surg Br* 88(3):377–379
44. Maranhão DA, Nogueira-Barbosa MH, Simão MN, Volpon JB (2009) Ultrasonographic evaluation of Achilles tendon repair after

- percutaneous sectioning for the correction of congenital club foot residual equinus. *J Pediatr Orthop* 29(7):804–810
45. Mangat KS, Kanwar R, Johnson K, Korah G, Prem H (2010) Ultrasonographic phases in gap healing following Ponseti-type Achilles tenotomy. *J Bone Joint Surg Am* 92(6):1462–1467
 46. Ippolito E, De Maio F, Mancini F, Bellini D, Orefice A (2009) Leg muscle atrophy in idiopathic congenital club foot: is it primitive or acquired? *J Child Orthop* 3(3):171–178
 47. Dobbs MB, Rudzki JR, Purcell DB, Walton T, Porter KR, Gurnett CA (2004) Factors predictive of outcome after use of the Ponseti method for the treatment of idiopathic club feet. *J Bone Joint Surg Am* 86-A(1):22–27
 48. Kessler JI (2008) A new flexible brace used in the Ponseti treatment of talipes equinovarus. *J Pediatr Orthop B* 17(5):247–250
 49. Garg S, Porter K (2009) Improved bracing compliance in children with club feet using a dynamic orthosis. *J Child Orthop* 3(4):271–276
 50. Zions LE, Dietz FR (2010) Bracing following correction of idiopathic club foot using the Ponseti method. *J Am Acad Orthop Surg* 18(8):486–493
 51. George HL, Unnikrishnan PN, Garg NK, Sampath J, Bruce CE (2011) Unilateral foot abduction orthosis: is it a substitute for Denis Browne boots following Ponseti technique? *J Pediatr Orthop B* 20(1):22–25
 52. Janicki JA, Wright JG, Weir S, Narayanan UG (2011) A comparison of ankle foot orthoses with foot abduction orthoses to prevent recurrence following correction of idiopathic club foot by the Ponseti method. *J Bone Joint Surg Br* 93(5):700–704
 53. Hemo Y, Segev E, Yavor A, Ovadia D, Wientroub S, Hayek S (2011) The influence of brace type on the success rate of the Ponseti treatment protocol for idiopathic club foot. *J Child Orthop* 5(2):115–119
 54. Zions LE, Frost N, Kim R, Ebramzadeh E, Sangiorgio SN (2012) Treatment of idiopathic club foot: experience with the Mitchell-Ponseti brace. *J Pediatr Orthop* 32(7):706–713
 55. Dimeo AJ Sr, Lalush DS, Grant E, Morcuende JA (2012) Development of a surrogate biomodel for the investigation of club foot bracing. *J Pediatr Orthop* 32(7):e47–e52
 56. Paulsen-Miller M, Dolan LA, Stineman A, Morcuende JA (2011) Understanding the educational needs for parents of children with club foot. *Orthop Nurs* 30(4):273–278
 57. Sala DA, Chu A, Lehman WB, van Bosse HJ (2013) Achievement of gross motor milestones in children with idiopathic club foot treated with the Ponseti method. *J Pediatr Orthop* 33(1):55–58
 58. Boehm S, Sinclair M (2007) Foot abduction brace in the Ponseti method for idiopathic club foot deformity: torsional deformities and compliance. *J Pediatr Orthop* 27(6):712–716
 59. Bor N, Herzenberg JE, Frick SL (2006) Ponseti management of club foot in older infants. *Clin Orthop Relat Res* 444:224–228
 60. Lourenço AF, Morcuende JA (2007) Correction of neglected idiopathic club foot by the Ponseti method. *J Bone Joint Surg Br* 89(3):378–381
 61. Spiegel DA, Shrestha OP, Sitoula P, Rajbhandary T, Bujukachhe B, Banskota AK (2009) Ponseti method for untreated idiopathic club feet in Nepalese patients from 1 to 6 years of age. *Clin Orthop Relat Res* 467(5):1164–1170
 62. Nogueira MP, Ey Battle AM, Alves CG (2009) Is it possible to treat recurrent club foot with the Ponseti technique after posteromedial release?: a preliminary study. *Clin Orthop Relat Res* 467(5):1298–1305
 63. Boehm S, Limpaphayom N, Alae F, Sinclair MF, Dobbs MB (2008) Early results of the Ponseti method for the treatment of club foot in distal arthrogyriposis. *J Bone Joint Surg Am* 90(7):1501–1507
 64. van Bosse HJ, Marangoz S, Lehman WB, Sala DA (2009) Correction of arthrogyrotic club foot with a modified Ponseti technique. *Clin Orthop Relat Res* 467(5):1283–1293
 65. Morcuende JA, Dobbs MB, Frick SL (2008) Results of the Ponseti method in patients with club foot associated with arthrogyriposis. *Iowa Orthop J* 28:22–26
 66. Gerlach DJ, Gurnett CA, Limpaphayom N, Alae F, Zhang Z, Porter K, Kirchhofer M, Smyth MD, Dobbs MB (2009) Early results of the Ponseti method for the treatment of club foot associated with myelomeningocele. *J Bone Joint Surg Am* 91(6):1350–1359
 67. Moroney PJ, Noël J, Fogarty EE, Kelly PM (2012) A single-center prospective evaluation of the Ponseti method in nonidiopathic congenital talipes equinovarus. *J Pediatr Orthop* 32(6):636–640
 68. Bor N, Coplan JA, Herzenberg JE (2009) Ponseti treatment for idiopathic club foot: minimum 5-year followup. *Clin Orthop Relat Res* 467(5):1263–1270
 69. Eberhardt O, Peterlein CD, Fernandez FF, Wirth T (2012) Mid-term results of idiopathic club feet treated with the Ponseti method. *Z Orthop Unfall* 150(2):190–197
 70. Church C, Coplan JA, Poljak D, Thabet AM, Kowtharapu D, Lennon N, Marchesi S, Henley J, Starr R, Mason D, Belthur MV, Herzenberg JE, Miller F (2012) A comprehensive outcome comparison of surgical and Ponseti club foot treatments with reference to pediatric norms. *J Child Orthop* 6(1):51–59
 71. Radler C, Gourdine-Shaw MC, Herzenberg JE (2012) Nerve structures at risk in the plantar side of the foot during anterior tibial tendon transfer: a cadaver study. *J Bone Joint Surg Am* 94(4):349–355
 72. Masrouha KZ, Morcuende JA (2012) Relapse after tibialis anterior tendon transfer in idiopathic club foot treated by the Ponseti method. *J Pediatr Orthop* 32(1):81–84
 73. McKay SD, Dolan LA, Morcuende JA (2012) Treatment results of late-relapsing idiopathic club foot previously treated with the Ponseti method. *J Pediatr Orthop* 32(4):406–411