Review Article

Bracing Following Correction of Idiopathic Clubfoot Using the Ponseti Method

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Abstract

The Ponseti method for the management of idiopathic clubfoot has recently experienced a rise in popularity, with several centers reporting excellent outcomes. The challenge in achieving a successful outcome with this method lies not in correcting deformity but in preventing relapse. The most common cause of relapse is failure to adhere to the prescribed postcorrective bracing regimen. Socioeconomic status, cultural factors, and physician-parent communication may influence parental compliance with bracing. New, more user-friendly braces have been introduced in the hope of improving the rate of compliance. Strategies that may be helpful in promoting adherence include educating the family at the outset about the importance of bracing, encouraging calls and visits to discuss problems, providing clear written instructions, avoiding or promptly addressing skin problems, and refraining from criticism of the family when noncompliance is evident. A strong physician-family partnership and consideration of underlying cognitive, socioeconomic, and cultural issues may lead to improved adherence to postcorrective bracing protocols and better patient outcomes.

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The Ponseti method for the correction of idiopathic clubfoot deformity received renewed interest in the late 1990s.[1] The technique involves a series of weekly manipulations and cast applications to simultaneously correct forefoot adduction, midfoot cavus, and hindfoot varus. In most patients, percutaneous Achilles tenotomy is performed after 4 to 6 weeks to completely correct the equinus component of the deformity. Following the initial correction, postcorrective bracing is used to prevent relapse of the deformity. Several centers worldwide have reported excellent early results with the Ponseti method.[2-16]

Initial correction of clubfoot deformity can be achieved in most infants treated with the Ponseti method. However, maintaining the correction is far more challenging, with relapse rates of 14%[2] to 41%[16] (Table 1). The most consistent factor leading to relapse is difficulty obtaining full parental compliance with the postcorrective bracing protocol.[2-4,6,8,12,13,16]

Origin of the Foot Abduction Orthosis

In 1948 at the University of Iowa, Ignacio Ponseti began developing a new manipulation technique for the management of clubfoot.[17] He soon recognized that relapse of the deformity occurred almost immediately

Table 1

Results of the Ponseti Method for Managing Idiopathic Clubfoot

Study	No. of Feet (Pts)	Initial Correction (%)	Nonadherence (%)	Relapse (%)
Abdelgawad et al[2]	137 (89)	93	34	14
Avilucea et al[3]	138 (100)	95	32	26
Dobbs et al[8]	86 (51)	100	41	31
Haft et al[16]	73 (51)	100	49	41
Richards et al[13]	267 (176)	94	61	37

following full correction. In 1963, Ponseti and Smoley[17] reported their use of Denis Browne splints with high-top shoes and well-molded heels to prevent recurrence of clubfoot. They advised bracing "full-time for the first 2 or 3 months after correction, and part-time thereafter until the child is from 3 to 5 years of age."

The original Denis Browne splint used a bar with an L-shaped metal foot plate at either end that was designed to forcibly evert the foot without abducting the calcaneus. Ponseti wanted to maintain correction by externally rotating the shoes on the bar to maintain the degree of foot abduction achieved by manipulation and cast application. Over time, as the original Denis Browne splint design was modified to prevent recurrence of a corrected clubfoot, medical personnel began referring to this device and others like it as foot abduction orthoses (FAOs).

Rationale for Bracing

An FAO is needed following clubfoot correction to minimize the incidence of relapse, that is, the reappearance of any component of clubfoot deformity following initial correction. According to Ponseti,[18] relapse typically occurs by age 5 years. The time when most relapses occur corresponds to a period of rapid growth of the foot. Anderson et al[19] observed that the foot achieves half of its adult length by age 2 years, much earlier than is seen for lower limb length. It may be that the rapid growth rate of the foot during infancy contributes to the risk of relapse.

The underlying cause of idiopathic clubfoot is unknown; thus, the reason for the effectiveness of the FAO is subject to conjecture. Ponseti[18] hypothesized that the more important relapses, which occur in the hindfoot, may be related to retracting fibrosis of the ligaments and musculotendinous units of the posterior and medial ankle—the same pathology that may cause the original deformity.

Figure 1

A B

A, Photograph of a clubfoot before treatment with the Ponseti method. **B,** Photograph of the foot following posttenotomy cast removal. At least 15° to 25° of dorsiflexion must be achieved.

Proper Use of the Foot Abduction Orthosis

The key to successful use of the FAO is obtaining full correction of the clubfoot. Achilles tenotomy is usually required to obtain the 15° to 25° of dorsiflexion necessary to allow proper use of the brace (Figure 1). Tenotomy should be done when any question exists regarding whether the technique may be necessary. Inadequate dorsiflexion will cause the heel to pull up out of the shoe, which may lead to irritation and possibly skin ulceration. The heel should easily sit in the shoe, and the width of the shoe should accommodate the width of the foot.

The several types of FAO that are currently available have many features in common. The brace consists of a bar with shoes attached to hold the affected foot in approximately 70° of external rotation. For the patient with unilateral deformity, the unaffected foot is positioned in 40° of abduction. The shoes are placed at

Table 2

Approximate Cost of Commonly Used Foot Abduction Orthoses

Orthosis	Cost (US dollars)
Markell	150[a]
Mitchell-Ponseti	350[b]
Dobbs	1,200[22]

[a] Cost includes standard shoes and bar. Does not include orthotist charges. (M. J. Markell Shoe Co, oral communication, May 2010.)
[b] Cost includes standard sandals and bar. Does not include orthotist charges. (MD Orthopaedics, Inc, oral communication, May 2010.)

shoulder width for comfort. The ends of the bar may be bent or adjusted to allow 5° to 10° of dorsiflexion.

The FAO should be used 23 hours per day for 3 months following cast removal from a fully corrected foot. The hour off is for bathing and a brace-free play period. After 3 months, the brace is worn at nighttime and nap time. For a foot that is difficult to correct, a longer initial period of brace wear may be needed, such as 18 hours per day, followed by gradual weaning to nighttime and nap time wear.

The foot grows quickly during infancy, and the surgeon should anticipate that up to two new pairs of orthotic shoes will be needed during the first year of bracing and that one new pair of shoes will be required for each year thereafter. The heel must fit well into the counter. Complete overlap of the toes at the edge of the sole is one indication that the infant is outgrowing the shoes.

The precise duration of FAO use required to maintain correction of the foot has not been thoroughly studied. In their original article, Ponseti and Smoley[17] recommended that bracing be continued until the child achieved age 3 to 5 years. Ponseti[18] later indicated that the brace should be worn at night for 2 to 4 years. Abdelgawad et al[2] observed that families in their study were no longer capable of convincing the affected child to sleep with the brace applied by the time the child reached age 3 years. They recommended that the device be continued as long as the child could tolerate it at night. Compliance with use of the brace at 2-year follow-up was infrequent in a study by Haft et al.[16] More study is needed to determine the minimal amount of time needed in the FAO to achieve a successful outcome.

Recurrence can be managed with two to three manipulations and cast applications at 1- to 2-week intervals. If dorsiflexion is limited, Achilles tenotomy may be repeated in infants aged <1 year. After age 1 year, open Achilles tendon lengthening is preferred. A second recurrence may be managed in a similar fashion. After correction of the foot is regained, the FAO is reapplied. The protocol for reinstituting the use of the FAO should be individualized. In general, full-time bracing is recommended for infants who developed a recurrence early in their treatment course. Nighttime and nap time bracing is resumed for infants who developed recurrence after completing a course of full-time bracing.

A patient may experience repeated recurrences because the family is having difficulty complying with use of the FAO. Reinstituting bracing is usually optimal; however, anterior tibial tendon transfer may be the best option in this situation. In these difficult cases, it is preferable to maintain bracing until the child is aged approximately 30 months because, by that time, the ossific nucleus of the third cuneiform is usually sufficiently large to permit anterior tibial tendon transfer. Tendon transfer will prevent further relapse without the need for bracing. The long-term outcome following tendon transfer appears to be equal to that attained without transfer.[20] If the foot is not passively correctable to neutral, serial casts should be applied to situate the heel in valgus before performing the tendon transfer. If 10° of dorsiflexion cannot be achieved, Achilles tendon lengthening should be done at the time of the transfer.

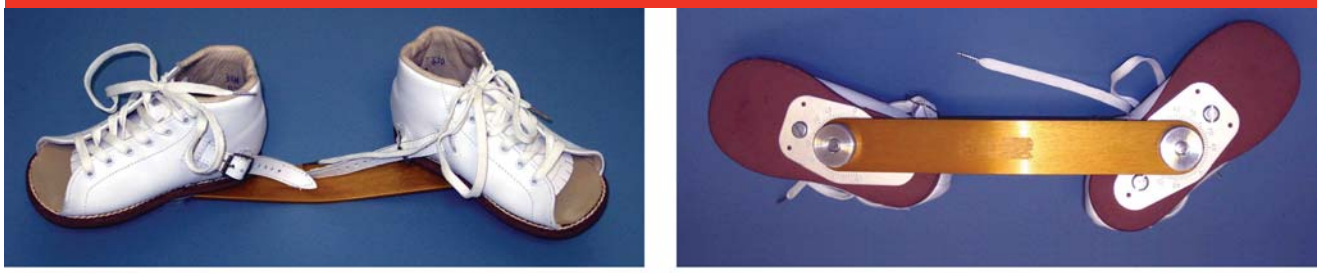
Commonly Available Orthoses

The Markell (M. J. Markell Shoe Co, Yonkers, NY) brace is used in most of the published reports on the Ponseti method. New braces have been introduced in an effort to improve adherence with postcorrective bracing, including the Mitchell-Ponseti brace and the Dobbs articulated brace.[21-23] The approximate cost of each of these braces is listed in Table 2. None of the published series that include these newer braces has a minimum follow-up of even 2 years. The Steenbeek brace was designed to be inexpensively and easily made for use in developing nations.[24]

Markell Brace

The Markell brace was the standard FAO at the University of Iowa for decades. The device consists of a pair of open-toed shoes mounted on an aluminum spreader bar (Figure 2). The flat bar is available in various sizes to allow widening of the distance between the shoes as the child grows. Alternatively, an adjustable bar consisting of two pieces attached by a bar clamp can be used. Aluminum foot plates are attached to the bar by a stainless steel bolt that fixes a serrated disk, which allows adjustment of the rotation of the foot plates. The shoes are then attached to the foot plates. The brace was recently modified to allow the shoes to be placed on the child before they are snapped into place on the bar. It

Figure 2



A B

A and **B,** Photographs of the Markell foot abduction orthosis, which has been used in most of the published studies to date on the Ponseti method. The device has been modified to allow placement of the shoes on the patient before attaching the shoes to the bar.

may be necessary to affix a piece of plastazote or similar material to the heel counter to keep the foot securely in the shoe.[25]

It can be difficult to confirm proper heel placement with this FAO. One of us (F.R.D.) marks the shoe where the toe edge is located when the heel is seated and with the shoe unlaced so that the foot can be easily observed. The parents are told that if the toes slip behind this line, the foot has likely lost its position in the brace. Alternatively, a shoe with a heel cutout can be used.

Figure 3

A B

A, Photograph of the Mitchell-Ponseti foot abduction orthosis in situ. **B,** The sandal has an opening at the counter so that the position of the heel can be viewed.

Mitchell-Ponseti Brace

The Mitchell-Ponseti brace is the product of a collaboration between John Mitchell, a local Iowa craftsman, and Ignacio Ponseti. Their idea was to create a shoe that would be more comfortable for the patient and to which it would be easier to attach an FAO. They developed a sandal with a soft, rubber-like sole and counter, with a leather support and three leather straps (Figure 3). The Mitchell-Ponseti brace was found to be particularly helpful in patients who had difficult-to-brace feet with limited dorsiflexion, such as those with complex clubfoot.[21] Often, 15° to 25° of dorsiflexion is not obtainable in the complex clubfoot. Reduced dorsiflexion leads to an increased tendency for the heel to pull up out of the shoe. The Mitchell-Ponseti shoe effectively holds the position of these difficult feet without excessive, potentially painful tightening of the shoe.

A useful feature of the Mitchell-Ponseti brace is that windows are located at the counter so that proper placement of the heel can be easily determined (Figure 3, B). The brace has been modified with a quick-release mechanism to allow the sandals to be applied before inserting them on the bar. There are no published series on the use of this brace. However, we use it extensively at our institutions.

Dobbs Dynamic Brace

Chen et al[22] recently described an articulated FAO design that allows active flexion and extension of each leg separately while maintaining the necessary external rotation of the foot (Figure 4). The shoe consists of a custom-molded insert that fits into a solid ankle-foot orthosis. The foot is secured in the shoe with Velcro straps. The brace has a detachable bar to facilitate donning and doffing. Although this brace is more expensive than the Markell brace and the Mitchell-Ponseti brace, an early report suggests that it may improve brace wear compliance.[22]

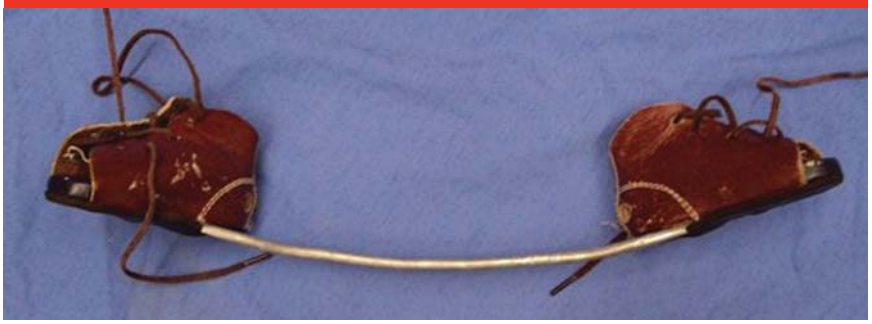
Steenbeek Brace

To our knowledge, the Steenbeek brace is the first to be designed and produced in the developing world. The outer sole is made of plywood, and the inner sole is made of card-

Figure 4

Photograph of the Dobbs dynamic foot abduction orthosis demonstrating the ability of the infant to flex and extend the knees while in the brace. (Reproduced with permission from Chen RC, Gordon JE, Luhmann SJ, Schoenecker PL, Dobbs MB: A new dynamic foot abduction orthosis for clubfoot treatment. *J Pediatr Orthop* 2007;27:522-528.)

Figure 5



Photograph of the Steenbeek brace, which was designed to be produced in the developing world to facilitate use of the Ponseti method worldwide. The leather shoes are attached to a simple metal plate that is riveted to a bar.

board. The upper, heel strap, heel counter, and tongue are made of leather. The shoes are attached to a simple metal plate that is riveted to the bar (Figure 5). Complete step-by-step instructions for making this brace are available on the Internet.[26] Similar FAOs are manufactured cheaply and locally using various designs in several countries, including Vietnam and Laos, allowing successful use of the Ponseti method in developing nations.

Factors Associated With Relapse

Several factors have been associated with relapse following initial correction of clubfoot deformity using the Ponseti method. These include nonadherence with postcorrective bracing,[2-4,6,8,12,13,16] parent education of a high school level or less,[3,8] annual family income of <$20,000,[3] and Native American ethnicity.[3] These factors may be useful to consider in individualizing the treatment approach.

Noncompliance with postcorrective bracing is the most consistent factor associated with relapse of deformity. Dobbs et al[8] reported that discontinuation of the brace "was the factor most related to the risk of recurrence," with an odds ratio of 183. In 2009, Avilucea et al[3] reported that failure of brace use was related to recurrence, with an odds ratio of 120. Haft et al[16] reported that failure to use the brace as prescribed resulted in a five times greater risk of relapse.

Abdelgawad et al[2] observed recurrence in 76% of feet in patients whose families were unable to use the FAO as prescribed versus 16% of feet in patients whose families adhered to the treatment protocol. Richards et al[13] noted that with proper brace use, 91% of the feet in their study had a good outcome and only 4 feet (4%) required surgical release. In those families that did not reliably use the brace, only 66% of the feet had a good outcome, and 27 feet (18%) required surgical release.

Several factors may play a role in influencing family acceptance of brace treatment. Parents frequently report that bracing makes their child fussy and limits movement.[3,13] Often, when an infant cries, the parents remove the brace. It is difficult to distinguish between a cry of pain and one of annoyance, and many parents assume the former. Frequent removal of the brace can promote relapse of the deformity, which may make it more difficult to properly apply the brace, which in turn may lead to increased discomfort and further protest from the infant, thereby creating a vicious cycle.

Other reasons for discontinuation of bracing include failure to understand the importance of bracing to the success of the treatment,[3] forgetting or confusing instructions, lack of continuity of care,[10] skin problems, transportation issues, lack of a support system at home, language barriers, and cultural factors.[3] Dobbs et al[8] speculated that psychosocial factors, such as the stigma associated with prolonged use of an orthosis, may affect compliance.

Strategies for Improving Postcorrective Orthosis Use

A recent review of research published in the past several decades showed that, for several medical conditions, as many as 40% of patients failed to adhere to treatment recommendations.[27] This failure represents

a major risk factor for poor health outcomes and carries a huge economic burden. Clinical research on the use of the Ponseti method for idiopathic clubfoot has shown rates of noncompliance with the use of a postcorrective FAO ranging from 32% to 61%.[2,3,8,13,16] These reported rates of compliance represent best case scenarios. No objective monitoring of brace use, such as with sensors, was employed in any of these studies. The success of the Ponseti method is dependent on the parents' ability to faithfully apply the postcorrective brace. Thus, it is important to develop strategies to enlist their cooperation (Table 3).

It is crucial to obtain full correction of the deformity before placing the infant in the FAO. The treating physician should use a device with which he or she is familiar. The importance of postcorrective bracing should be stressed to the family at the start of treatment and reinforced weekly at each cast change.[6,16] The parents should be encouraged to call or visit the clinic if the family experiences any problem.

At the initial brace application, the specific steps must be explained and important details reviewed. Written instructions tailored to the persons receiving them may be useful. Most experts recommend that the readability of patient educational material should be less than a sixth-grade level.[28] Often, noncompliance is the result of misunderstood or forgotten instructions. Anxiety has been shown to impair memory, so it is important to minimize anxiety in the parents or caregivers during the visit.[27] Before they leave the clinic, the family should demonstrate that they are comfortable applying the brace. A follow-up phone call from the clinic nurse the following day may be helpful in identifying difficulties the parents may be having. As recommended by Haft et al,[16] one of the authors of this paper (L.E.Z.) follows the family weekly until the clinic staff is certain that the infant is tolerating the brace.

At each visit to the clinic, the treating physician should assess whether the parents are following the recommended brace protocol. The physician should ask how many hours the infant is using the brace each day and whether there are any problems. The brace should be inspected for signs of appropriate wear. Noonan[29] observed that a slight narrowing of the ankle represents the "hallmark of a compliant family." This finding is especially useful early in the treatment course when the patient is using the brace full-time (Figure 6). If the family is noncompliant, the physician should refrain from criticizing them so as to maintain trust in the therapeutic relationship. Instead, the physician should inquire about rea-

Table 3

Strategies to Improve the Use of Postcorrective Bracing Following the Management of Clubfoot With the Ponseti Method

Obtain and maintain complete correction of the deformity
At the beginning of treatment and at each subsequent clinic visit, discuss with the family the importance of postcorrective bracing in achieving a successful outcome
Carefully review with the family the specific steps to properly apply the brace and provide written instructions
Recommend that the brace be applied whenever the child is placed in the crib or bed to sleep so that the child associates the brace with nap time and bedtime
Encourage calls and visits to the clinic to address any problems with the orthosis
See the family weekly after the brace is applied until the physician and/or clinic staff is certain that the infant is tolerating the device
Assess brace adherence at each patient visit and avoid criticism of the parents when addressing problems that may have arisen
Schedule regular follow-up appointments and use telephone calls or certified letters to remind parents of missed appointments
Address skin problems immediately

Figure 6

Photograph demonstrating the appearance of the feet following 6 weeks of full-time brace wear applied by an adherent family. Note the slight narrowing of the soft tissue in the region of the ankles (arrows). (Reproduced with permission from Kessler JI: A new flexible brace used in the Ponseti treatment of talipes equinovarus. *J Pediatr Orthop B* 2008;17:247-250.)

Figure 7

Photograph demonstrating ulceration of the skin over the heel of the unaffected foot caused by improper application of a foot abduction orthosis. Brace use was discontinued on the affected foot and a cast was applied instead to allow the skin on the unaffected foot to heal.

sons for not using the brace and address those issues.

One of the more common reasons cited by parents for removing the brace is sporadic crying of the infant. We recommend that the parents apply the brace whenever the child is placed in the crib or bed to sleep so that wearing the brace becomes an invariable part of going to bed. This consistency seems to improve acceptance of the brace by both patient and parents.

Engaging the infant in play while she or he is in the brace is often helpful in alleviating crying. A strategy that is useful with orthoses with quick-release shoe attachments involves applying the shoe portion of the braces before the child falls asleep and attaching the bar once the child is sleeping. However, if the child continues to cry and cannot be easily consoled, the parents should be instructed to remove the brace to inspect the skin. Before the parents leave the clinic, the surgeon should ask them to apply the brace to confirm that the shoes fit properly and the length of the bar is appropriate.

Regular follow-up visits are important for early identification and treatment of recurrent deformity. In general, once the treating physician is certain that the family is using the brace properly, the patient is seen after 6 weeks and 12 weeks of full-time brace use. After switching to nighttime and nap-time use, the patient is followed every 3 to 4 months during the first year. In subsequent years, the patient may be followed every 4 to 6 months, depending on the past reliability of the family. Telephone calls and certified letters are helpful in notifying caregivers of missed appointments.

Skin problems should be addressed immediately. Improper application of the FAO can lead to skin irritation and ulceration (Figure 7). Superficial skin problems can usually be managed with brace modification, by temporary use of moleskin to cover areas that are prone to irritation, or by applying a second pair of socks.[29] The Mitchell-Ponseti FAO has pressure saddles to help alleviate irritation of the dorsal skin. Full-thickness sores are uncommon and should be managed by discontinuing the brace until the sores have fully healed. Casting the feet during treatment of a significant ulcer prevents relapse. The cast may be windowed for dressing changes or the ulcer may be covered by the cast, depending on the cleanliness of the ulcer and its location.

Parents who are well-informed and involved in the treatment of their child tend to be compliant with postcorrective bracing. Many parents have found information about the Ponseti method online.[30] Several educational sites have proved to be valuable by encouraging parents to seek physicians who use the Ponseti method. Several parent support-group Web sites are available, as well. Although some provide helpful information, others are of questionable merit and may dispense bad advice. The surgeon should direct parents away from sites with suspect information and toward online resources that he or she deems to be most helpful. Internet-educated parents tend to be more compliant with postcorrective bracing.[8]

Summary

The successful use of the Ponseti technique to correct clubfoot deformity has been demonstrated in several centers worldwide,[2-16] and satisfactory long-term function of feet corrected using this technique has been demonstrated.[20] Although initial correction of the deformity can be reliably achieved, the real challenge in the successful use of the Ponseti method lies in preventing relapse. The key to maintaining initial correction of the foot lies in educating and encouraging parents in the proper use of the postcorrective brace.

References

Evidence-based Medicine: Levels of evidence are listed in the table of contents. In this article, reference 3 is a level I study. References 8, 13, 16, and 19 are level II studies. References 9-11 are level III studies. References 2, 5-7, 12, 14, 15, 17, 20-24, and 30 are level IV studies. Reference 25 is level V expert opinion.

Citation numbers printed in **bold type** indicate references published within the past 5 years.

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