Review Article

Management of the Relapsed Clubfoot Following Treatment Using the Ponseti Method

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Abstract

The Ponseti method to treat idiopathic clubfoot deformity has proven to be reliable, and several centers have reported excellent outcomes. Although the method has been dependable in obtaining initial correction of the foot, relapse rates ranging from 26% to 48% have been reported. When a relapsed deformity is detected early, treatment with a short series of manipulations and cast applications followed by resumption of postcorrective bracing may be all that is required to regain and maintain correction. In patients aged >2.5 years, especially those who may be refractory to further brace use, deformity correction by preoperative cast treatment, followed by anterior tibial tendon transfer to the third cuneiform, is a good treatment option. Other procedures, such as combined cuboid-cuneiform osteotomy, posterior ankle and subtalar release, and, rarely, comprehensive posteromedial release or correction by gradual distraction, may be useful in select patients.

The Ponseti method of clubfoot correction involves a series of weekly manipulations of the foot, followed by the application of long leg casts. After 4 to 6 weeks, a percutaneous Achilles tenotomy is needed in most patients to completely correct the equinus component of the deformity. After correction is achieved, a postcorrective brace known as a foot abduction orthosis (FAO) is used to prevent a recurrence of the deformity. The FAO is worn full time for 3 months, followed by night and naptime use.

Ponseti[1] observed that, regardless of the method used to obtain correction, "the clubfoot has a stubborn tendency to relapse." He believed that relapse, or recurrence, resulted from the same pathology that caused the original deformity. A relapse usually involves equinus of the ankle and varus of the subtalar joint, although any of the components of a clubfoot deformity may reappear.[1,2] Relapses appear most frequently and most quickly during the first 5 years of life, during a period of rapid growth of the foot. Ponseti[1] and Dietz[2] have noted that a relapsed deformity is seen only rarely in patients aged ≥5 years and is extremely rare after age 7 years. A relapsed deformity is a common problem that has been reported in 26% to 48% of patients undergoing treatment with the Ponseti method[3-9] (Table 1). Because this problem does not resolve spontaneously, early detection and prompt treatment of the affected feet are warranted.

Cause of Relapse

In addition to the original clubfoot pathology, other causes of relapse

Table 1

Relapsed Deformity in Clinical Series Using the Ponseti Method

Study	No. of Patients	No. of Feet	Relapses (%)
Avilucea et al[3]	100	138	26
Dobbs et al[4]	51	86	31
Haft et al[6]	51	73	41
Ramírez et al[7]	53	73	33
Richards et al[8]	176	267	37
Zionts et al[9]	57	84	48

have been suggested. Ponseti[1] suggested that relapsed deformity was not the result of incomplete correction. Dietz[2] noted, however, that AP radiographs often showed incomplete correction of a medially displaced navicular bone and a diminished talocalcaneal angle in patients with dynamic supination of the forefoot, a common component of a relapsed foot.

Some investigators have suggested that a muscle imbalance may play a role in the development of a relapsed deformity.[10,11] Gelfer et al[12] recently reported that poor evertor muscle activity was associated with recurrent deformity. Other evidence indicating a role of muscle imbalance in some clubfoot relapses recently was provided by Moon et al,[13] who found extensive soft-tissue abnormalities on MRI, including intramuscular fat replacement and unique patterns of hypoplasia in specific muscle groups in a cohort of clubfoot patients experiencing multiple relapses, compared with a group that responded appropriately to the initial treatment.

Factors That May Predispose to Relapse

A careful evaluation of the infant before the start of the cast phase of treatment may help identify factors that could predispose the foot to treatment resistance. Flexion contracture of the wrist and fingers may suggest a diagnosis of distal arthrogryposis. The spine should be evaluated for cutaneous signs of dysraphism. Edmonds and Frick[14] described the drop toe sign, a resting position of the toes in plantar flexion along with no active toe extension in response to plantar stimulation of the foot, which was associated with absent function of the anterior and lateral compartment muscles. Patients with this clinical sign were predisposed to relapse, a finding that recently has been confirmed.[13]

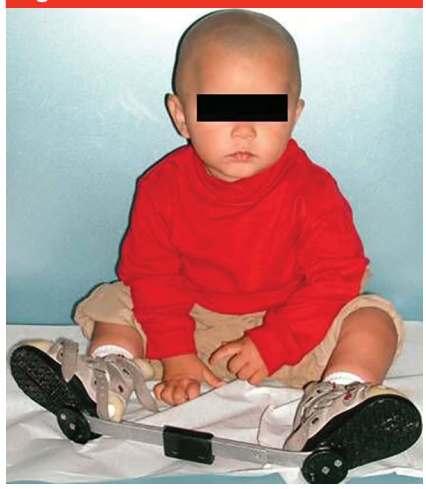
Preventing Relapses

Several studies have demonstrated the importance of the appropriate use of a postcorrective FAO to prevent recurrent deformity.[3,4,6-8,15,16] Ponseti[17] postulated that failure to use the brace to maintain the corrected clubfoot in external rotation allowed the pull of retracting fibrosis in the ligaments and tendons around the medial aspect of the foot and ankle, causing the deformity to return.

Several types of FAOs currently are available, but they have many features in common. In general, these braces consist of a bar with attached shoes that holds the affected foot in approximately 60° to 70° of external rotation. For the patient with unilateral deformity, the unaffected foot is positioned in 40° of abduction. The shoes are positioned at shoulder width for comfort. The ends of the bar may be adjusted to allow 5° to 10° of dorsiflexion (Figure 1). Because foot abduction is important in maintaining correction of clubfeet treated using the Ponseti method, simple ankle-foot orthoses without an attached bar have proven ineffective.[18]

Several strategies may help to influence a family to accept brace treatment (Table 2). The importance of the brace should be emphasized at the prenatal consultation (if sought), at the outset of treatment, and at each subsequent visit. The parents must be informed that failure to use the FAO as prescribed likely will lead to additional cast applications or surgery for the child. When the brace is first applied, the clinician should ask the family to apply the brace to ensure the application is performed properly. If the parents have difficulty applying the brace, it may be

Figure 1



Clinical photograph showing a patient in a foot abduction orthosis. The brace consists of a bar with attached shoes that hold the affected foot in approximately 60° to 70° of external rotation. The shoes are positioned at shoulder width for comfort. The ends of the bar may be adjusted to allow 5° to 10° of dorsiflexion.

prudent to ask the family to return in 1 week to make certain they are using the brace correctly. Because the infant is more likely to accept the brace if it is applied in a consistent manner, the clinician should recommend that the device be applied whenever the infant is put in the crib or bed for sleep. Skin problems should be addressed promptly to avoid lapses in brace use. Lastly, the clinician should refrain from criticizing the family if noncompliance becomes evident.

The clinician usually must rely on parent reporting to determine the adherence to brace use. A recent study by Morgenstein et al[19] used pressure sensors to objectively monitor brace wear in a group of infants beginning FAO use. They found a mean adherence rate of 91.7% during the first month of use, whereas the rate declined to 77.1% by the third month. The study suggests that parents or other caregivers may overestimate the amount of bracing their child is receiving. Future research along these lines may help to better determine the number of hours of brace use needed to minimize relapsed deformity.

Ponseti[1] observed that a relapse often occurs when the infant begins to walk because the parents then become less insistent that their child wear the brace as prescribed. It is important that the treating clinician and family understand that walking does not substitute for bracing. Accordingly, it is important to be vigilant during this time because, as Dietz[2] has noted, most feet that relapse after walking age eventually require a tendon transfer when the child is old enough to undergo the procedure.

The age at which bracing can be discontinued is controversial. The senior author (L.E.Z.) prescribes nighttime bracing with the FAO until age 5 years based on the work of Ponseti, which showed that the risk of recurrence is highest in the first 5 years of life. The duration of brace wear at other centers ranges from 2 to 5 years, but most centers recommend brace wear until age 3 to 4 years. Further study is required to identify the necessary length of brace treatment in children with idiopathic clubfoot.

Table 2

Strategies to Encourage Consistent Brace Use

Stress to the parents the importance of postcorrective bracing in achieving a successful outcome at the prenatal consultation, the first clinic visit, and all subsequent visits.
Recommend that the brace be used at night and at nap time so the infant will associate bracing with sleep.
When the brace is initiated, have the parents apply and remove it while the clinician remains in the room.
If concerns exist about the parents' ability to apply the brace consistently, ask the family to return the following week to make certain no problems with the brace or skin have occurred.
Promptly address any skin problems.
Refrain from criticizing the family if noncompliance with bracing becomes apparent.
Remind parents that walking does not substitute for bracing; urge continued use of the brace at night and at nap time when the child begins to walk.

Presentation and Treatment of Relapsed Deformity

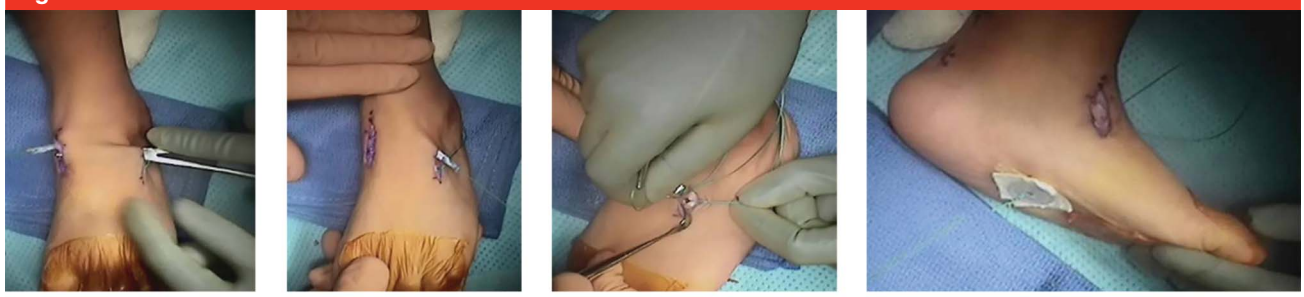
Relapses are managed more easily and effectively if they are recognized promptly. After postcorrective bracing is started, the patients should be seen at 3- to 4-month intervals, especially during the first 2 years, when growth of the foot is rapid. It is very important for the clinician to document the amount of ankle dorsiflexion, heel varus, and abduction of the foot at each follow-up visit.

The parents of an infant in whom a relapse is developing often report difficulty getting the child's heel all the way down into the back of the shoe or sandal of the FAO. Some report having to apply the brace several times a day because of slippage and sometimes report that, after applying the brace before bedtime, they find it has slipped off by morning.

The earliest sign of a relapse is less dorsiflexion than that noted during the previous examination. In older infants, some mild forefoot adductus, cavus, heel varus, and limited abduction of the foot may be present. If the child has reached walking age, the gait may show increased contact of the lateral border of the forefoot during stance phase, varus of the heel, an inward deviation of the foot to the forward line of progression, and dynamic supination of the forefoot during swing phase (See Videos, Supplemental Digital Content 1, http://links.lww.com/JAAOS/A26, Supplemental Digital Content 2, http://links.lww.com/JAAOS/A27, and Supplemental Digital Content 3, http://links.lww.com/JAAOS/A28, Management of the Relapsed Clubfoot Following Treatment Using the Ponseti Method). All of these findings may be present to varying degrees.

A mild loss of dorsiflexion that occurs early in the course of postcorrective bracing may be managed with a trial of home stretching exercises and an increase in the amount of time spent in the FAO. If the ankle is unable to be dorsiflexed passively 10° or cannot fit easily into the brace,

Figure 2



Intraoperative photographs demonstrating anterior tibial tendon transfer to the third cuneiform. **A,** The tendon is detached from its insertion, and a whip suture is placed to secure it. **B,** A subcutaneous tunnel is created, and the tendon is pulled through the tunnel. **C,** After Keith needles have been applied to the ends of the sutures, the sutures are passed through the drill hole in the third cuneiform through the plantar aspect of the foot. **D,** The suture ends are tied over a padded button. The ankle should lie in approximately 10° of dorsiflexion.

more formal treatment of the relapse should begin.[2]

The original correction of the foot generally can be regained by further manipulation and cast application done in two to three sessions, 1 to 2 weeks apart. The technique of manipulation and cast application used to regain the correction of a relapsed deformity is the same as that used to originally treat the clubfoot. A repeat tenotomy generally is indicated if at least 15° of dorsiflexion cannot be achieved in this manner.[1]

Once correction of the foot is regained, use of the FAO is reinstituted. The protocol used to resume bracing should be based on the age at which the relapse occurred. Generally, full-time bracing is recommended for infants who relapsed early in the treatment course. In older infants, the orthosis is resumed for a minimum of 12 to 14 hours and gradually is tapered to night and naptime use if the correction is maintained. A relapsed deformity in infants or toddlers may occur more than once. Each time the problem is identified, the foot should be treated in the same manner.

An anterior tibial tendon transfer (ATTT) may be considered in patients who experience a relapsed deformity and are aged ≥2.5 years.[1,2,20] By this age, sufficient ossification has occurred in the third cuneiform to allow bone-to-tendon healing, which is thought to be desirable. Although bracing may be reinstituted after regaining correction of the foot in these older patients, a tendon transfer may be the best option for those who have experienced multiple relapses, which indicate that the family is having difficulty using the FAO reliably. Following this procedure, foot abduction bracing is no longer needed because the everting force of the transferred tendon maintains correction of the foot.[2]

Before performing an ATTT, the original correction of the foot must be recovered. This step is achieved in most patients by further manipulation and cast application done in two to three sessions, 1 to 2 weeks apart. If 10° of dorsiflexion cannot be achieved, an Achilles lengthening procedure should be performed at the time of surgery.[2] Rarely, a posterior ankle and subtalar release or plantar fasciotomy is needed to achieve sufficient correction of the foot and ankle.

Ponseti recommended that the tibialis anterior tendon never should be split, to avoid weakening its eversion power; instead, the tendon should be transferred to the third cuneiform to reduce the risk of overcorrection.[1,2,10,17] This observation has been reinforced by biomechanical studies.[21,22]

An ATTT is a straightforward procedure, although several minor modifications have been described in the literature. The method and postoperative management described are those used by the senior author (L.E.Z., Figure 2). A 3- to 4-cm incision is made over the dorsomedial aspect of the foot in line with the anterior tibial tendon beginning just distal to the medial aspect of the navicular and extending proximally. The tendon is released from its insertion on the base of the first metatarsal and is freed of any soft-tissue attachments that would tether it during the transfer. Care should be taken to maintain the integrity of the inferior extensor retinaculum. A heavy nonabsorbable suture is placed in the distal end using a whip or Bunnell stitch. A second 3-cm incision is made over the third cuneiform located at the base of the third metatarsal. The dorsal surface of the bone is exposed by blunt dissection just lateral to the extensor

digitorum communis. Precise localization of the center of the bone can be confirmed by placing a Keith needle or 18-gauge needle into its dorsal aspect and obtaining an image. A drill hole large enough to allow passage of the tendon is made in the center of the bone. It is important to confirm that the hole passes through the plantar aspect of the bone.

A large, straight hemostat is passed under the subcutaneous tissue from the incision over the cuneiform to the medial incision in a proximal and medial direction. The suture ends are grasped with the hemostat, and the tendon is brought into the lateral wound. The suture ends holding the anterior tibial tendon are threaded onto Keith needles. The needles are passed through the third cuneiform, out through the plantar aspect of the foot, and then through a piece of Xeroform gauze (DeRoyal), a thick felt pad, and a button. It is important that the first needle remain in the hole before passing the second needle to avoid cutting the suture with the second needle. The ankle is dorsiflexed, and the hindfoot is everted while the suture is tied over the button. The position of the ankle is assessed; it should lie in approximately 10° of dorsiflexion. To supplement the fixation, the tendon is sutured to the dorsal periosteum or bone of the third cuneiform.

With the knee flexed 90°, a long leg cast is applied, to discourage weight bearing for 6 weeks; at that time, the cast and button are removed. The patient is placed in an articulating ankle-foot orthosis worn full time for an additional 6 weeks to limit the loss of dorsiflexion while the transferred muscle regains strength. At 3 months following surgery, the brace can be used at night only until it is outgrown.

When drilling through the third cuneiform, nerve and vascular structures on the plantar aspect of the foot are potentially at risk of injury. Based on a cadaver study, Radler et al[23] recommended aiming the drill at the middle of the plantar aspect of the foot to minimize the risk of nerve damage when performing an ATTT. The authors also suggested using blunt needles when passing the tendon through the bone.

Studies of mid-term outcomes of ATTT have shown the procedure to be effective for correcting dynamic forefoot supination and for maintaining the clinical improvement of ankle dorsiflexion and subtalar eversion.[10,11,24] Similarly, plantar pressure testing of patients who underwent an ATTT showed findings suggestive of better foot alignment and a more even pressure distribution throughout the foot.[25] Generally, it was believed that a tendon transfer would obviate the need for further use of the FAO and that the foot would not be prone to later relapse. Two recent studies have reported relapsed deformity following an ATTT; however, this problem may be more likely to occur in patients undergoing the transfer at a younger age.[26,27] These studies suggest that patients who undergo tendon transfer should continue to be monitored.[26,27]

Satisfactory long-term outcomes of patients who underwent ATTT have been reported. Cooper and Dietz[28] reported good outcomes in 45 patients who had 71 clubfeet treated using the Ponseti method and were followed until an average age of 34 years; 38 feet (54%) had undergone an ATTT. In a more recent study by Holt et al,[29] the authors compared 14 clubfoot patients treated with Ponseti casting who subsequently underwent an ATTT with 21 patients who were treated by Ponseti casting alone. The average age of the patients was 47 years. The authors found that no patient in either group had a later additional relapse, and outcome questionnaires showed no statistically significant difference between the groups ($P > 0.18$ for the Foot Function Index and $P = 0.5$ for the Laaveg-Ponseti questionnaire).

Other Procedures to Manage Residual Foot Deformity

Several bone and soft-tissue procedures have been described to correct residual clubfoot deformity. Many of these procedures have been described for the treatment of deformity in feet that have undergone surgical releases, in rigid syndromic feet, and in feet with an underlying neurologic condition, but these procedures may have applicability in the occasional idiopathic clubfoot that does not correct fully using the Ponseti method.

Osteotomies of the Midfoot

The combined cuboid-cuneiform osteotomy may be indicated for persistent or recurrent adduction of the forefoot that is unresponsive to manipulation and cast application. This deformity has been referred to as the "bean-shaped foot." The surgery is performed ideally in children aged 4 to 9 years who have a well-formed medial cuneiform ossific nucleus.[30,31] The technique involves separate incisions over the medial cuneiform and the cuboid. A closing wedge osteotomy is performed through the cuboid, and the medial opening wedge osteotomy is performed through the cuneiforms (Figure 3).

More recently, Elgeidi and Abulsaad[32] reported the results of combining a closing wedge osteotomy of the cuboid, an opening wedge osteotomy of the medial cuneiform, and a transcuneiform osteotomy. Similarly, Mahadev et al[33] used a closing wedge osteotomy of the cuboid in combination with a transcuneiform osteotomy, leaving the medial cuneiform intact. The authors noted that

Figure 3

A B

A, Preoperative standing AP radiograph of the feet showing residual forefoot adduction and supination of the right foot. **B,** Postoperative standing AP radiograph depicting the same feet following cuboid-cuneiform osteotomy and anterior tibial tendon transfer.

this technique achieved correction of the residual forefoot supination and the forefoot adduction. In addition, because the procedure did not involve osteotomy of the medial cuneiform, it could be used in patients aged <5 years.

Distal Tibial Hemiepiphysiodesis

Al-Aubaidi et al[34] described anterior distal tibial epiphysiodesis using Richards staples or Eight-Plates (Orthofix) to correct recurrent equinus. The authors noted that, although the anterior distal tibial angle improved, no correlation was found between the radiographic changes and clinically measured dorsiflexion, which showed minimal improvement. They postulated that the posterior soft-tissue contracture was resistant and that the anterior capsule stretched out as the anterior aspect of the distal tibia moved proximally from the anterior aspect of the talus. Based on this study, the effectiveness of this method warrants further investigation before its use can be advocated.

Posterior Ankle and Subtalar Release

Posterior ankle and subtalar capsulotomy has been used to correct residual ankle equinus but has been associated with ankle stiffness. Jauregui et al[35] described the outcome of 16 patients who had posterior ankle and subtalar capsulotomy followed by cast immobilization for an average of 26 days, followed by immediate physical therapy consisting of passive stretching exercises for 10 minutes 2 to 3 times daily, which was administered by the parents. The authors noted improved dorsiflexion, which was maintained after a mean follow-up of 61.8 months. Although this report suggests that short-term improvement of ankle equinus can be achieved by ankle capsulotomy and early mobilization, the long-term efficacy of this procedure and the precise period of postoperative immobilization that is necessary warrant additional study.

Posteromedial Release

Since the wide adoption of the Ponseti method, the use of extensive soft-tissue procedures to treat idiopathic clubfoot deformity has declined.[36] A review of several recent clinical series shows that a posteromedial release (PMR) ultimately was needed in 0% to 16% of patients treated with the Ponseti method. Most series reported <5% of patients requiring release surgery[4-6,8,9,15,16] (Table 3).

A PMR generally involves release of the tight soft tissues by lengthening the tendons and releasing the joint capsules around the posterior, medial, and lateral aspects of the foot. These procedures vary based on which structures specifically are addressed. Although the short-term results of PMR surgery to treat clubfoot are encouraging, the long-term results include the development of pain, stiffness, and

weakness in late adolescence and early adulthood.[37-39]

Despite the overall success of the Ponseti method in achieving clubfoot correction, certain patients may require a PMR, including a small percentage of patients whose parents are unwilling to allow repeated cast and brace treatment and patients with feet that are otherwise refractory to the Ponseti method. Recently, acceptable outcomes of PMR surgery have been reported in two centers, albeit with two different approaches. Hsu et al[40] described the outcomes of 80 patients with 120 idiopathic clubfeet who were managed with aggressive posterior medial and lateral releases and followed for an average of 21 years. The authors emphasized the need for circumferential release of the subtalar, talonavicular, and calcaneocuboid joint, leaving only the deep deltoid ligament intact and correcting the malrotated talus. In patients with a unilateral clubfoot, a statistically significant reduction was observed in the range of motion of the involved ankle and subtalar joints ($P < 0.0001$). Later additional surgery was needed in 32 feet (27%). Based on outcome questionnaires, the authors concluded that their approach yielded acceptable results.

Mahan et al[41] described the outcomes of a la carte posteromedial and lateral release surgery for clubfoot in 148 patients. The mean follow-up was 9.7 years. The authors emphasized preservation of the deltoid ligament and the interosseous ligament. Later additional surgery was deemed necessary in 13 feet (17.6%). Despite the relatively short follow-up, the authors concluded that this judicious approach to release surgery may lead to satisfactory results in some patients. Because varying degrees of clubfoot correction may be obtained using manipulation and cast application, it would seem logical that an a la carte approach to release surgery, limited to addressing the remaining deformity, would be most beneficial in these patients to preserve as much motion and strength in the foot as possible.

Table 3

Clinical Series of Ponseti-treated Patients Undergoing Posterior Medial Release

Study	No. of Feet	No. of PMRs (%)
Bor et al[15]	111	2 (2)
Dobbs et al[4]	86	0 (0)
Göksan et al[5]	134	4 (3)
Haft et al[6]	73	10 (14)
Morcuende et al[16]	256	1 (0.4)
Ramírez et al[7]	73	4 (5)
Richards et al[8]	267	42 (16)
Zionts et al[9]	84	0 (0)

PMR = posterior medial release

Ilizarov Correction

Severe, recalcitrant clubfoot deformities also can be treated with gradual correction using Ilizarov principles.[42,43] A combination of osteotomies and soft-tissue release can be used to achieve some initial flexibility, which then can be exploited with gradual correction into a plantigrade position. Multiplanar correction is achieved by first obtaining a stable base of fixation within the tibia/fibula segment, followed by careful placement of fixation points, motors, and hinges that results in gradual correction of each of the component deformities of the clubfoot. Following gradual correction, further soft-tissue release with or without arthrodesis may be required to maintain correction and prevent recurrence. Although this technique has been used successfully in many cases of severe, recurrent clubfoot deformity, the psychological impact of Ilizarov treatment must be considered carefully, and rehabilitation can be quite challenging.

Summary

A relapsed deformity is a common problem associated with the Ponseti method of clubfoot treatment and usually results from the family's lack of adherence to postcorrective bracing. Compliance with bracing remains a difficult challenge for clinicians, but some steps may be taken to improve brace use. A relapsed deformity will not resolve spontaneously; therefore, early detection and prompt treatment of the feet are warranted. Early treatment of a mild relapse may consist of stretching exercises and increased time in the brace. If the relapse is more advanced, serial manipulations, cast applications, and a possible repeat tenotomy followed by resumption of bracing may be used to regain and maintain correction. In patients who experience a relapsed deformity and who are aged >2.5 years, an ATTT may be advisable. ATTT has been found to be a reliable treatment approach, with excellent long-term outcomes reported in patients who have undergone this procedure.

For the occasional patient whose foot does not respond to manipulation and cast application alone,

osteotomies to correct residual deformity of the forefoot and posterior ankle and subtalar releases to correct residual equinus may be needed. Since the wide adoption of the Ponseti method to treat idiopathic clubfoot, the use of posteromedial release surgery has declined sharply. Rarely, release surgery may be needed in a patient who does not respond to the Ponseti technique, however. If necessary, a more judicious a la carte approach to release surgery may be the best approach to preserve the strength and motion of the foot.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 3 and 13 are level I studies. References 4, 6, 9, 25, 26, and 28 are level II studies. References 8, 24, 27, 29, 35, 37-39, and 41 are level III studies. References 5, 7, 10-16, 20, 30-34, 40, 42, and 43 are level IV studies. Reference 2 and 17 are level V expert opinion.

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