

A method for the early evaluation of the Ponseti (Iowa) technique for the treatment of idiopathic clubfoot

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The Ponseti casting technique is reported to have a high success rate in the treatment of idiopathic clubfoot. Non-operative treatment of clubfoot provides a lower complication rate, less pain, and higher function as the patient ages than operative treatment. To demonstrate serial post-treatment change in clubfeet over time, three clubfoot rating systems were utilized in the current study. Patients compliant with the Ponseti technique and treated before the age of 7 months, had a 92% success rate at an early follow-up after casting was completed. It is not the purpose of this article to analyze the long-term clubfoot treatment result but to establish tools which can be used to judge initial success with the Ponseti technique. Complications are few and minor, limited to equipment used and cast

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Introduction

Historically, treatment of clubfoot is challenging. Lloyd-Roberts wrote in 1964, 'clubfoot will doubtless continue to challenge the skill and ingenuity of orthopaedic surgeons, but so long as much fundamental knowledge eludes us, our practice will continue to be flavored with a certain ingenious empiricism. Art has had its day. Let us now resolve to concentrate on the science of orthopaedic surgery' [1].

The prevalence of clubfoot has been reported in the orthopaedic literature to be two per 1000 births [2], with the definitive treatment being largely surgical. The majority of all clubfeet in reported series end in surgical releases, primarily in patients between the ages of 3 months and 1 year, despite early serial casting [2].

The most common surgical procedure is a soft tissue release of those structures that create the deforming forces in the clubfoot. The primary disadvantages of soft tissue release in the young clubfoot patient are a high complication rate and, when complications do occur, they are difficult to treat. The most common complications are recurrence of the deformity, with an average rate of 25% (13–50% range) [2–4]. Other complications include infection, neurovascular injury, loss of limb and over-correction [2]. It is to avoid the high recurrence rate previously perceived by the authors following soft tissue clubfoot release and the difficult revision procedures

necessary for salvage that the Ponseti method was considered and tested statistically.

The serial casting technique most often cited was described by Kite [5]. His reported success was greater than 90%. However, consistent reproducibility of this rate has not been noted in many studies. Ponseti described another fundamentally different casting technique, which is coming under greater scrutiny after being initiated at the University of Iowa in 1950 [6,7]. However, the techniques, as described by Ponseti and Kite, have not been analyzed by any statistical means. Our purpose was to describe the early results of the Ponseti (Iowa) casting technique in a center specifically designed to serially monitor the outcomes with previously established rating methods.

Method

As part of our clubfoot center, care is taken to exactly duplicate the Ponseti technique.

Description of the Ponseti casting technique

A brief description of the Ponseti casting technique is provided here. For a more detailed description, the reader is referred to the published works of Ignacio V. Ponseti MD [8–10].

While both Kite's and Ponseti's techniques analyze the deformity of the clubfoot in terms of its component parts,

there is a distinctly different approach to each part. Both state the components to include the midfoot adductus, cavus, and hindfoot varus and equinus; however, Kite's technique attempts to correct the deformity using the calcaneocuboid joint as the fulcrum point [2]. Ponseti's technique, on the other hand, centers around the talonavicular joint and, unlike the Kite method, there is no direct manipulation of the calcaneus out of its varus position [2,3,6,10]. The Ponseti technique utilizes five basic cast types, each of which has specific purposes in the treatment scheme [8,10]. The actual number of casts used on a foot vary in accordance with the response to each subsequent cast.

The first cast attempts to correct the relative pronation of the first metatarsal and cavus by maximally supinating the foot but without dorsiflexion. This correction is achieved by bringing the first metatarsal in line with the varus of the hindfoot which is, by Ponseti's description, pronated in relation to the other metatarsals. While the first cast is quite counterintuitive, the second, third, and fourth casts use sequentially increasing amounts of abduction to achieve the maximal amount of correction prior to addressing the hindfoot equinus. At no point during the casting is there direct manipulation of the calcaneus. Instead, Ponseti's theory is that the calcaneus moves out of its varus position during the manipulation.

After correction of the adductus, cavus and hindfoot varus, if there is easy, passive dorsiflexion of the foot to 15° above neutral, a final cast is placed on for 3 weeks in a dorsiflexed position. If this passive dorsiflexion is not possible with the examiner using the pressure of one finger, a percutaneous release of the Achilles tendon is performed, and the final cast is placed for 3 weeks. After the 3-week time period, the feet are placed in a foot abduction orthosis modified with a 15° bend to maintain the correction achieved. The foot abduction orthosis is worn full time for 3 months or until the child is cruising, whichever event occurs first. Afterwards, the bar is kept in place only at night until the child is 3–4 years of age.

Description of the clubfoot clinic protocol

The purpose of the clubfoot center, established in December 1999, at the Hospital for Joint Diseases, was to scientifically detail our results with the Ponseti casting technique. A pediatrician evaluated each patient enrolled in the clubfoot center, and a detailed birth history was obtained. Any prior casting treatment was also noted. Prior to initiation of treatment, parental instruction and teaching was performed. All patients had their first casts placed on their first visit.

To chart progress or decline during the course of treatment of each patient, three described clubfoot rating methods were utilized: (1) a modified Dimeglio/

Bensahel [11] method, (2) the Catterall/Pirani [12,13], and (3) a modification of the functional rating developed at the Hospital for Joint Diseases [3]. The Dimeglio/Bensahel classification incorporated eight components: equinus, varus, position of the talo-calcaneal-forefoot unit, forefoot adduction, and the presence of abnormal musculature, cavus, a medial crease, and a posterior crease. A total of 20 points was possible, the higher the number, the more rigid the clubfoot (Fig. 1).

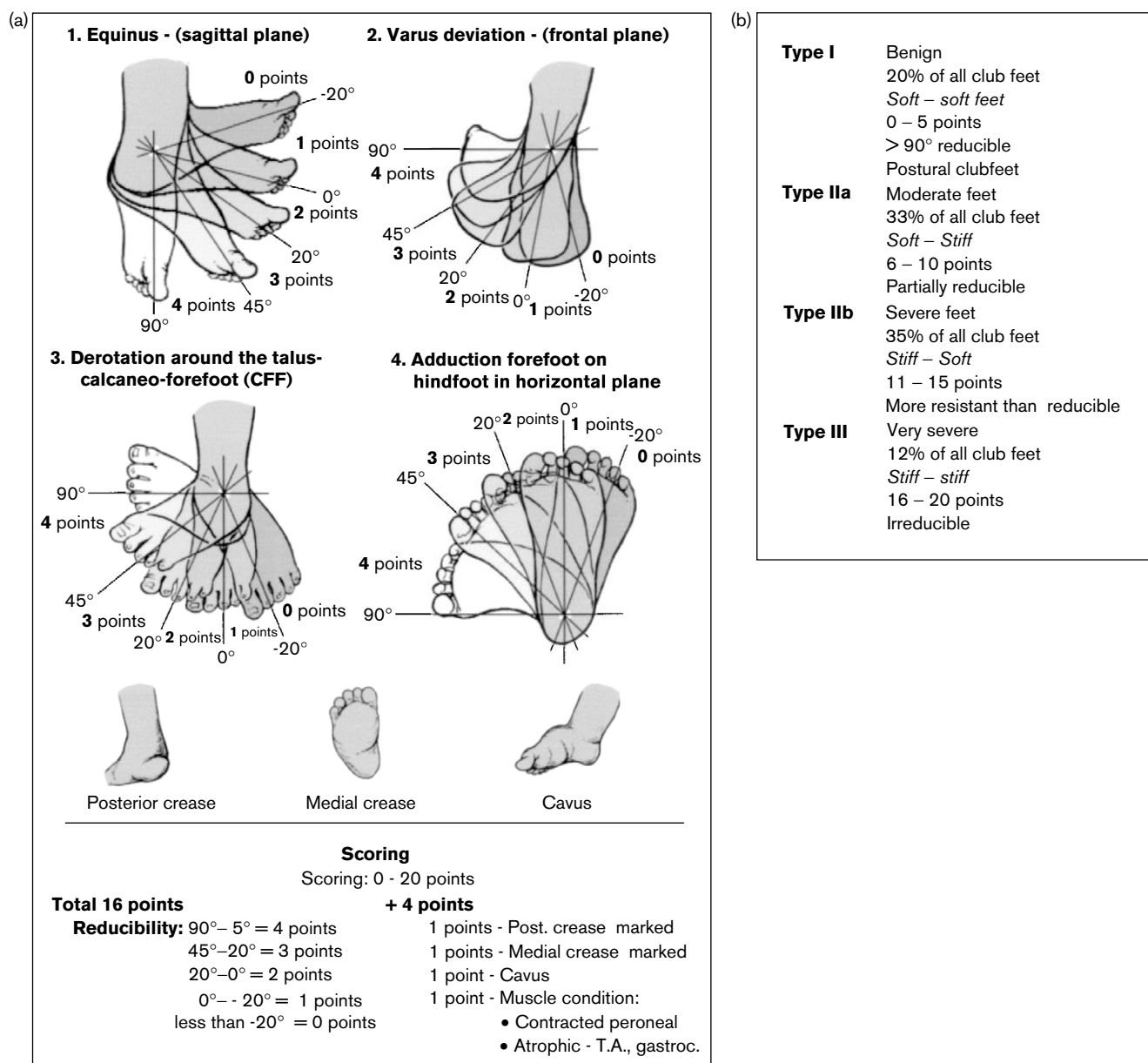
The Catterall/Pirani method utilized by our clinic was the most recent version; it incorporated six components rather than the originally described 10. These items were the position of the lateral border of the foot, amount of medial and posterior creasing, the emptiness of the heel, degree of palpation of the lateral head of the talus, and the extent of ankle dorsiflexion passively. Again, similar to the Dimeglio/Bensahel scoring, the higher the score, the more rigid was the clubfoot, with six being the highest possible sum (Fig. 2). The Hospital for Joint Diseases Functional Rating involved a maximum score of 60 (best), with six components being rated. These were ankle dorsiflexion and heel position with maximum passive manipulation, quantity of subtalar motion, the forefoot appearance, the amount of medial creasing, and the quantity of cavus (Fig. 3).

It was hoped that consistency between the methods would note trends during the treatment of each clubfoot. For ease of recording of our data, a single sheet was created to contain all relevant information. Posters of each rating system were placed in each examining room to minimize variation in scoring (Fig. 4). To maintain all data in a succinct manner in our records, derotation of the talo-calcaneo-forefoot in the Dimeglio/Bensahel rating system was characterized as supination/pronation but with the same scoring.

All individuals involved in casting and rating were instructed in the rating methodology. All castings were performed by or under the direct supervision of either pediatric orthopaedic attendings or pediatric orthopaedic fellows to allow for consistency in the casting and rating. At each visit to the clinic, all feet were rated prior to each casting or tenotomy and prior to placement in foot abduction orthoses.

After casting was completed, the rating of feet continued during the foot abduction orthosis stage of the treatment. Along with the rating of the feet, other details were noted, including if the patient had a percutaneous Achilles tenotomy, complications with treatment, and compliance with the treatment plan. These factors were regularly monitored at each visit to the clinic (Fig. 4).

Fig. 1



(a) The modified Dimeglio/Bensahel method [5]. (b) The modified Dimeglio/Bensahel shown as type I, type IIa, type IIb, and type III [5].

Selection of patients and data collection

Since inception of the clubfoot center at the Hospital for Joint Diseases 63 patients (87 feet) have been treated. Those patients selected for inclusion in our study group numbered 30 patients, a total of 45 clubfeet, with 15 patients having bilateral clubfoot. The first 30 patients with 45 clubfeet followed for 3 months form the substance of this review. None of these patients were lost to follow-up. Inclusion criteria included patients

casted by the Ponseti technique with a minimum of 3 months follow-up after the last cast applied. All patients had idiopathic clubfoot. Clubfeet secondary to syndromic involvement were excluded. Data collected for each patient included sex, right or left foot, age at treatment onset, total number of casts placed, ratings of feet at each clubfoot center visit, and pretreatment radiograph, which was not used in our treatment scheme.

Fig. 2

LOOK			
Curvature of lateral border	Medial crease	Posterior crease	
0 = Normal			
0.5 = Moderate			
1 = severe			
FEEL			
Lateral part of head of talus	Emptiness of the heel		
0 = Complete reduction		0 = Tuberosity palpable	
0.5 = Partial reduction		0.5 = Tuberosity partially palpable	
1 = Fixed subluxed		1 = Tuberosity not palpable	
MOVE			
Rigidity of equinus			
	0		0.5
			1
Catterall / Pirani (Normal: 0 points; Most abnormal: 1.0 points)			
Hindfoot contracture (HFCS)	Points	Midfoot contracture (MFCS)	Points
a. Posterior crease: 0, 0.5 or 1.0 points		a. Curvature of lateral border: 0, 0.5 or 1.0 points	
b. Empty heel: 0 or 1.0 points		b. Medial crease: 0, 0.5 or 1.0 points	
c. Rigid equinus 0, 0.5 or 1.0 points		c. Lateral head of talus: 0, 0.5 or 1.0 points	
HFCS sub-total		MFCS sub-total	
		Total Score (HFCS and MFCS)	

The modified Catterall/Pirani scoring [10].

Results

Patients were divided into two groups. Group I included all patients using foot abduction orthoses, while group II involved those who were not placed into a foot abduction orthosis because of failure with casting. Group I numbered 40 feet, while group II numbered five feet.

The mean age of presentation for all patients was 10.8 weeks (range 0.5–40 weeks). Group I and group II had mean ages at presentation of 8.2 weeks (range 0.5–28 weeks) and 34 weeks (26–40 weeks), respectively. However, the median for group I was 4 weeks of age and 36 weeks of age for group II.

The total number of castings per foot averaged 5.4 (range 4–9) for the entire study group. Group I averaged 5.3 castings (range 4–9), while Group II averaged 6.4 (range 4–9). The number of castings performed varied with each patient. When all components of the clubfoot other than equinus were corrected, the foot was placed into the last cast, either with or without percutaneous tenotomy.

The number of percutaneous tenotomies, after only one series of castings, numbered 25 while three patients had open Achilles tendon lengthening and posterior releases

Fig. 3

Ankle dorsiflexion		15 points 5 points 0 points	Above neutral To neutral Less than neutral	Points 15 5 0
Subtalar motion		15° < 15° Stiff		10 5 0
Heel position (with max ankle dorsiflexion)		> 5° Valgus 0°–5° Valgus Varus		10 5 0
Forefoot appearance		> 5° Abduction Neutral > 5° Adduction		10 5 0
Medial crease		Absent Present		5 0
Cavus		None < Mild > Severe		10 5 0
Total (Normal = 60)				

The modified Hospital for Joint Diseases functional rating system [1].

done intraoperatively. Two of these feet had previous percutaneous tenotomies performed. The open Achilles tendon and posterior releases were done to analyze under image intensification the effectiveness of the release in our first cases. This is not done now and is not part of the Ponseti technique.

Utilizing the Wilcoxon signed ranks test, there was a significant difference between the initial and last follow-up scores using all three scoring systems in group I (40 feet). As seen in Table 1, the Dimeglio/Bensahel score changed from a mean of 14.4 to 4.2 while the Catterall/Pirani decreased from 4.6 to 0.6. The functional rating was shown to increase from 16.8 to 52.9. All three had *P* values of below 0.0001 (Table 1).

Patients were labeled as having a good result if two of three criteria were met: (1) Dimeglio/Bensahel 6 points or better (Fig. 1); (2) Catterall/Pirani 1.5 points or better (Fig. 2); (3) functional rating greater than 30 (Fig. 3). Thirty-eight feet had good results prior to application of the foot abduction orthosis. There were two feet in group I that had poor results after casting and were indicated for open Achilles tendon lengthening/

Fig. 4

Name _____ **Foot (circle):** R L
Cast Number (circle): 0 1 2 3 4 5 6 7 8 9 **Date DBB Applied** _____ **Compliance: 1) YES 2) NO**
Complications (circle) 0)None 1)Rocker sole 2)MAceration 3)Abrasion 4)Blister 5)Slough 6)Decubitus
7)Cast saw injury 8)Cast intolerance/removal)Other _____
Surgical Date: _____ **Procedure: (circle) 1)None 2)Per-Q Achilles tenotomy 3)Open TAL/post release**
4)PMR 5)Anterior tibialis transfer 6)Other _____

Dimeglio/Bensahel

1. Equinus	Points	3. Midfoot Rotation (horizontal plane)	Points	For Parts 5-8, Mark Points as Present =1, Absent =0	Points
Plantarflexion 45° - 90°	4	Supination 45° - 90°	4	5. Posterior crease	
Plantarflexion 20° - 45°	3	Supination 20° - 45°	3	6. Medial crease	
Plantarflexion 0° - 20°	2	Supination 0° - 20°	2	7. Cavus	
Dorsiflexion 20° - 0°	1	Pronation 20° - 0°	1	8. Abnormal underlying musculature	
Dorsiflexion > 20°	0	Pronation > 20°	0		
2. Hindfoot varus		4. Forefoot Adduction (on hindfoot)		TOTAL SCORE/TYPE	
Varus 45° - 90°	4	Adductus 45° - 90°	4	Type I: 0 - 5 points	
Varus 20° - 45°	3	Adductus 20° - 45°	3	Type IIa: 6 - 10 points	
Varus 0° - 20°	2	Adductus 0° - 20°	2	Type IIb: 11 - 15 points	
Valgus 20° - 0°	1	Adductus 20° - 0°	1	Type III: 16 - 20 points	
Valgus > 20°	0	Adductus > 20°	0		

Functional Rating (circle corresponding point valuation, add up total)

1. Ankle Dorsiflexion	Points	3. Heel Position (with man ankle) dorsiflexion)	Points	5. Medial Crease	Points
Above neutral	15	> 5° Valgus	10	Absent	5
To neutral (+/- 5°)	5	0° - 5° Valgus	5	Present	0
Less than neutral	0	Varus	0	6. Cavus	
2. Subtalar Motion		4. Forefoot Appearance		None	10
15°	10	> 5° Abduction	10	< 5 millimeters	5
15°	5	Neutral	5	> 5 millimeters	0
Suff	0	> 5° Abduction	0	Total (of 60)	

Catteral/Pirani (Normal; 0 points; m,ost abnormal 1.0 points)

Hindfoot contracture (HFCS)	Points	Midfoot contracture (MFCS)	Points
a. Posterior crease: 0.0.5. or 1.0 points		a. Curvature of lateral border: 0.0.5 or 1.0	
b. Empty heel: 0.0.5 or 1.0 points		b. Medial crease: 0.05 or 1.0 points	
c. Rigid equinus: 0.0.5 or 1.0 points		c. Lateral head of talus: 0. 0.5. or 1.0 points	
HFCS Sub-total		MFCS Sub-total	
Total Score (HFCS and MFCS)			

Data sheet for the clubfoot clinic with all pertinent data to be collected for each visit.

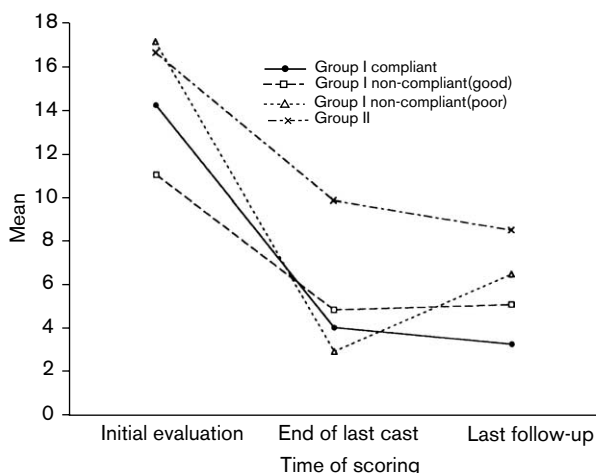
posterior release. These two feet had good results at 3 months follow-up.

The thirty-eight feet placed into Foot Abduction Orthoses were divided based on their compliance with the orthosis. Twenty-seven feet were compliant with orthosis wear. Of the compliant patients, all 27 feet had good results at 3 months follow-up. Of the patients compliant with foot abduction orthosis wear and with good initial results after casting, all maintained their correction at last follow-up (Table 2). We have followed 15 of the 27 feet to a follow-up of 6 months with good

results; 10 feet were followed to 9 months and two feet were followed to 12 months.

Despite noncompliance with foot abduction orthosis wear, five of the 11 feet in the non-compliant patients had good results. Three of the six feet with poor results were recast, but two of the feet were lost to follow-up. The remaining foot had a good result at 6 months following the second casting session. One of the six feet had a second casting session and an open Achilles tendon lengthening and posterior release with a good result at 6 months follow-up. Two of the six feet with a poor result

Fig. 5



Group I compliant, group I non-compliant (with good result), group I non-compliant (with poor result) and group II plotted against modified Dimeglio/Bensahel score initially, after casting and at last follow-up.

Table 1 Comparison of initial evaluation and last follow-up scores for entire group I (n=40 feet)

Scoring system	Initial evaluation		Last follow-up		P-value*
	Mean	SD	Mean	SD	
Dimeglio/Bensahel	14.4	3.0	4.2	2.8	<0.0001 (significant)
Functional rating	16.8	10.8	52.9	8.7	<0.0001 (significant)
Catterall/Pirani	4.6	1.2	0.6	0.6	<0.0001 (significant)

*Wilcoxon signed ranks test.

Table 2 Comparison of initial evaluation and last follow-up scores for group I patients compliant with foot abduction orthosis (n=27 feet)

Scoring system	Initial evaluation		Last follow-up		P-value*
	Mean	SD	Mean	SD	
Dimeglio/Bensahel	14.2	2.8	3.2	2.6	<0.0001 (significant)
Functional rating	18.7	11.0	55.6	7.0	<0.0001 (significant)
Catterall/Pirani	4.5	1.4	0.4	0.4	<0.0001 (significant)

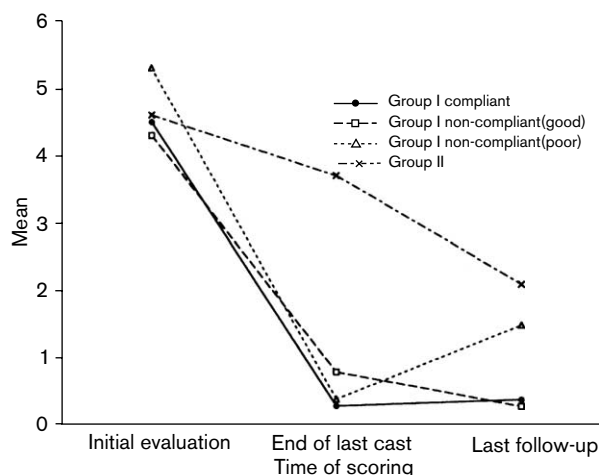
Scores for group I compliant patients only. *Wilcoxon signed ranks test.

had a second casting session with percutaneous Achilles tenotomy. One of these feet had a tenotomy previously while the other did not. Both had good results at 6 months follow-up. The versatility of this technique is that even an unacceptable result can be salvaged by recasting and further tenotomy.

Table 3 Dimeglio/Bensahel types for group I (n=40 feet)

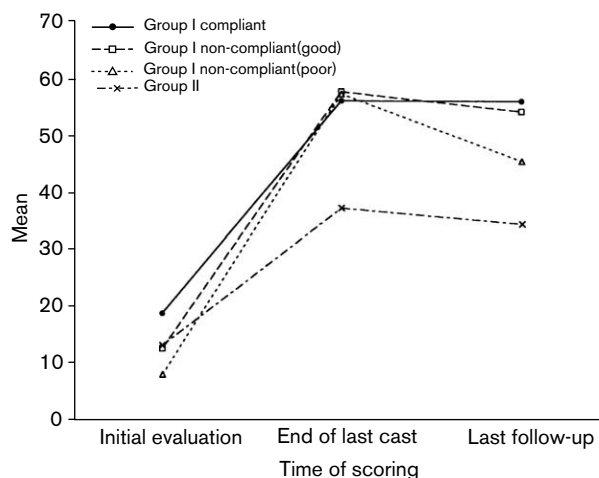
Type	Initial evaluation	End of last cast	Last follow-up
I	0	35 (87.5%)	29 (72.5%)
Ila	7 (17.5%)	5 (12.5%)	11 (27.5%)
Ilb	19 (47.5%)	0	0
III	14 (35.0%)	0	0

Fig. 6



Group I compliant, group I non-compliant (with good result), group I non-compliant (with poor result) and group II plotted against Catterall/Pirani score initially, after casting and at last follow-up.

Fig. 7



Group I compliant, group I non-compliant (with good result), group I non-compliant (with poor result) and group II plotted against Hospital for Joint Diseases functional rating score initially, after casting and at last follow-up.

Five feet were in group II with all five patients eventually being recommended for open Achilles tendon lengthening/posterior release because of failure with Ponseti casting. This was despite the larger number of casts

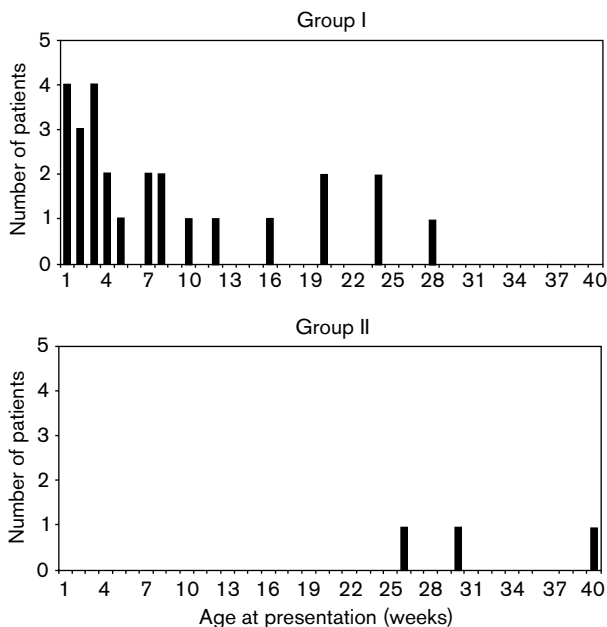
placed in this group (average 6.4, range 4–9). All of these patients were over 7 months of age when treated.

Figures 5, 6, and 7 show the Dimeglio/Bensahel, Catterall/Pirani, and Hospital for Joint Diseases scoring systems by group I (compliant and non-compliant with foot abduction orthosis) and group II. While all group I patients showed improvement, those non-compliant with foot abduction orthosis wear had a worsening of their outcomes at last follow-up. Rather than use the initial classification to predict outcome, our results so far have shown that no matter how severe the initial classification is if the technique is done properly a good result can be anticipated.

The age of the patient at initiation of treatment was much higher in group II patients than in group I patients. The average age of group I patients was 8.2 weeks (range 0.5–28 weeks) while the group II patients averaged 34 weeks of age (range 26–40 weeks) (Fig. 8).

When the group I feet (40 feet) were divided by Dimeglio types (I, IIa, IIb, III), a significant shift in classification was shown. While 19 feet were noted to be IIb and 14 feet were type III at initial evaluation, there were no type IIb or III feet at last follow-up (Table 3). There were 11 IIa feet when the entire group I was analyzed. However, when only patients compliant with foot abduction orthoses (27 feet) were noted, only four patients were IIa (Table 4).

Fig. 8



Age distribution for group I and group II.

Table 4 Dimeglio/Bensahel types for group I patients compliant with foot abduction orthosis (n=27 feet)

Type	Initial evaluation	End of last cast	Last follow-up
I	0	25 (92.6%)	23 (85.2%)
IIa	5 (18.5%)	2 (7.4%)	4 (14.8%)
IIb	14 (51.9%)	0	0
III	8 (29.6%)	0	0

Table 5 Complications list

Complication	Quantity
Cast saw injury	7
Abrasions	6
Cast intolerance/removal	5
Maceration	4
Blister	2
Slough	1

There were 25 complications among all the castings performed. This led to a 10.2% complication rate. Nearly 25% of all complications were cast saw injuries (seven total). By switching to the cast knife technique described by Ponseti, these injuries were eliminated (Table 5). Macerations and abrasions occurred more often in the early months of the opening of the clubfoot center. Some patients with marked equinus had casts fall off secondary to the shape of the infant’s extremity.

Discussion

The current philosophy on the treatment of clubfoot initially involves a course of serial casting with surgical intervention at age 3–12 months if correction of the components of the clubfoot are not achieved [2]. Most authors have felt that stiff, rigid clubfeet such as Dimeglio type IIb or III, are not amenable to casting alone and that surgical intervention will eventually be warranted. However, the complication rate of clubfoot surgery has been reported to be between 11 and 33% [3,4].

The advantages of a reproducible, easily followed casting method with a high success rate are, therefore, obvious. The casting technique introduced by Ponseti has had a high success rate with Ponseti reporting a success rate of over 90% with anecdotal or descriptive follow-up of 30 plus years [14]. However, there have been no other reports with such high success using his methods in the current literature, but we anticipate more frequent positive reports will be forthcoming [6,15]. In addition, there is currently no literature using existing clubfoot rating methods to evaluate progress with the Iowa casting technique.

Our clubfoot center sought to systematically and exactly reproduce the Ponseti technique in its entirety. To

serially follow the progress of the clubfeet treated in our clinic, feet were rated with two described classification systems and a third system that was developed at our institution [11–13].

When our results were analyzed in terms of age, there was a definite correlation with success of the casting technique. In particular, patients treated over the age of 7 months appear to have an increased probability of poor results. Compliance with the foot abduction orthosis has also been an issue. Those patients compliant with foot abduction orthosis wear had nearly 100% success at last follow-up if treatment was applied before the child was 7 months of age. Patients not compliant with foot abduction orthosis wear but, with good results after casting, still had good results in 50% of the feet. The Ponseti technique is flexible in that it provides an opportunity to recast patients who lose correction. Poor outcomes were salvaged by recasting or by recasting with tenotomy.

Our longest follow-up to date has been 12 months. However, the majority of our patients fall into the 3–6 month follow-up period. Ponseti's long-term outcomes, as noted by Cooper and Dietz, have higher function, less pain, and slightly less stiffness in these feet than in those with more extensive surgical procedures [14]. As Ponseti has indicated, some patients may require tibialis anterior tendon transfers to compensate for possible muscle imbalance, resulting in some deformity recurrence. This limited procedure may be required in the future in some of our patients, however, long-term follow-up will determine this. Based on our current data, the Ponseti (Iowa) casting technique provides excellent early results and may limit the necessity of extensive surgical

procedures at early ages. Similar statistical evaluation of other techniques, such as early motion and physical therapy may show similar early success, but that was not the purpose of our paper. We anticipate our long-term results to be similar and also to correspond to the short-term data we report here.

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