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Retrospective Comparative Analysis of Ponseti Method of Treatment for Idiopathic and Nonidiopathic Clubfoot: A 4 year follow-up study

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Learning Point of the Article:

Prompt Ponseti correction fundamentally alters clubfoot natural history, significantly curtailing future surgical release.

Abstract

Introduction: This study sought to critically evaluate the effectiveness of the Ponseti method in treating idiopathic and non-idiopathic clubfoot, and compared clinical outcomes over a 4-year follow-up.

Materials and Methods: A total of 75 children (105 clubfeet) were treated with the Ponseti casting protocol at an institution-based clubfoot clinic. Group I comprised 45 patients (63 clubfeet) with idiopathic clubfoot, while Group II included 30 patients (42 clubfeet) with non-idiopathic clubfoot, including arthrogryposis multiplex congenita, flail myelomeningocele, spina bifida, and various syndromic clubfoot. Demographic characteristics, number of casts, tenotomy rate, recurrence, need for minimally invasive adjunct procedures in recurrent or residual cases, and treatment success were compared. Clinical outcomes were assessed using the Pirani score at each follow-up, while brace compliance was based on subjective parent-reported adherence at brace initiation and treatment completion.

Results: Group I required significantly fewer casts than Group II (median 5.0 vs. 8.0; $P < 0.001$), whereas tenotomy rates were comparable (75.5% vs. 73.3%). Multivariable linear regression identified higher initial Pirani score, older age at presentation, rigid non-idiopathic foot type, and recurrent presentation as independent predictors of increased casting requirements. The flail subtype did not differ significantly from idiopathic clubfoot in casting burden. Recurrence was significantly lower in Group I (5/63 [7.9%]) than in Group II (9/42 [21.4%]; $P = 0.042$). A significant Spearman correlation between initial Pirani score and casting requirement was observed only in the flail subgroup ($P = 0.007$) of Group II. At final follow-up, treatment success (Pirani score ≤0.5) was achieved in 98.82% of Group I and 95.41% of Group II, $P < 0.001$.

Conclusion: The Ponseti method is an effective and reliable treatment for both idiopathic and non-idiopathic clubfoot. In recurrent cases, timely minimally invasive adjunctive procedures may restore correction and reduce the need for extensive surgical release at later stages.

Keywords: Arthrogryposis multiplex congenita(AMC), myelomeningocele(MMC), congenital talipes equinovarus(CTEV), ankle foot orthosis(AFO), foot abduction-orthosis(FAO), Joshi's external stabilization system(JESS).

Introduction

Clubfoot is one of the most common congenital foot deformities, affecting approximately 1.2/1,000 live births [1]. Since its introduction, the Ponseti method has revolutionised the management of idiopathic clubfoot, achieving reported success rates of 93–100% and markedly reducing the need for extensive surgical release [2,3,4]. This success has led to its increasing application in selected cases of non-idiopathic

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Author's Photo Gallery

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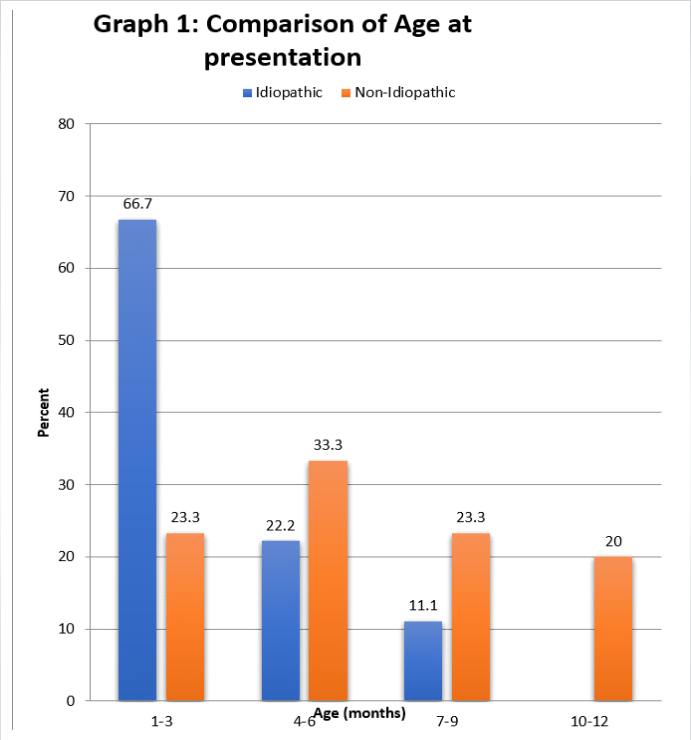

Figure 1: Comparison of age at presentation between Idiopathic & Non idiopathic clubfoot
2/3rd of Idiopathic group presented within the first 3 month, whereas nearly half(43.3%) of the Non idiopathic ones presented later after 6 month.

clubfoot, including those associated with arthrogryposis multiplex congenital (AMC), myelomeningocele (MMC), spina bifida, and syndromic disorders [5,6,7]. Historically, non-idiopathic clubfoot was managed primarily with extensive soft-tissue release, often resulting in residual deformity, stiffness, pain, functional limitation, and high recurrence rates [7,8]. Although modified Ponseti techniques have demonstrated encouraging outcomes in these complex deformities [6,7,8], variations in treatment protocols and the predominance of diagnosis-specific studies limit meaningful comparisons across heterogeneous non-idiopathic populations. These heterogeneous cohort subgroups (AMC, Spina bifida, and syndromic cohort) introduce clinical variability, but we had addressed this partially through the rigid versus flail sub-classification of non-idiopathic clubfoot based on soft-tissue phenotype in the literature.

Robust evidence evaluating the standard Ponseti protocol in non-idiopathic clubfoot remains limited. Therefore, this study aimed to compare the clinical outcomes of the standard Ponseti method in idiopathic and non-idiopathic clubfoot over a 4-year follow-up period, with minimally invasive adjunct procedures reserved exclusively for recurrent or residual cases.

Materials and Methods

This was a retrospective cohort study that used data from an institutional clubfoot registry that was kept up to date. Patients were enrolled consecutively and categorised according to etiology into idiopathic (Group I) and non-idiopathic (Group II) clubfoot. Randomization was not possible as the treatment allocation for both groups was determined by the underlying etiology and not by the investigator's choice.[1.1][d1.2]

The results were compared between the two groups over a 4-year follow-up period.

The required sample size was calculated as 91 clubfeet based on a clubfoot incidence of 1/1,000 live births, with a 95% confidence interval (CI), and a 6.5% margin of error. Eighty patients were initially enrolled; five (6.25%) were excluded because of loss to follow-up, leaving a final cohort of 75 patients (105 clubfeet). Group I comprised 45 patients (63 clubfeet) with idiopathic clubfoot, whereas Group II comprised 30 patients (42 clubfeet) with non-idiopathic clubfoot. The total sample size (105 feet) was sufficient to meet the predetermined sample size (91 feet) with adequate post hoc power (>99% for the primary outcome). However, the individual non-idiopathic subgroups (21 Rigid vs. 21 Flail) remained relatively small and are acknowledged as a limitation for subgroup-level analyses only, separate from the adequately powered overall comparison. This study received Institutional ethics committee approval on January 28th, 2022.

Demographic variables including age at presentation, sex, and laterality were recorded. All children underwent evaluation by an orthopedic surgeon. Patients with postural clubfoot, metatarsus adductus, calcaneo-valgus foot, atypical clubfoot, or post-traumatic equinus deformity were excluded from the study. Children with suspected syndromic associations

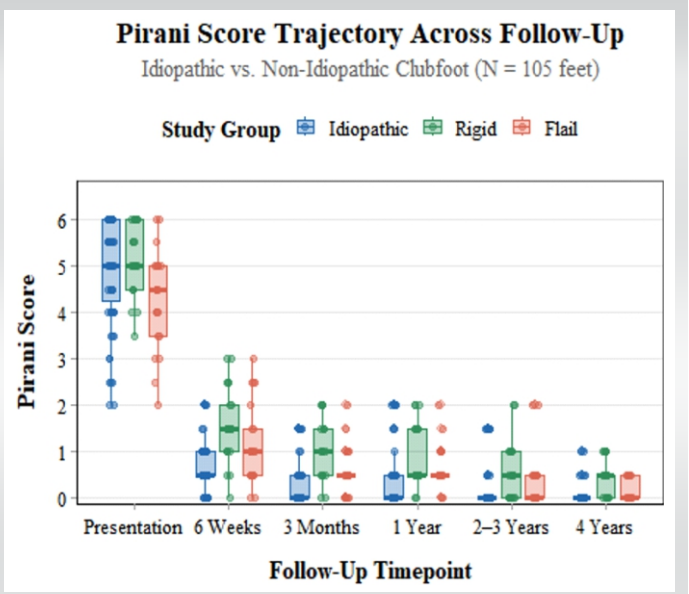

Figure 2: Comparison of various subgroups of Non-idiopathic clubfoot (Rigid and Flail type) and Idiopathic clubfoot, Box-whisker plot demonstrates the dispersion of Pirani score at each follw-up.

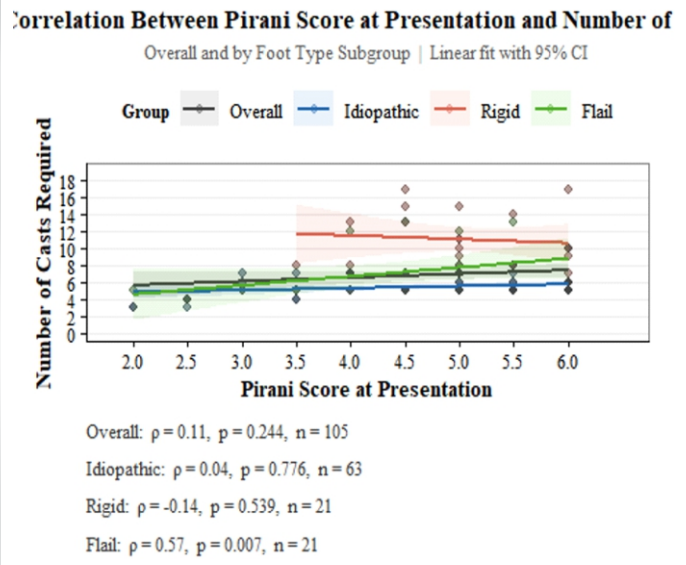

Figure 3: Spearman correlation between initial Pirani score and number of casts was significant only in the flail subgroup (ρ = 0.57, p = 0.007).

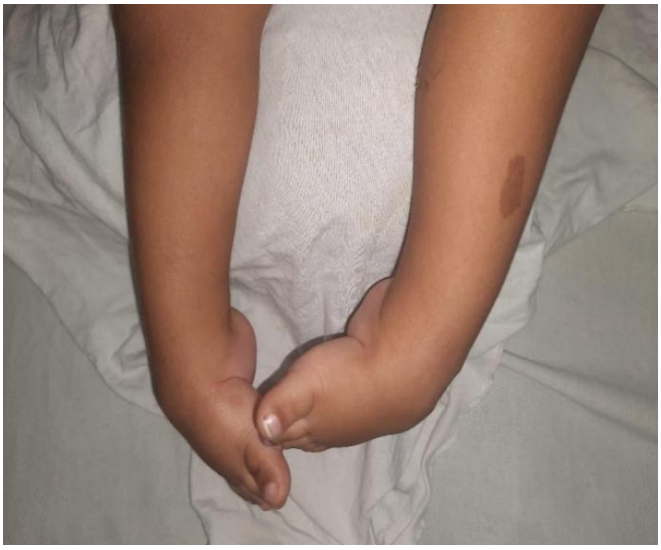

Figure 4: Four-month-old male child with Myelomeningocele (MMC) presented with bilateral clubfoot.
Left foot had Pirani score 4.5 and Right foot with score of 4 as depicted.

underwent multidisciplinary assessment, including pediatricians, neurologists, cardiologists, and genetic evaluation where indicated. Following clinical assessment, Pirani scoring was performed at presentation and every follow-up visit.

The Ponseti method was employed for manipulation and casting. During the first cast, the first metatarsal was elevated by supinating the forefoot to align it with the hindfoot, thereby correcting cavus deformity. In subsequent casts, pure abduction of the foot to 60–70° was achieved with counter-pressure applied over the head of the talus, as this manoeuvre alone results in complete correction of the subtalar joint and adequate stretching of the medial soft tissues. Each above-knee cast was changed on a weekly basis, and careful attention was paid to identify any cast slippage at subsequent visits. According to Ponseti's recommendations, 60° of forefoot abduction and ≤15° of dorsiflexion were considered the threshold before performing tendo-Achilles tenotomy. This permits the calcaneus to swing completely beneath the talus, thereby correcting subtalar malalignment. Attempts to correct equinus before addressing heel varus and forefoot supination were avoided, as this may lead to rocker-bottom deformity. Particular care was taken to ensure appropriate alignment of the forefoot and midfoot before correcting hindfoot equinus.

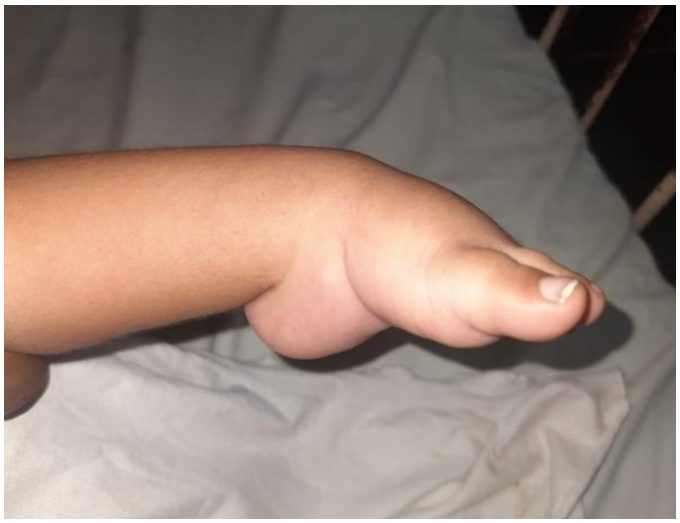

Figure 5: Left foot with initial Pirani score 4.5 at four month of Age .
Child having Midfoot score of 2 which included medial crease score 1, curved lateral border 0.5, talar head coverage 0.5, and the Hindfoot score were 2.5 of which Equinus were 1, posterior crease 1 and empty heel 0.5.

Adequate coverage was confirmed by the absence of palpable talar head laterally after the cast, indicating adequate forefoot abduction. When the midfoot Pirani score dropped below 1 while the hindfoot score remained >1, tendo-Achilles tenotomy was indicated. Tenotomy was not performed when the hindfoot score was ≤1 either at presentation or following initial correction, provided dorsiflexion of up to 15–20° was achievable. All tenotomies were performed in the outpatient clinic under local anesthesia.

Following tenotomy, above-knee casts were applied in the maximum achievable corrected position and maintained for 3 weeks. After cast removal, Pirani scores were reassessed. Children with satisfactory correction received full-time bracing (23 h/day) for the initial 3 months, followed by night-time and nap-time bracing. Because bracing maintains rather than achieves correction, adequate correction was confirmed before brace initiation. During the first 2 weeks of FAO or AFO application, patients were monitored for midfoot instability, rocker-bottom deformity, heel slippage, loss of hindfoot

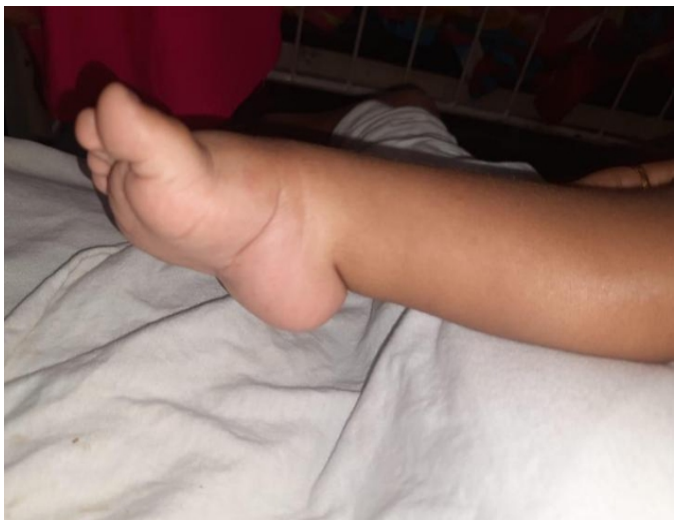

Figure 6: Right foot having initial Pirani Score 4 at four-month Age.
Child having a Midfoot score of 2 which included the Talar head coverage score 1, medial crease 0.5, curved lateral border 0.5 whereas the Hindfoot score were 2 in which equinus score was 1, posterior crease 0.5 and empty heel 0.5.

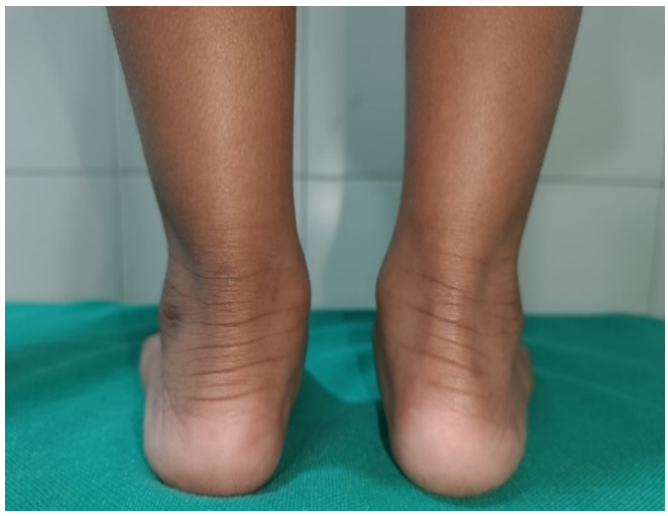

Figure 7: No Residual Equinus at mean follow-up of 4 years in the same MMC (Meningomyelocele) Child.
This patient did require an AFO (Ankle Foot Orthoses) for a longer period due to weakness of dorsiflexors in the foot.

correction, and skin-related complications such as blisters. AFO usage strictly related to the rigid variety was excessive when dorsiflexion was not needed; rather, co-contracture also required addressing.

Patients were reviewed monthly for 3 months, every 3 months during the 1st year, and every 6 months thereafter. At each follow-up visit, Pirani scores were assessed, and early heel rise during squatting, brace wear issues, and skin complications were meticulously evaluated. Recurrence was defined as a Pirani score >1 at any stage following final casting or during subsequent follow-up, attributable to excessive deformity components such as equinus, cavus, or heel varus, resulting in a midfoot or hindfoot score >1 and not amenable to casting. Recurrent equinus was treated with repeat casting and re-tenotomy, whereas recurrent heel varus or dynamic supination was managed by tibialis anterior transfer. No patient underwent postero-medial release, and no bony procedures.

All follow-up Pirani assessments were performed by the same orthopedic surgeon, reducing inter-observer variability, although inter-observer agreement was not formally evaluated using kappa statistics. Brace compliance was based on subjective parent-reported adherence recorded in the institutional clubfoot registry throughout the 4-year follow-up.

The primary outcome was successful correction, defined as a Pirani score ≤0.5 at completion of the casting phase (3 months). Secondary outcomes included number of casts, tenotomy rate, recurrence during 4 years, requirement for adjunct procedures, and subjective parent-reported brace compliance. The primary treatment objective was to achieve a stable, plantigrade, painless, and braceable foot after 4 years of follow-up.

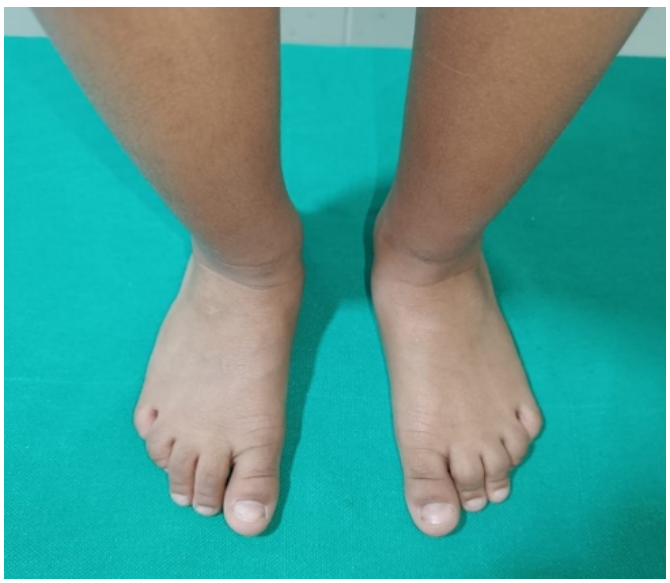

Figure 8: Full correction achieved at the completion of the Treatment.
No Forefoot deformity and foot length compromise at the completion of treatment in the same MMC Child.

Statistics

Data were entered into Microsoft Excel (Windows 10; Version 2021), and all statistical analyses were performed using R (version 4.4.0; R Foundation for Statistical Computing, Vienna, Austria) with the gtsummary , rstatix , and ggplot2 packages. Descriptive statistics, including median and interquartile range for continuous variables, and frequencies with percentages for categorical variables, were computed for each study group. The foot was used as the unit of analysis for casting-related outcomes (n = 105 feet: Group I = 63, Group II =

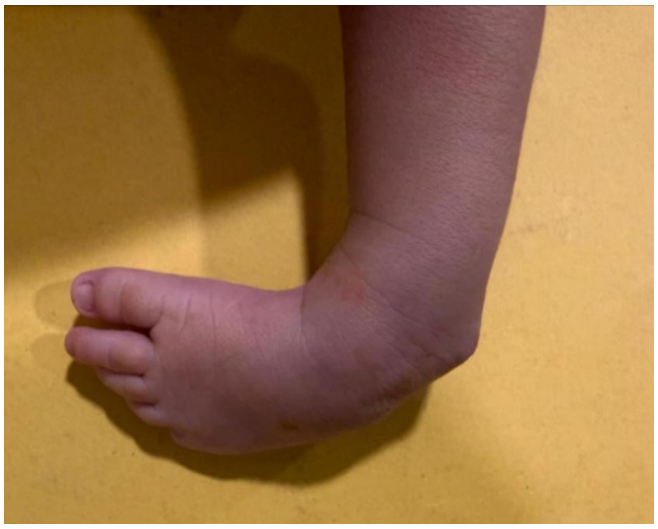

Figure 9: 2-month-old child with left sided unilateral idiopathic clubfoot and Pirani score is 5.

42), while the patient was the unit for brace compliance and surgical outcomes (n = 75 patients).

Between-group comparisons of continuous and ordinal variables (including Pirani score at each timepoint and number of casts) were performed using the Mann–Whitney U test (Wilcoxon rank-sum test), as these variables did not conform to a normal distribution. Associations between categorical variables were assessed using the Chi-square test. Spearman's rank correlation (ρ) was used to assess the relationship between initial Pirani score and number of casts required, reported with 95% confidence intervals. A multivariable linear regression model was constructed with number of casts as the dependent variable; independent predictors included Pirani score at presentation, age at presentation, foot type (Idiopathic/Rigid/Flail), and virgin versus recurrent/residual status. Model fit was assessed using R2 and adjusted R2, with variance inflation factors examined to rule out multicollinearity.

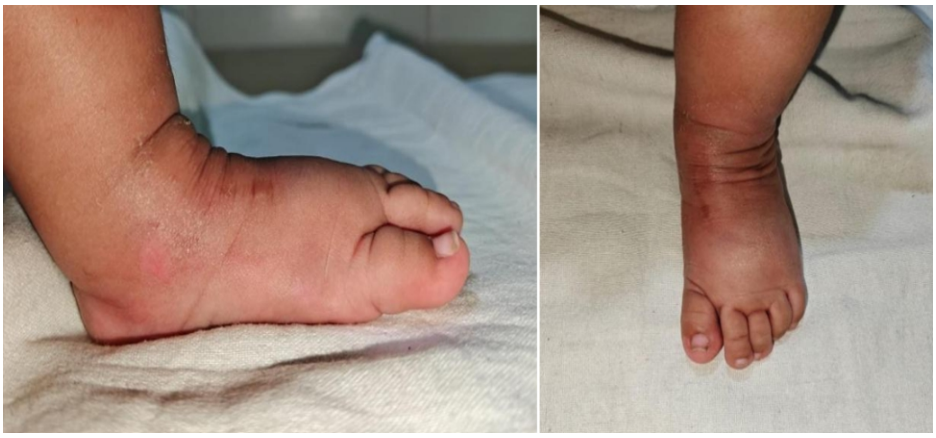

Figure 10: Clinical image depicts full correction of left foot at 4 yr treatment completion.

A post hoc power analysis was performed using observed effect sizes to confirm adequacy of the achieved sample following 17.6% attrition. The level of statistical significance was set at $P < 0.05$ (two-tailed) for all analyses.

Results

The median age at presentation in Group I (Idiopathic clubfoot) was 2.00 (0.8–4.0) months, and 5.5 (3.5–8.5) months in Group II (Non-idiopathic clubfoot). Two-thirds of patients in Group I (66.7%) presented before 3 months of age, whereas patients in Group II presented later, as illustrated in Fig. 1. Demographic characteristics, including age at presentation, sex, laterality, recurrence and subjective parent-reported brace compliance, are summarized in Table 1.

Although the baseline Pirani score at presentation was comparable between groups (Table 2, P = 0.14), alleviating concern for gross baseline imbalance in deformity severity. The non-idiopathic group required a significantly greater number of casts (median 8 [6.0–12.0] per clubfeet of which median of 10 in the rigid type versus 6 in the flail type, as shown in Table 3). 40% (12/30) of patients in Group II required ≥10 casts, of whom approximately 83.3% (10/12) were non-compliant with bracing. Group I required a (median 5.0 [5.0–6.0] casts) per clubfoot; 30% of patients (15 patients) required more than the median number of casts. Among these 15 patients, 5 were non-compliant with bracing and subsequently required additional procedures due to recurrence.

Table 2 demonstrates a statistically significant improvement in Pirani scores at 3 months, 1 year, and 4 years in both groups ($P < 0.001^*$, 0.001^*, and 0.001^*, respectively). Fig. 2 illustrates a Box-whisker plot with dispersion of Pirani score correction in both groups, including various subgroups within Group II. Other demographic parameters such as sex and laterality did not differ significantly. The cumulative tenotomy rate was comparable (75.4% in Group I versus 73.3% in Group II). Notably, 8 patients (26.4% of Group II) in the Flail type sub-group did not require tenotomy, reflecting the greater flexibility observed in subgroups such as flail MMC, Down syndrome, Larsen syndrome and other syndromic feet.

Although there was no significant difference in brace compliance between groups, the recurrence was significantly lower in Group I than in Group II (5/63 clubfeet [7.9%] vs. 9/42 clubfeet [21.4%] P = 0.042* as shown in Table 2). Among the 14

Table 1: Demographic details and comparison of various outcomes between Group(I) & Group(II), Total N= 75 Patients.

Characteristic	Group I (Idiopathic) N = 45[1]	Group II (Non-idiopathic) N = 30[1]	Difference[2]	Statistic[2]	p-value[2]
AGE(MONTHS)	2.00, 0.80 - 4.00	5.50, 3.50 - 8.50	-3.000081	296	<0.001
SEX				0	>0.9
F	13 (29%)	8 (27%)			
M	32 (71%)	22 (73%)			
UNI/ BIL				0.682	0.7
BIL	18 (40%)	12 (40%)			
LT	6 (13%)	6 (20%)			
RT	21 (47%)	12 (40%)			
recurrence				2.31	0.13
No	38 (84%)	20 (67%)			
Yes	7 (16%)	10 (33%)			
BRACE COMPLIANCE				5.92	0.015
NO	8 (18%)	14 (47%)			
YES	37 (82%)	16 (53%)			

[1] *Median, Q1 - Q3; n (%)*

[2] *Wilcoxon rank sum test; Pearson's Chi-squared test*

recurrent clubfeet, 5 clubfeet in Group II required cavus release only. Tibialis anterior transfer was performed in 3 clubfeet in Groups I and 2 clubfeet in Group II, while the remaining 4 clubfeet required both procedures. Subgroup analysis in Table 3 showed that adjunct surgery was required more frequently in the rigid subgroup than in the Flail subgroup (7/21 [33.3%] vs. 2/21 [9.5%], P = 0.021*).

Spearman's correlation demonstrated a significant association between the initial Pirani score and number of casts only in the flail subgroup (ρ = 0.57, P = 0.007), indicating that casting burden in rigid non-idiopathic feet is influenced by foot type rather than initial deformity severity, as shown in Fig. 3. At 4-year follow-up, final Pirani scores ≤0.5 were achieved in approximately 88.37% in recurred clubfeet Group I and 90.62% in Group II.

Multivariable linear regression (Table 4) identified four independent predictors of number of casts required (R2 = 0.707, F = 47.7, P < 0.001): Higher Pirani score at presentation (β = 0.87, 95% CI: 0.53–1.21, P < 0.001), older age at presentation (β = 0.43, 95% CI: 0.29–0.58, P < 0.001), rigid foot type compared to idiopathic (β = 3.93, 95% CI: 3.02–4.84, P < 0.001), and recurrent presentation (β = 1.41, 95% CI: 0.46–2.35, P = 0.004). In contrast, the Flail subtype did not differ significantly from idiopathic clubfeet in terms of casting burden (β = –0.45, P = 0.392).

Post hoc power analysis confirmed adequate statistical power despite the 6.25% attrition. The primary outcome (number of casts; Cohen's d = 1.34) achieved 99.98% power, while Pirani score at 4 years (Cohen's d = 0.74) and brace compliance (Cohen's h = 0.63) achieved powers of 87.40% and 76.69%, respectively.

Fig. 4, 5, 6, 7, 8 demonstrate representative outcomes in a child with MMC and bilateral clubfoot, whereas Fig. 9 and 10 illustrate correction of idiopathic clubfoot from initiation till completion of Ponseti treatment.

Discussion

The Ponseti method has consistently achieved excellent outcomes in idiopathic clubfoot, with reported success rates of 93–100% [2,3,4]. Historically, non-idiopathic clubfoot was managed primarily with extensive soft-tissue release, frequently resulting in residual deformity, stiffness, pain, functional limitation, and high recurrence rates [9,10,11,12,13,14]. Although favorable outcomes have recently been reported with the Ponseti method in non-idiopathic clubfoot, most studies have evaluated isolated etiologies or modified Ponseti protocols [5,6,7]. In contrast, the present study compared idiopathic and heterogeneous non-idiopathic clubfoot using the standard Ponseti protocol, reserving minimally invasive adjunct procedures exclusively for recurrent or relapsed cases.

The poor long-term outcomes associated with extensive soft-tissue release and bony procedures have led many authors to advocate Ponseti treatment even for complex clubfoot deformities [8,15,16,17,19,20,21,22]. Our demographic findings, including male predominance and the pattern of bilateral and right-sided involvement, are consistent with previous reports by Lochmiller et al. [23], Chung et al. [24], and others.

Ponseti [25,26] reported an average requirement of approximately 7.6 casts per foot. Consistent with previous literature, idiopathic clubfeet in our series required significantly fewer casts than non-idiopathic feet. Recurrence (11.1%) in Group I occurred only in children presenting after 6 months of age. Nearly one-quarter of idiopathic feet did not require tenotomy, and none of these patients' developed recurrence, emphasising the importance of early presentation, meticulous casting technique, and strict brace compliance. Initial Pirani score correction at 3 months was achieved in 93.72% of idiopathic cases[27-29].

As expected, non-idiopathic clubfeet required significantly more casts, reflecting greater deformity rigidity. Despite this increased casting burden, tenotomy rates were comparable between groups, while recurrence remained within the range

Table 2: Comparison of Various independent variables & Pirani score in both the groups (N=105 clubfeets)

Characteristic	Overall N = 105[1]	Idiopathic N = 63[1]	Non-Idiopathic N = 42[1]	Statistic[2]	p-value[2]
PIRANI SCORE AT PRESENTATION	5.00 (4.00 - 6.00)	5.00 (4.00 - 6.00)	5.00 (4.00 - 5.50)	1,544	0.14
6WKS PIRANI SCORE	0.50 (0.50 - 1.00)	0.50 (0.50 - 1.00)	1.25 (0.50 - 2.00)	615	<0.001
3MONTH	0.50 (0.00 - 0.50)	0.00 (0.00 - 0.50)	0.50 (0.50 - 1.00)	542	<0.001
1YR	0.50 (0.00 - 0.50)	0.00 (0.00 - 0.50)	0.50 (0.50 - 1.00)	518	<0.001
2-3YR	0.00 (0.00 - 0.50)	0.00 (0.00 - 0.00)	0.50 (0.00 - 0.50)	762	<0.001
4YR	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.50)	836	<0.001
NO OF CASTS	6.00 (5.00 - 7.00)	5.00 (5.00 - 6.00)	8.00 (6.00 - 12.00)	517	<0.001
TENOTOMY				6.47	0.039
0	23 (22%)	13 (21%)	10 (24%)		
1	73 (70%)	48 (76%)	25 (60%)		
2	9 (8.6%)	2 (3.2%)	7 (17%)		
extra surg				8.2	0.042
Both(Cav rel + tib ant)	4 (3.8%)	2 (3.2%)	2 (4.8%)		
Cavus release	5 (4.8%)	0 (0%)	5 (12%)		
No	91 (87%)	58 (92%)	33 (79%)		
Tibial Anterior	5 (4.8%)	3 (4.8%)	2 (4.8%)		

[1] Median (Q1 - Q3); n (%)

[2] Wilcoxon rank sum test; Pearson's Chi-squared test

reported in previous studies [8,15,16,17,18,19,20,21,22]. Significant improvement in Pirani scores was observed throughout follow-up, with a final correction rate of 95.41% in non-idiopathic clubfoot, comparing favorably with published literature [15,30,31].

Janicki et al. [15] and Shah et al. [31] reported fewer casts but lower correction rates and higher recurrence than observed in our cohort. These findings suggest that a more persistent casting strategy, combined with strict brace adherence, may improve correction while reducing recurrence. Recurrent deformities in our series responded satisfactorily to repeat casting and minimally invasive adjunct procedures, avoiding extensive surgical release.

Final Pirani scores among recurrent feet were not uniformly zero, consistent with Khan et al. [32], who demonstrated that a clinically corrected clubfoot does not necessarily achieve a Pirani score of zero. This finding is particularly relevant because most recurrent feet in our study belonged to the heterogeneous non-idiopathic cohort.

Morcuende et al. [5] reported satisfactory correction of arthrogrypotic clubfeet using the Ponseti method, while Boehm et al. [6] demonstrated successful management of recurrence with repeat casting. Our findings support these observations. Based on our experience, rigid non-idiopathic clubfeet may require a realistic target of 30–40° forefoot abduction and 5–10° dorsiflexion before brace application. In patients with severe associated joint contractures, particularly those with AMC, ankle-foot orthoses may provide better maintenance than standard foot abduction orthoses.

Mehta and Gopinathan [33] proposed classification of non-idiopathic clubfoot into rigid and flail phenotypes, which was supported by our findings. Flexible deformities, including flail MMC, Down syndrome, Larsen syndrome, and other syndromic feet, required fewer casts, whereas rigid phenotypes required prolonged casting. The significant correlation between initial Pirani score and casting requirement observed only in the flail subgroup suggests that deformity severity predicts casting burden primarily in flexible feet, while rigidity itself determines treatment duration in rigid deformities.

Table 3. Intra-subgroup comparison in Group II between Rigid type and Flail type clubfoot patients

Characteristic	Overall N = 42[1]	Rigid N = 21[1]	Flail N = 21[1]	Statistic[2]	p-value[2]
PIRANI SCORE AT PRESENTATION	5.00 (4.00 - 5.50)	5.00 (4.50 - 6.00)	4.50 (3.50 - 5.00)	322	0.01
6WKS PIRANI SCORE	1.25 (0.50 - 2.00)	1.50 (1.00 - 2.00)	1.00 (0.50 - 1.50)	290	0.08
3MONTH	0.50 (0.50 - 1.00)	1.00 (0.50 - 1.50)	0.50 (0.50 - 0.50)	323	0.008
1YR	0.50 (0.50 - 1.00)	0.50 (0.50 - 1.50)	0.50 (0.50 - 0.50)	260	0.3
2-3YR	0.50 (0.00 - 0.50)	0.50 (0.00 - 1.00)	0.00 (0.00 - 0.50)	279	0.12
4YR	0.00 (0.00 - 0.50)	0.50 (0.00 - 0.50)	0.00 (0.00 - 0.50)	309	0.013
NO OF CASTS	8.0 (6.0 - 12.0)	10.0 (8.0 - 13.0)	6.0 (5.0 - 7.0)	378	<0.001
TENOTOMY				5.25	0.073
0	10 (24%)	2 (9.5%)	8 (38%)		
1	25 (60%)	14 (67%)	11 (52%)		
2	7 (17%)	5 (24%)	2 (9.5%)		
BRACE COMPLIANCE	22 (52%)	8 (38%)	14 (67%)	2.39	0.12
extra surg				9.76	0.021
Both	2 (4.8%)	2 (9.5%)	0 (0%)		
Cavus release	5 (12%)	5 (24%)	0 (0%)		
No	33 (79%)	14 (67%)	19 (90%)		
Tibial Anterior	2 (4.8%)	0 (0%)	2 (9.5%)		

[1] Median (Q1 - Q3); n (%)

[2] Wilcoxon rank sum test; Pearson's Chi-squared test

Table 4. Multivariable linear regression analysis with the number of casts as dependent variable and other as independent variables.

Predictor	β Coefficient	95% CI	p-value
Pirani Score at Presentation	0.401	0.092, 0.710	**0.011**
Age at Presentation (months)	0.291	0.163, 0.419	**<0.001**
Foot Type			
Idiopathic	—	—	
Rigid	3.8	3.05, 4.55	**<0.001**
Flail	0.228	-0.641, 1.10	0.604
recurrence			
No	—	—	
Yes	1.13	0.354, 1.91	**0.005**
TENOTOMY	2.02	1.44, 2.60	**<0.001**
Abbreviation: CI = Confidence Interval			
R^2 = 0.803; Adjusted R^2 = 0.791; Residual SE = 1.35; F-statistic = 66.7; Model p-value = <0.001; N (feet) = 105			

Nevertheless, variability in casting requirements remains inevitable, as highlighted by De Mulder et al. [22], and surgical intervention should be considered when further casting is unlikely to improve correction.

The heterogeneous non-idiopathic cohort (arthrogryposis, spina bifida, MMC, and syndromic clubfoot) introduces unavoidable clinical variability. We addressed this partially by analyzing the predefined rigid and flail subgroups based on the soft-tissue phenotype described by Mehta and Gopinathan [33]. Analysis at the level of the individual diagnostic subgroups (e.g. AMC alone, Spina bifida alone) were underpowered; therefore, diagnosis-specific conclusions cannot be drawn.

Brace compliance was assessed using serial Pirani scores during maintenance together with subjective parent-reported adherence. Overall compliance at 4 years was 73.3%, including 87.3% in Group I and 52.4% in Group II ($P < 0.015$), which compares favorably with the findings of Funk et al. [30]. However, these results should be interpreted cautiously because compliance was assessed subjectively, the sample size was modest, and the non-idiopathic cohort was heterogeneous. Objective monitoring using sensor-based brace compliance systems would provide more reliable assessment in future studies.

Limitation of study

This study has several limitations. Although data were derived from a prospectively maintained institutional clubfoot registry with predefined variables, its retrospective design cannot eliminate unmeasured confounding. As a single-center study, the findings may not be generalisable to institutions with different casting protocols, patient demographics, socioeconomic settings, brace-compliance practices, or surgical thresholds.

The heterogeneous non-idiopathic cohort and the relatively small size of individual diagnostic subgroups limited diagnosis-specific analyses. Consequently, the results should not be extrapolated to neglected or severely rigid clubfeet presenting late, particularly those with AMC or spina bifida, who may occasionally require extensive soft-tissue release or differential distraction techniques such as the JESS system. No such patients were encountered in the present series.

Brace compliance was assessed using subjective parent-reported adherence rather than objective monitoring, introducing the possibility of reporting bias. Furthermore, socioeconomic status, caregiver education, and access to healthcare or rehabilitation services, all recognised determinants of Ponseti success, were not systematically evaluated and should be incorporated into future prospective multicentre studies.

Conclusion

The Ponseti method is an effective and reliable treatment for both idiopathic and non-idiopathic clubfoot, providing excellent correction while substantially reducing the need for extensive soft-tissue release. Early initiation of treatment and meticulous adherence to the Ponseti protocol remain the key determinants of successful outcomes. In recurrent cases, timely minimally invasive procedures, including repeat tendo-Achilles tenotomy, cavus release, and tibialis anterior transfer, can effectively restore correction and minimise the need for major reconstructive surgery.

Long-term follow-up into adolescence is required to evaluate the durability of correction, functional outcomes, and late recurrence. Future studies should complement the Pirani score with validated functional outcome measures, such as the Ezra score and the Oxford foot and ankle questionnaire for children, to provide a more comprehensive assessment of gait, function, and quality of life. Although contemporary Ponseti guidelines emphasise clinical assessment over routine radiography, selective imaging remains valuable in resistant, residual, and syndromic clubfoot to supplement clinical evaluation.

Clinical Message

Meticulous Ponseti protocol fidelity and expeditious therapeutic initiation are the quintessential determinants of durable correction. Judiciously timed minimally invasive salvage interventions effectively mitigate recurrence, preserve musculoskeletal integrity, and circumvent extensive future reconstructive surgery.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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