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ORIGINAL ARTICLE

Midterm outcomes of complex clubfoot treated with the modified Ponseti method: A comparative study of primary and referred cases

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Congenital talipes equinovarus, commonly known as clubfoot, is one of the most common congenital musculoskeletal deformities, with an incidence of approximately 1 to 2 per 1,000 live births.[1] The Ponseti method, consisting of gentle manipulation, serial casting, Achilles tenotomy, and bracing, has become the gold standard for the treatment of idiopathic clubfoot, providing high success rates and reducing the need for extensive surgical interventions.[1,2]

A subset of patients presents with a more rigid and atypical deformity known as complex (or atypical) clubfoot. This variant is characterized by severe equinus, deep plantar creases, a short and stubby forefoot, and marked plantar flexion

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ABSTRACT

Objectives: This study aims to evaluate the midterm clinical outcomes of patients with complex clubfoot treated using the Ponseti method and to assess the sustainability of deformity correction over time.

Patients and methods: Between January 2016 and January 2021, a total of 38 feet in 26 patients with complex clubfoot treated using the modified Ponseti method were retrospectively analyzed. The patients were divided into two groups: those treated entirely in our institution (study center group) and those referred from external centers after unsuccessful initial treatment (external center group). Clinical severity was assessed using the Pirani score, and ankle dorsiflexion (DF) was measured during follow-up. Functional outcomes were evaluated using the Pirani-Based Score (PBS) and the Oxford Ankle Foot Questionnaire (OxAFQ). Relapse rates, additional procedures, and treatment success were analyzed. Independent predictors of outcomes were identified.

Results: Of a total of 26 patients included in the study, 2 were male and 24 were female with a mean age of 6.78±1.29 (range, 5 to 8) years. Of these patients, 14 (53.8%) had unilateral involvement, while 12 (46.2%) had bilateral deformity. The external clinic group presented at a significantly later age than the study center group ($p < 0.001$), while baseline deformity severity was comparable. Pirani scores and DF measurements improved significantly in both groups, with no intergroup differences during follow-up ($p > 0.05$). Functional outcomes showed a significant difference in PBS scores, which were higher in the external clinic group ($p = 0.045$), indicating worse functional performance, while the OxAFQ scores were similar between groups ($p = 0.911$). Relapse rates were higher in the own clinic group but did not reach statistical significance ($p = 0.254$). Multivariate analysis revealed that age was the only independent predictor of treatment success (odds ratio [OR] = 2.067, $p = 0.019$), while referral status was not an independent determinant.

Conclusion: The modified Ponseti method provides effective midterm correction in complex clubfoot regardless of referral status. Although referred patients present later and may demonstrate worse functional outcomes, referral source does not independently influence treatment success. Early recognition and appropriate application of modified Ponseti principles remain critical for optimal outcomes.

Keywords: Atypical clubfoot, complex clubfoot, modified Ponseti method.

of the metatarsals, making the deformity more resistant to standard manipulation techniques.[3] Proper recognition of this condition is crucial, as inappropriate casting techniques may worsen the deformity. Ponseti et al.[4] emphasized that modified manipulation and casting strategies were required to achieve successful correction in these cases.

Although the modified Ponseti technique has been reported to achieve satisfactory correction in patients with complex clubfoot, the available literature remains limited. Most published studies have focused on short-term outcomes, small patient cohorts, or technical aspects of treatment, whereas evidence regarding the durability of correction, recurrence patterns, and midterm functional outcomes is scarce. In our previous study, we reported the short-term outcomes of complex clubfoot treated with the modified Ponseti method and demonstrated that satisfactory correction can be achieved with appropriate technique.[5] However, despite these encouraging short-term results, there is still limited evidence regarding the midterm outcomes and durability of correction in patients with complex clubfoot. In the current study, we, hypothesized that patients referred from external centers after unsuccessful initial treatment might demonstrate poorer clinical and functional outcomes compared to patients who initiated and completed treatment in our institution. We, therefore, aimed to evaluate the midterm clinical outcomes of patients with complex clubfoot treated using the Ponseti method and to assess the sustainability of deformity correction over time.

PATIENTS AND METHODS

This single-center, retrospective cohort study was conducted at Harran University Faculty of Medicine, Department of Orthopedics and Traumatology between January 2016 and January 2021. Patients who were treated for complex idiopathic clubfoot using the modified Ponseti method were screened for eligibility. All patient data were prospectively collected and retrospectively analyzed. The present study included patients from our previous short-term study,[5] together with additional patients and extended follow-up data, allowing evaluation of midterm clinical and functional outcomes. A total of 26 patients (total 38 feet; study center: foot n = 21; external centers foot n = 17) with complex clubfoot deformities were included in the study. Patients were divided into two groups: those who initiated and completed treatment in our clinic (study center) and those referred from other institutions after unsuccessful initial treatment (external centers). Patients with myelomeningocele, arthrogryposis, neuromuscular disorders, or syndromic clubfoot were excluded. Finally, a total of 38 feet in 26 patients with complex clubfoot deformity were included in the study. A written informed consent was obtained from the parents and/or legal guardians of the patients. The study protocol was approved by the Gaziantep University Non-Interventional Clinical Research Ethics Committee (Date: 25.03.2026, Approval No.: 2026/183). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Demographic data, including sex, affected side, family history, and clinical characteristics such as short foot, deep plantar crease, hyperflexion, and severe equinus, were recorded. Initial clinical severity was assessed using the Pirani scoring system, and ankle dorsiflexion (DF) was measured at baseline and during follow-up.

Modified Ponseti method

All patients were treated by the same experienced orthopedic surgeon using the modified Ponseti method.[4] In patients with complex clubfoot, treatment was performed using the modified Ponseti method with several key technical differences from the standard technique. While correction was initiated similarly by addressing cavus followed by forefoot adduction, foot abduction was limited to a maximum of 40° to avoid midfoot subluxation. After correction of adduction and heel varus, unlike typical clubfoot, persistent severe equinus and plantar flexion of all metatarsals were addressed simultaneously. This was achieved by applying direct plantar pressure to the metatarsal heads while stabilizing the knee, allowing correction of both equinus and forefoot plantar flexion as a single unit. To prevent cast slippage, which is more common in complex clubfoot due to the short and rigid foot structure, the knee was maintained in at least 110° of flexion during casting. If ankle DF remained < 10° after serial casting, a mini-open Achilles tenotomy was performed.

Following correction, a foot abduction brace (FAB) was applied at 40° of abduction (lower than standard protocols), and patients were closely monitored for brace compliance and potential slippage. After cast removal, DF and Pirani scores were reassessed.

Following correction, all patients were prescribed a foot abduction brace, worn for 23 h per day for the first 3.5 months, and subsequently during night

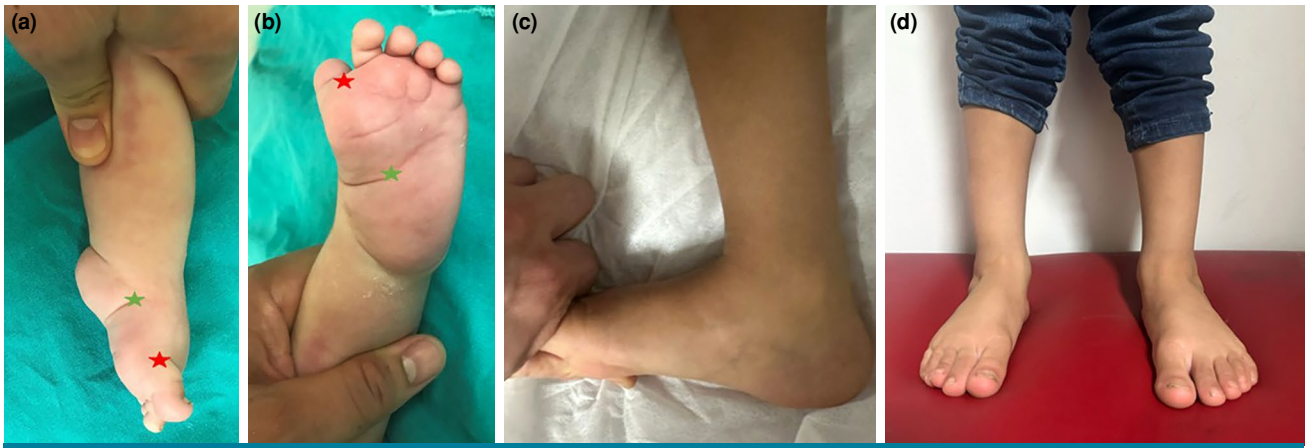


FIGURE 1. Clinical photographs of a four-month-old male patient referred from an external center due to treatment-resistant complex clubfoot. **(a, b)** Pretreatment images demonstrating characteristic findings of complex clubfoot, including deep plantar crease (green star) and short, hyperflexed hallux (red star). **(c, d)** Clinical appearance at four-year follow-up after treatment with the modified Ponseti method, demonstrating satisfactory correction of the deformity.

sleep and naps. Brace compliance was recorded and categorized. Follow-up visits were scheduled monthly until 12 months of age and every three months thereafter (Figure 1). Relapses that occurred during follow-up were evaluated at routine visits and treated with serial casting. Tibialis anterior tendon transfer was performed in patients with dynamic supination after the age of three.

Relapse was defined as the recurrence of any component of the deformity requiring additional treatment, including recasting, repeat Achilles tenotomy.

Outcome measures

Outcome measures included Pirani scores assessed at 12 weeks, six months, 12 months, 24 months, and at the final follow-up. Ankle DF measurements were recorded at baseline, as well as during early and midterm follow-up periods. Relapse-related parameters, including relapse rate, type of relapse, number of relapses, and time to relapse, were evaluated. The need for additional procedures, such as tendon transfer, was also documented. Functional outcomes were assessed using the Pirani-Based Score (PBS) and the Oxford Ankle Foot Questionnaire (OxAFQ). Treatment success was defined as achieving and maintaining correction without the need for extensive surgical intervention.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 25.0 software (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed separately for the own clinic and external clinic groups using the Shapiro-Wilk test. Continuous variables with a normal distribution were compared using the independent samples t-test, whereas non-normally distributed variables were compared using the Mann-Whitney U test. Categorical variables were analyzed using Pearson's chi-square test or Fisher's exact test, as appropriate. Univariate and multivariate binary logistic regression analyses were performed to identify independent factors associated with the outcome. Effect sizes were expressed as odds ratios (ORs) with 95% confidence intervals (95% CIs). A p-value < 0.05 was considered statistically significant. Statistical analyses were performed at the foot level, with each foot considered an independent unit of analysis.

RESULTS

Of a total of 26 patients included in the study, 2 were male and 24 were female with a mean age of 6.78±1.29 (range, 5 to 8) years. Of these patients, 14 (53.8%) had unilateral involvement, while 12 (46.2%) had bilateral deformity. Among the bilateral cases, seven patients were in the study center and five patients were in the external centers. Overall, 21 feet were treated entirely in our institution (study center), while 17 feet were referred from external centers after unsuccessful initial treatment (external centers). Given that the unit of analysis was the foot, all demographic and clinical variables were expressed on a per-foot basis.

TABLE I

Demographic and baseline characteristics of the study groups (per-foot analysis)

	Study center (Foot = 21)					External centers (Foot = 17)					Effect			
Variables	n	%	Mean ± SD	Median	Min-Max	n	%	Mean ± SD	Median	Min-Max	OR	95% CI	r	*p*
Age (year)			6.76 ± 1.51	7	5-8			6.65 ± 1.22	7	5-8			0.03	0.844
Sex														
Female	13	61.9				11	64.7				0.886	0.235-3.347		0.859
Right side	16	76.2				11	64.7				1.745	0.425-7.174		0.491
Initial age, weeks			2.24 ± 0.77	2	1-3			9.65 ± 3.66	10	4-15			0.86	< 0.001
Family history	4	19.0				3	17.6				0.911	0.174-4.769		1.000
Short foot	8	38.1				6	35.3				0.886	0.235-3.347		0.859
Deep plantar crease	9	42.9				7	41.2				0.933	0.255-3.411		0.917
Short and hyperflexed hallux	10	47.6				10	58.8				1.571	0.432-5.714		0.492
Severe equinus	12	57.1				12	70.6				1.800	0.464-6.976		0.393

SD, standard deviation; OR, odds ratio; CI, confidence interval.

TABLE II

Treatment characteristics and follow-up parameters

	Study center (Foot = 21)					External centers (Foot = 17)					Effect				
Variables	n	%	Mean ± SD	Median	Min-Max	n	%	Mean ± SD	Median	Min-Max	OR	95% CI	d	r	*p*
Brace duration (months)			22.81 ± 7.19	23	13-35			22.53 ± 6.33	22	13-33			0.04		0.901
Follow-up (months)			95.00 ± 18.78	96	62-119			91.29 ± 20.11	94	63-119			0.19		0.561
Cast number														0.07	0.684
5	3	14.3				1	5.9								
6	4	19.0				3	17.6								
7	4	19.0				6	35.3								
8	7	33.4				3	17.6								
9	3	14.3				4	23.5								
Achilles tenotomy	16	76.2				15	88.2				2.344	0.393-13.964			0.427
Brace compliance score														0.13	0.432
0	4	19.0				3	17.6								
1	8	38.1				4	23.5								
2	9	42.9				10	58.8								

SD, standard deviation; OR, odds ratio; CI, confidence interval; d, Cohen d; r, effect size.

The groups were comparable regarding sex distribution, side involvement, age at final evaluation, and baseline clinical characteristics (all $p > 0.05$). However, the initial age at the time of presentation was significantly higher in the external center group (9.65 ± 3.66 weeks *vs.* 2.24 ± 0.77 weeks, $p < 0.001$) (Table I).

Treatment-related variables were comparable between the two groups. Brace duration (22.81 ± 7.19 months *vs.* 22.53 ± 6.33 months, $p = 0.901$) and follow-up duration (95.00 ± 18.78 months *vs.* 91.29 ± 20.11 months, $p = 0.561$) did not differ significantly between the groups (Table II). The distribution of total cast number did not differ significantly between the groups ($p = 0.684$). Achilles tenotomy was performed in 16 feet (76.2%) in our study center and 15 feet (88.2%) in the external centers, with no significant intergroup difference ($p = 0.427$). Brace compliance was also similar between groups ($p = 0.432$) (Table II).

Initial ankle DF and initial Pirani scores were comparable between the groups. The mean initial DF was –14.05 ± 3.98 degrees in the study center and –13.76 ± 4.39 degrees in the external centers ($p = 0.836$). The mean initial Pirani scores were 5.29 ± 0.44 and 5.21 ± 0.40, respectively ($p = 0.476$).

Pirani scores improved progressively in both groups during follow-up. However, no significant intergroup differences were observed at 12 weeks, six months, 12 months, 24 months, or final follow-up (all $p > 0.05$). Early and midterm DF measurements were also statistically similar between the groups (Table III).

Functional outcome analysis showed a significant difference in PBS scores. The external center group had higher PBS scores than the study center group (6.12 ± 2.18 *vs.* 4.62 ± 2.25, $p = 0.045$; d = 0.68), indicating worse functional outcome according to this scale. In contrast, OxAFQ scores were comparable between the groups (77.11 ± 9.84 *vs.* 76.71 ± 11.81, $p = 0.911$; d = 0.04) (Table IV).

Relapse was observed in 10 feet (47.6%) in the study center group and in five feet (29.4%) in the external center group; however, this difference was not statistically significant (odds ratio [OR] = 0.458, 95% confidence interval [CI]: 0.119-1.768, $p = 0.254$). Relapse type and relapse count were also similar between the groups ($p = 0.261$ and $p = 0.130$,

TABLE III
Dorsiflexion and Pirani score outcomes

	Study center (Foot = 21)			External centers (Foot = 17)			Effect		
Variables	Mean ± SD	Median	Min-Max	Mean ± SD	Median	Min-Max	d	r	*p*
DF initial (°)	–14.05 ± 3.98	–14	–20 to –6	–13.76 ± 4.39	–14	–20 to –6	0.07		0.836
DF early (°)	4.91 ± 3.06	6	0-9	3.88 ± 2.52	4	0-8		0.19	0.236
DF midterm (°)	10.52 ± 6.57	12	–5 to 18	13.71 ± 3.31	14	8-19		0.22	0.180
Pirani initial	5.29 ± 0.44	5.5	4.5-6	5.21 ± 0.40	5	4.5-6		0.12	0.476
Pirani 12 weeks	2.38 ± 0.81	2.5	1-3.5	2.24 ± 0.86	2.5	1-3.5	0.17		0.596
Pirani 6 months	1.52 ± 0.83	1.5	0-3	1.18 ± 0.81	1.5	0-2.5	0.42		0.202
Pirani 12 months	0.83 ± 0.75	1	0-2	0.59 ± 0.57	0.5	0-1.5		0.16	0.314
Pirani 24 months	0.50 ± 0.74	0.5	0-2	0.46 ± 0.52	0.5	0-1.5		0.13	0.425
Pirani final	1.26 ± 0.66	1.5	0-3	0.88 ± 0.89	0.5	0-2.5		0.16	0.323

SD, standard deviation; d, Cohen d; r, effect size; DF, dorsiflexion.

TABLE IV
Functional outcomes

	Study center (Foot = 21)			External centers (Foot = 17)			Effect / 95% CI	
Variables	Mean ± SD	Median	Min-Max	Mean ± SD	Median	Min-Max	d	*p*
PBS score	4.62 ± 2.25	5	1-9	6.12 ± 2.18	6	1-9	0.68	0.045
Oxford score	76.71 ± 11.81	79	61-96	77.11 ± 9.84	77	63-99	0.04	0.911

CI, confidence interval; SD, standard deviation; d, Cohen d; PBS, Pirani-Based Score.

TABLE V
Relapse, additional procedures, and treatment success

	Study center (Foot = 21)		External centers (Foot = 17)		Effect		
Variables	n	%	n	%	OR	95% CI	*p*
Relapse	10	47.6	5	29.4	0.458	0.119-1.768	0.254
Relapse type							0.261
None	11	52.4	12	70.6			
Varus	2	9.5	1	5.9			
Adductus	4	19.0	4	23.5			
Equinus	4	19.0	0	0			
Tibialis anterior tendon transfer	5	23.8	3	17.6	0.686	0.138-3.400	0.709
Treatment success	9	42.9	11	64.7	2.444	0.654-9.130	0.180

OR, odds ratio; CI, confidence interval.

TABLE VI
Multivariate regression analyses

Variables	Outcome	Model	Result (OR)	*p*	95% CI	Model statistics
Age	Treatment success	Logistic regression	2.067	0.019	1.124-3.799	χ^2 = 8.430 model *p* = 0.038 Nagelkerke R^2 = 0.266 Hosmer-Lemeshow *p* = 0.916
Referral source	Treatment success	Logistic regression	Not independent	0.114	-	-
PBS score	Treatment success	Logistic regression	Not independent	0.583	-	-
Overall model	PBS score	Linear regression	Not significant	0.185	-	F = 1.583; R^2 = 0.234 Adjusted R^2 = 0.086
Overall model	Relapse	Logistic regression	Not significant	0.385	-	χ^2=4.157 model *p* = 0.385 Nagelkerke R^2 = 0.140 Hosmer-Lemeshow *p* = 0.964
Age week group	Relapse	Logistic regression	0.121	0.277	0.003-5.440	-
Initial age (weeks)	Relapse	Logistic regression	1.181	0.425	-	-
Brace compliance	Relapse	Logistic regression	0.656	0.375	-	-

OR, odds ratio; CI, confidence interval; PBS, Pirani-Based Score.

respectively). Tibialis anterior tendon transfer was performed in five feet (23.8%) in the study center group and three feet (17.6%) in the external center group (p = 0.709). Treatment success was achieved in nine feet (42.9%) in the study center group and 11 feet (64.7%) in the external center group, indicating no statistical significance (OR = 2.444, 95% CI: 0.654-9.130, p = 0.180) (Table V).

In the multivariate logistic regression analysis evaluating treatment success, the overall model was statistically significant (p = 0.038) and showed acceptable (p = 0.916). The model explained 26.6% of the variance (Nagelkerke R^2 = 0.266). Age was the only independent predictor of treatment success (OR = 2.067, 95% CI: 1.124-3.799; p = 0.019), while referral source and PBS score were not independent predictors.

Multivariate linear regression analysis for PBS score was not statistically significant (F = 1.583, p = 0.185; Nagelkerke R^2 = 0.234; adjusted R^2 = 0.086). None of the included variables, including age week group, initial age, brace duration, brace compliance or follow-up duration independently predicted PBS score. Similarly, multivariate logistic regression analysis for relapse was not significant (p = 0.385; Nagelkerke R^2 = 0.140), and no independent predictor of relapse was identified (Table VI).

DISCUSSION

In the present study, we compared complex clubfoot patients who initiated treatment at our institution with those referred from external centers after unsuccessful initial treatment. The main findings

were as follows: first, referred patients presented at a significantly later age; second, baseline deformity severity and clinical characteristics were comparable between groups; third, Pirani scores and DF measurements improved similarly in both groups; and fourth, functional outcome according to the PBS was worse in the referred group in the univariate analysis, although referral source was not an independent predictor of treatment success in the multivariate analysis. These findings suggest that referral after unsuccessful initial treatment does not compromise the ability to achieve satisfactory deformity correction with the modified Ponseti method, although delayed referral may be associated with less favorable functional outcomes.

Complex clubfoot is a distinct and challenging subtype of idiopathic clubfoot. Ponseti et al.[4] described the typical clinical features of complex idiopathic clubfoot and emphasized that these feet did not respond adequately to the standard Ponseti protocol, requiring a modified method with limited abduction, greater knee flexion in the cast, and simultaneous correction of metatarsal plantar flexion and equinus. Our previous early-term results also showed that the modified Ponseti method could achieve satisfactory correction in complex deformities and that referred, treatment-resistant feet should alert clinicians to the possibility of complex clubfoot.[5] Similarly, Göksan et al.[6] reported that early recognition of atypical and treatment-resistant clubfeet was essential to achieve successful correction and avoid treatment failure. The current study extends that experience by comparing midterm clinical and functional outcomes between primary and referred cases.

A central issue in the literature is whether complex clubfoot is primarily congenital or iatrogenic. Ponseti et al.[4] acknowledged that it might be difficult to determine whether treatment failure was caused by the intrinsic nature of the foot or by the treatment itself. Dragoni et al.[7] further discussed complex iatrogenic clubfoot and suggested that faulty manipulation and poor casting technique could contribute to the development of a complex deformity. Excessive abduction, failure to identify the talar head correctly, inadequate knee flexion, and cast slippage may lead to compression, edema, plantar and posterior creases, and a short, stubby foot appearance. In line with these observations, a considerable proportion of patients referred from external centers in our cohort had a history of frequent cast slippage during prior treatment. This finding supports the notion that at least some cases of complex clubfoot may develop secondary to improperly applied Ponseti technique. However, the presence of patients presenting primarily to our clinic, as well as bilateral involvement in some cases, suggests that complex clubfoot cannot be explained solely by iatrogenic factors. Future studies may benefit from distinguishing between primary (intrinsic) complex clubfoot and secondary (iatrogenic) complex clubfoot.

Nevertheless, the present findings suggest that once the complex deformity pattern has developed, the modified Ponseti method can provide comparable structural correction regardless of whether the deformity is congenital, iatrogenic, or mixed. Initial Pirani scores and initial DF values were similar between the groups, and no significant intergroup differences were found during follow-up. This supports the concept that the modified technique addresses the final pathoanatomical pattern of the deformity rather than its initial cause. These findings are consistent with Matar et al.[8] who reported that the modified Ponseti method was an effective first-line treatment for complex idiopathic clubfoot, although these patients might require more casts and have a higher risk of relapse or additional procedures. Mandlecha et al.,[9] similarly, reported successful results with the modified Ponseti technique in complex clubfeet, particularly when combined with Achilles tenotomy when needed. In the present study, relapse rates were relatively high in patients with complex clubfoot, and a higher number of casts was required, in agreement with the existing literature. Although the difference was not statistically significant, the relatively lower relapse rate observed in patients referred from external centers may suggest that these cases were not initially true complex clubfoot, but rather developed a complex deformity secondary to improper Ponseti casting. Therefore, once treated with an appropriately applied technique after referral, their relapse profile may resemble that of non-complex clubfoot. Chu and Lehman[10] similarly reported that patients with persistent deformities following Ponseti treatment frequently require additional procedures and prolonged follow-up, highlighting the complexity of managing these challenging cases.

Recent studies have further demonstrated that complex and atypical clubfoot cases require a greater number of casts and are associated with higher relapse rates compared to typical idiopathic clubfoot, emphasizing the need for careful technique modification and close follow-up.[11-13] In the present study, relapse rates were relatively high in patients

with complex clubfoot, and a higher number of casts was required, in agreement with the existing literature.

In the current study, the only significant intergroup difference among functional outcomes was the PBS score, which was higher in the external centers. This may indicate that functional recovery is more sensitive than Pirani score or DF to delayed presentation, previous inappropriate manipulation, prolonged deformity, or soft-tissue stiffness. This finding may also be explained by the inherent differences between scoring systems. The discrepancy between PBS and Pirani scores can be explained by the different constructs measured by these assessment tools. While the Pirani score primarily evaluates the severity of residual deformity and is mainly intended for use in infants during the correction phase, it may not adequately reflect functional performance in ambulatory children. In contrast, the PBS score incorporates both static and dynamic functional parameters, including gait characteristics, and has been shown to be a reliable and valid instrument for assessing functional outcomes in walking-age children with clubfoot. Therefore, functional impairments related to previous treatment difficulties or delayed presentation may be detected by PBS despite comparable Pirani scores between groups[14] The absence of an independent effect of referral source in multivariate analysis suggests that this difference should be interpreted cautiously. In other words, referral status may be a marker of delayed or suboptimal previous treatment rather than a direct determinant of poor outcome.

An important finding of the present study was that age at presentation was the only independent predictor of treatment success. This finding is consistent with previous studies emphasizing the importance of early diagnosis and treatment initiation in clubfoot management. Ponseti et al.[1,4] reported that early treatment took advantage of the greater flexibility and remodeling capacity of infant soft tissues, thereby facilitating correction and improving outcomes. Similarly, Göksan et al.[6] showed that delayed presentation might adversely affect treatment response and increase treatment complexity. Our findings further support the concept that earlier recognition and appropriate management of complex clubfoot are associated with more favorable outcomes.

An important finding of the regression analysis was that age was the only independent predictor of treatment success. This suggests that patient-related biological factors and tissue adaptability may play a more important role than treatment origin alone. Clinically, this finding reinforces the importance of early recognition and early application of the correct technique. However, it also indicates that previously treated or referred complex cases should not be considered poor candidates for correction, provided that the modified Ponseti principles are strictly followed.

The clinical implications of this study are relevant for both primary and referral centers. Complex clubfoot should be suspected in feet with severe equinus, hyperflexion of the first toe, plantar crease, short and stubby appearance, cast slippage, or resistance to standard correction. In such cases, continuing standard Ponseti correction with excessive abduction may worsen the deformity. Instead, clinicians should promptly shift to the modified Ponseti method. Therefore, complex clubfoot should be viewed not only as a rare congenital subtype, but also as a potentially preventable iatrogenic treatment failure when the standard technique is applied incorrectly.

Nonetheless, this study has several limitations that should be acknowledged. First, the retrospective design may have introduced selection bias. Second, the sample size was limited, which is expected given the low frequency of complex clubfoot but reduces the power to detect small differences. Third, the external center group was heterogeneous in terms of previous treatment protocols, and the exact details of prior manipulation and casting were not available for all patients. Finally, although the follow-up period was sufficient to evaluate midterm outcomes, longer follow-up is needed to assess late relapse and the need for additional surgical procedures.

In conclusion, the modified Ponseti method provides effective correction in complex clubfoot patients regardless of referral status. In our study, referred patients presented later and had worse PBS scores in the univariate analysis; however, referral source was not an independent predictor of treatment success. The results support the view that complex clubfoot may be congenital, iatrogenic, or mixed in origin. Careful recognition of warning signs and strict adherence to modified Ponseti principles are essential to prevent iatrogenic worsening and to obtain satisfactory outcomes.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: M.A.D., A.Y.K., C.B.: Idea/concept; B.V.Ç.,, M.A.A.: Design control/supervision; M.I., T.B.: Data collection and/or processing; A.Y.K., M.I.: Analysis and/or interpretation literature; A.Y.K., C.B.: Review; M.A.D.,, A.Y.K.: Writing the article; M.A.A., C.B.: Critical review; M.I., T.B.: References and fundings; Materials; A.Y.K., M.I., M.A.D.

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