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Management of atypical clubfoot by modified ponseti method: A clinical study

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Abstract
Background and Objectives: Clubfoot is one of the most common foot deformity found in newborns. While the Ponseti method is highly effective for typical idiopathic cases, a subset of patients presents with atypical or complex clubfoot, characterized by resistance to correction and a higher incidence of relapse. Literature is sparse on its etiology, and its unique phenotypic features often complicate management. To address these challenges, a modified Ponseti method has been developed.
Materials and Methods: This study included 45 atypical clubfeet from 30 patients under 1 year of age, treated between April 2023 and November 2024 using the modified Ponseti method. Relevant perinatal and postnatal histories were recorded. Pirani scores were assessed weekly. Treatment involved serial manipulation and casting according to the modified Ponseti method, followed by percutaneous tendoachilles tenotomy. A post-tenotomy cast was applied in 10° dorsiflexion and 110° knee flexion for three weeks. After cast removal, a foot abduction brace was applied. Follow-up visits assessed on brace compliance and relapse.
Results: The average age at presentation was 3.5 months (56.7%), with a male-to-female ratio of 3:1. Bilateral involvement was seen in 50%, and 10% had a positive family history. The mean number of casts required before tenotomy was 7.16 per foot. Mean Pirani score improved from 5.8 ±0.3 at presentation to 1.1 ±0.4 post tenotomy ($p< 0.001$). Cast slippage occurred in 23.3%, relapse in 10%, and minor skin complications were noted in 10 children. Following tenotomy, 86.7% of cases achieved functional dorsiflexion of >10°. Follow-up continued for up to 18 months.
Conclusion: The modified Ponseti method is an effective first-line treatment for atypical clubfoot, achieving functional correction with minimal complications. It significantly reduces the need for complex bony surgeries and extensive soft tissue release procedures.

Keywords: Atypical clubfoot, modified Ponseti method, Pirani score

Introduction
Clubfoot is one of the most common musculoskeletal deformities, affecting about 1 in every 1,000 live births [1]. Atypical clubfoot is characterized by severe equinus, a deep transverse crease across the plantar midfoot, hyperplantarflexion of all metatarsals, and a short, hyperextended great toe [2]. Unlike typical idiopathic clubfoot, which usually responds well to the Ponseti method within 5 to 7 weeks of serial casting, complex cases are often resistant to standard techniques and require a higher number of casts or modifications to achieve full correction [2]. Though the terms "atypical" and "complex" are often used interchangeably, a distinction exists: atypical clubfeet are present at birth, whereas complex clubfeet typically develop after the first few casts during the course of treatment [3]. Turco, in his study, observed such cases with atypical features and said, “They respond altogether differently to both operative and non-operative treatment, and early surgery results in a grotesquely deformed foot,” and warned against surgery in such cases [4]. These cases are marked by a fibrotic, tight Achilles tendon and a smaller gastrocnemius-soleus complex. According to Ponseti, approximately 6.5% of idiopathic clubfeet exhibit atypical features [1]. The exact etiology of atypical clubfoot is not known, but these are seen in bulky feet and in cast slippage cases. The recurrence of these deformities necessitates their early recognition. There is limited literature on the modified Ponseti method that is used in treating these cases in the Indian population. This study aims to assess the outcomes of the modified Ponseti technique in the treatment of

atypical clubfoot.

Materials and Methods

Study Design

This prospective study was conducted in the Department of Orthopaedics at Karnataka Medical College and Research Institute, Hubli, Karnataka, from April 2023 to November 2024. The study was conducted in coordination with the institution's clubfoot clinic, which operates weekly. Institutional Ethics Committee approval was obtained prior to the initiation of study. Informed consent was obtained from the parents or guardians of all participants after detailed explanation of the study protocol and its objectives.

Selection Criteria

A total of 45 atypical clubfeet in 30 patients were included in the study and treated using the modified Ponseti method, which incorporated percutaneous achilles tendon tenotomy. Patients were followed for a duration of 18 months, and no dropouts were recorded. Clubfoot cases exhibiting atypical features Figure 1, including rigid equinus, severe plantarflexion of the metatarsals, deep transverse plantar crease, short and hyperextended great toe, forefoot adduction and supination, and prominent posterior heel crease were included in the study. Patients with age greater than 1 year at presentation, previous surgical intervention for clubfoot, syndromic clubfoot or associated neurological disorders, postural, relapsed, or neglected clubfoot, refusal to provide informed consent were excluded.

Statistical analysis

Data collected for this study included both quantitative variables (age, Pirani scores at different treatment stages, number of casts, and degree of dorsiflexion achieved post-tenotomy) and qualitative variables (gender, laterality, family history, brace compliance, and recurrence). All data were entered into Microsoft Excel 2021 (Microsoft Corp., Redmond, WA, USA) and analyzed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA).

Descriptive statistics were used to summarize demographic and clinical characteristics. Quantitative variables were expressed as mean ± standard deviation (SD), while qualitative variables were presented as frequencies and percentages. Changes in Pirani scores across treatment stages (initial presentation, pre tenotomy, post-tenotomy, and final follow-up) were analyzed using the paired Student's t-test. A p-value of <0.05 was considered statistically significant. Correlation between age at presentation and number of casts required was evaluated using Pearson's correlation coefficient (r).

Treatment Protocol

Upon inclusion, a detailed perinatal history and clinical examination were performed. Pirani scores [5] were recorded for each foot at first visit and at every follow-up. Weekly manipulation and casting were performed according to the modified Ponseti method. At each visit, changes in Pirani score, cast compliance, and any cast-related complications were documented. Radiographic evaluation was not routinely performed.

Once neutral foot abduction and correction of metatarsal hyperflexion were achieved, a percutaneous tendo-Achilles tenotomy was performed. Post-tenotomy, a cast was applied for three weeks with the foot positioned in 10°-15° dorsiflexion, 30°-40° abduction, and the knee flexed at 100°-110°. Following cast removal, all patients were fitted with a foot abduction brace (FAB) set at 40° abduction and 15° dorsiflexion.

Modified Ponseti Technique

The Modified Ponseti method was adapted to address the specific characteristics of atypical clubfoot:

The talar head was localized via subtalar joint movement and clasped between the thumb and index finger. The opposite hand gently abducted the forefoot while ensuring the talar head remained stabilized during both stretching and casting. Counter pressure was applied to the lateral talar head using the thumb, with the index finger over the posterior aspect of the lateral malleolus [Figure 2]. This technique facilitated simultaneous correction of midfoot inversion and hindfoot varus.

Severe hyperplantarflexion of the metatarsals and rigid equinus were addressed concurrently by applying a dorsiflexion force using both thumbs positioned under the first and fifth metatarsal heads. The foot was stabilized at the ankle, and a below-knee cast was transitioned to an above-knee cast with the knee maintained in 100°-110° flexion by an assistant. Serial casting was continued weekly until neutral forefoot abduction and correction of hindfoot varus were achieved.

Percutaneous Achilles Tenotomy

Tenotomy was performed in all the cases under aseptic conditions and local anesthesia, approximately 1.5 cm proximal to the heel crease [Figure 3]. The effectiveness of the procedure was assessed intraoperatively by the degree of dorsiflexion achieved. A post-tenotomy cast was then applied with the foot in 10°-15° dorsiflexion, 30°-40° abduction, and the knee flexed to 100°-110°, maintained for three weeks.

Splinting Protocol

Following cast removal, all the patients were provided with a foot abduction brace (FAB), consisting of shoes attached to a metal bar set at 40° of foot abduction less than the standard 70° used for idiopathic clubfoot. Brace application was initiated only after achieving at least 10° of dorsiflexion post-tenotomy. If the desired dorsiflexion was not achieved, casting in dorsiflexion was continued for two additional weeks and then reassessed. The brace was worn for 23 hours per day during the initial three months, followed by night time use for a duration of five years. Patients were reviewed monthly to monitor clinical progress, brace compliance and detect any early signs of relapse.

Results

A total of 30 children with 45 atypical clubfeet were included in the study and managed using the Modified Ponseti method. This consisted of serial above-knee plaster of Paris (POP) cast applications followed by percutaneous tendoachilles tenotomy. The severity of the deformity was assessed using the Pirani scoring system at multiple time points from April 2023 to November 2024. All patients completed the treatment protocol, with no reported dropouts.

The mean age at presentation was between 3 and 5 months (56.7%). The youngest patient was 45 days old, while the oldest was 7 months. A male predominance was noted, with males accounting for 70% of cases, yielding a male-to-female ratio of 3:1. Bilateral involvement was observed in 15 patients (50%), while the remaining 15 (50%) had unilateral

deformities, with right-sided involvement being more common. A positive family history of foot deformity was reported in 10% of cases, including one child whose father had untreated clubfoot.

Treatment Outcome

The mean Pirani score at the time of presentation was 5.4 ± 0.5 (range: 4.5-6.0). Following serial casting, the score decreased significantly to 1.3 ± 0.3 (range: 1.0-1.5) at the time of tenotomy, suggesting substantial correction of deformities prior to surgical intervention. At the time of foot abduction brace application, the mean score further decreased to 0.2 ± 0.3 (range: 0.0-0.5), and at final follow-up, it reached 0.03 ± 0.1 (range: 0.0-0.5) [table1-2]. These improvements in Pirani scores across treatment phases were statistically significant ($p< 0.05$), indicating the effectiveness of the modified Ponseti method in the management of atypical clubfoot.

Post-tenotomy, 86.7% (n = 26) of patients achieved dorsiflexion of ≥10°. The average number of casts required prior to tenotomy was 7.16 per foot. Notably, older infants required a higher number of casts, attributed to increased stiffness and rigidity of the deformities.

A relapse was documented in 3 patients (10%). Two cases underwent repeat tenotomy and recasting, while one required posteromedial soft tissue release. Cast slippage were reported in 7 cases (23.3%), including single-episode slippage in 5 patients (16.7%) and two episodes in 2 patients (6.7%). Minor skin complications were observed in 10 cases, which comprised 5 cases (16.6%) with pressure sores, 3 cases (10%) with rashes, and 2 cases (6.7%) with edema. All were managed conservatively by adjusting cast tightness and applying additional padding. No complications were associated with the tenotomy procedure.

Follow-up assessments were performed in 80% (n = 24) of the cohort at 12-14 months (mid-term) and in 20% (n = 6) at 18 months (long-term), underscoring the challenge of maintaining extended follow-up in this population. Higher compliance rate with the foot abduction brace, with an adherence rate of 93.3%, reinforcing the importance of post-correction bracing in maintaining long-term outcomes in atypical clubfoot

Discussion

Atypical clubfoot poses significant diagnostic and therapeutic challenges due to its distinctive clinical presentation and resistance to standard treatment protocols. This variant is characterized by a short, stubby foot with marked plantarflexion and adduction of the forefoot, deep plantar and posterior creases, rigid equinus, and a pronounced hindfoot varus deformity. The etiology remains unclear but is thought to involve shortening and tightness of deep plantar intrinsic muscles, hyperfibrosis of medial tarsal ligaments, the gastrosoleus complex, tibialis posterior, and long toe flexors [6]. Dragoni *et al.* [3] reported that faulty manipulation and poor casting technique may convert typical clubfoot into a complex deformity. Severe plantarflexion of the metatarsals and the rigid equinus deformity, both of which become more evident as the foot is abducted during serial casting becomes a major therapeutic difficulty. These cases also carry a higher risk of cast slippage due to the foot's altered morphology and stiffness. In contrast to idiopathic clubfoot, where foot abduction during casting is upto 70°, abduction in atypical clubfoot is limited to 30°-40°. Hyperabduction beyond this range increases the risk of subluxation at the Lisfranc joint, entailing careful manipulation. Once forefoot adduction has been adequately addressed, the persistent metatarsal hyperflexion and rigid equinus are addressed simultaneously. This is achieved by applying a dorsiflexion force at the metatarsal heads using both thumbs, while the remaining fingers stabilize the ankle. This technique not only facilitates correction of the deformity but also reduces the incidence of cast slippage by ensuring secure positioning during the cast moulding process.

The incidence of atypical clubfoot is likely underreported, primarily due to the diagnostic challenges in differentiating it from typical idiopathic clubfoot. In our study cohort, atypical clubfoot was identified in 9.3% of cases (30 out of 323), with a higher prevalence among males. The mean age at presentation was 3.5 months. Bilateral involvement was observed in 50% of cases, while the remaining 50% presented unilaterally. The management of complex clubfoot necessitates a modified Ponseti method, which involves meticulous dorsiflexion of the midfoot and avoidance of excessive abduction. In our series, the mean number of casts required to achieve correction, excluding post-tenotomy casts, was 7.16 per foot.

Previous studies have reported variable incidences of complex clubfoot. Ponseti *et al.* [2] documented an incidence of 6.5%, with a male-to-female ratio of 1.63:1. Dragoni *et al.* [3] reported a higher incidence of 17%, while Yoshioka [7] *et al.* noted an incidence of 13%. According to Ponseti's observations, the mean age at presentation was 3 months, and correction was achieved with a mean of 5 casts (range: 1-10) using a modified Ponseti technique. Matar *et al.* [8] evaluated 17 complex clubfeet in 11 patients and reported a mean age at presentation of 1.2 months (M:F = 9:2), requiring an average of 7 casts (range: 5-10) for correction. Similarly, Mandelcha *et al.* [9] reported a mean of 7.44 casts per foot (range: 6-10) to achieve satisfactory correction.

Progressive and sustained correction was observed in all patients, as assessed by the Pirani scoring system. There was a statistically significant improvement in the mean Pirani score from presentation (5.4 ± 0.5) to the time of tenotomy (1.3 ± 0.3), and further to 0.03 ± 0.1 at the final follow-up. Similar findings were reported by Mandelcha *et al.* [9], who observed mean Pirani scores of 5.57 at the start of treatment, 0.18 at the first application of the foot abduction brace (FAB), and 0.06 at final follow-up.

Percutaneous tendoachilles tenotomy was performed in all patients to correct residual equinus deformity. Relapse occurred in 3 patients (10%) of which two cases had equinus relapse and one case had forefoot adduction relapse. Of these, two required repeat tenotomy and one underwent posteromedial soft tissue release to achieve satisfactory correction. In comparison, Ponseti reported relapse in seven patients, managed by recasting and secondary tenotomy in three. Matar [8] reported a higher relapse rate of 53% (9 out of 17 cases), while Mandelcha *et al.* [9] reported a relapse rate of 11.1%, managed successfully with recasting and repeat tenotomy.

Minor cast-related complications were noted in 5 cases [16.6%] and were managed conservatively through adjustments in cast tightness, improved padding, and application of topical emollients. Morcuende *et al.* [10] reported a lower complication rate of 8%, including erythema, mild toe swelling, and cast slippage. Dobbs *et al.* [11] described serious bleeding complications in four patients following percutaneous tenotomy. However, no such complications were observed in our cohort.

Limitations

This study has several limitations. The sample size was relatively small and derived from a single centre, limiting the generalizability of the findings. The follow-up duration of up to 18 months was insufficient to evaluate long-term relapse rates, functional outcomes and changes at skeletal maturity. Absence of a control group treated with the standard Ponseti method or surgical techniques restricted comparative analysis. Assessment relied solely on clinical parameters such as the Pirani score without radiological evaluation, potentially limiting objective validation of correction. Additionally, brace compliance was based on parental reporting, which may introduce reporting bias. Functional outcomes, including gait and activity levels, were not analysed. These factors collectively limit the strength of conclusions and highlight the need for larger, multicentre studies with extended follow-up and comprehensive outcome assessment.

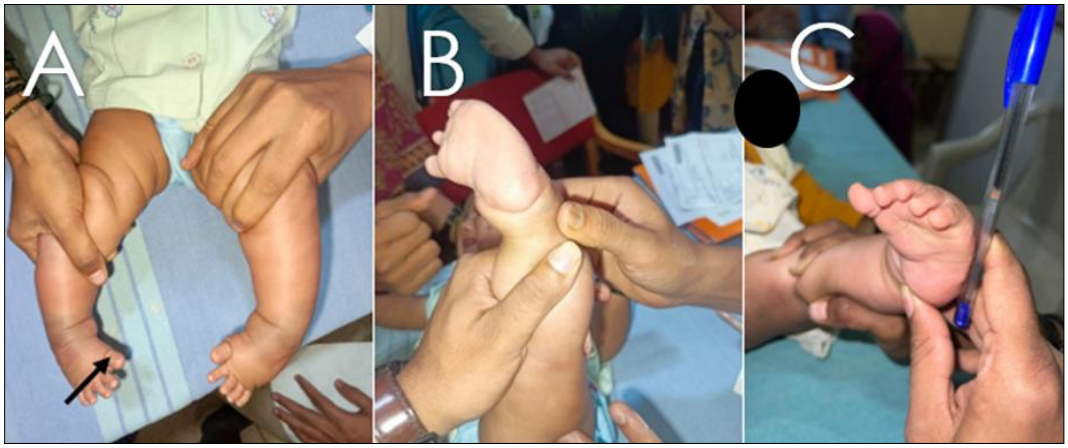

Fig 1: Illustrating characteristic features of atypical clubfoot A. hyperextended great toe (arrow). B. deep posterior crease. C. curved lateral border

Fig 2: Showing manipulation according to modified Ponseti method A. Pressure over lateral head of talus and lateral malleoli with forefoot abduction. B. Pressure over head of 1st and 5th metatarsal with ankle stabilized. C. Cast application in 100°-110° knee flexion.

Fig 3: Tenotomy procedure. A. Preparation of tenotomy area using betadine. B. infiltration of local anaesthesia. C. Incision 1.5cm proximal to the calcaneal tuberosity

Fig 4: Follow up at 5 months post tenotomy. A. disappearance of posterior crease. B. disappearance of curved lateral border. C. neutral ankle dorsiflexion. D. on foot abduction brace.

Conclusion

Early recognition of complex clubfoot is essential to differentiate it from idiopathic variants and initiate appropriate treatment. The modified Ponseti method addresses these atypical deformities through gentle manipulation, structured serial casting and a tailored bracing protocol. This minimally invasive technique significantly reduces the need for extensive soft tissue releases or bony corrective surgeries, making it a compelling first-line treatment option. A larger, well-powered study with extended follow-up through skeletal maturity is essential to more accurately evaluate long-term functional outcomes and relapse rates.

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Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations: The work described in the manuscript is original research that has not been published previously, and the manuscript is not under consideration for publication elsewhere, either in whole or in part.

Ethics approval and consent to participate: Ethical approval was waived by the Institutional Ethics Committee. Informed consent was obtained from all individual participants included in the study

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Declaration of competing interest: None.

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