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Surgical Correction of Residual Deformities after Ponseti Treatment of Club Feet in Walking Children

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Abstract

Background: Clubfoot (CF) deformity is not a uncommon deformity, and the majority of children show reduced height. The Ponseti serial casting (PSC) method for CF is a highly effective and minimally invasive. However, a six-year night-splinting period is difficult to comply with and predisposes to CF persistence or recurrence.

Aim of Study: Assessment of the outcomes of selective surgical procedures for walking CF children and were previously treated with PSC method.

Patients and Methods: 35 feet with residual deformities after PSC in children aged <7 years were evaluated. Patients aged <4 years with flexible deformity received soft tissue procedures. Patients aged >4 years and had rigid deformity underwent bony procedures. Postoperative (PO) follow-up entailed assessment of preoperative complaints, PO complications, and radiologic judgment of the correction of residual deformities, and the position of K-wires. PO Pirani severity scores were determined and compared to the preoperative scores.

Results: Pain and the residual deformity completely disappeared in 80% and 82.9% of feet. PO residual hindfoot varus, adduction of midfoot, and cavus deformities were detected in 6 feet. Two feet had wound infections that were managed conservatively in one, but the other required intervention for wound debridement and cleansing. All feet were plantigrade, with complete disappearance of preoperative difficulties. The PO Pirani scores were significantly lower, and PO radiologic estimation of various angles improved significantly than preoperative measures.

Conclusion: The selective surgical procedures for CF residual deformities after PSC are an appropriate, effective, and safe management policy with a success rate >80% and minimum complication rate.

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Key Words: *Clubfoot deformity – Ponseti serial casting – Residual deformity – Surgical correction – Soft tissue procedures – Bony procedure – Surgical outcomes.*

Introduction

CONGENITAL talipes equinovarus (CTEV) or Clubfoot (CF) deformity is encountered in about 200,000 newborns yearly, and the majority of patients were of low and middle-income status **[1]**. Children with idiopathic CF also showed a higher risk of neurodevelopmental delays and reduced height compared to their age-matched children, and this indicated the importance of early recognition through regular monitoring by parents and pediatricians **[2]**.

The Ponseti method is a highly effective, minimally invasive, and reliable therapeutic modality for idiopathic congenital clubfoot **[3]**. The Ponseti method for CF treatment includes a six-year night-splinting period, which is difficult to comply with and predisposes to the persistent or recurrence of the deformity **[4]**.

A network meta-analyses suggest that despite considering the Ponseti method as the optimal treatment, the long casting duration, the high tenotomy rates, relapse, and the need for additional surgery are its potential drawbacks **[5]**.

The factors that may influence the outcomes of CF treatment as regards favorable outcomes and recurrence included the proper diagnosis of cases of idiopathic and complex CF, the severity of CF, and age at the start of treatment **[6]**. The presence

of neuromuscular imbalance, poor nutritional status, noncompliance with brace use, and treatment adherence also modifies the outcomes of the Ponseti method for CF treatment **[7].** Early and multiple CF recurrences are suggested as a leading cause for more frequent subsequent recurrence and earlier second recurrence following Ponseti casting **[8].**

Aim of the work:

This work aims to assess and compare the outcomes of selective surgical procedures for walking CF children who were treated by the Ponseti casting technique.

Patients and Methods

Design:

Prospective study.

Setting:

Abo-Elreesh Hospital, Cairo University, in collaboration with the National Institute of Neuro-motor System, during the period from March 2013 to March 2017.

Patients:

Children previously treated with serial Ponseti casting and still have residual clubfoot deformities were evaluated for the enrolment criteria.

Inclusion criteria:

The study aimed to include children aged 1 to 7 years who were previously treated by the Ponseti method for idiopathic or non-idiopathic clubfoot and presented with residual deformity or partial relapse.

Exclusion criteria:

Children older than 7 years, not treated at the start by the Ponseti method, or received other previous surgical interventions, were excluded from the study. Children with associated congenital abnormalities and neuromuscular, genetic, and chromosome disorders were also excluded.

Preoperative evaluations:

Clinical assessment:

Demographic data, including age, gender, bilaterality, and the affected side, were defined. Complaints included the presence of pain and walking, running, or jumping difficulties, easy fatigability, insightfoot appearance, and difficulty in shoe wear. The history of previous trials of Ponseti serial casting and the frequency of trials (Table 1). Search for the possible causes of the relapse or the residual deformities, including noncompliance with the foot abduction brace after Ponseti treatment, incomplete course of serial casting, wrong Ponseti technique, non-idiopathic clubfoot, or negligence. Local clinical foot assessment in weight-bearing for true deformities and functions. Skin integrity was assessed to identify unsafe foot pressures, especially in children with insensate skin. Evaluation of muscle strength, sensation, reflexes, and vascularity. Then, each segment of the foot was evaluated for the number and flexibility of residual deformity. Each patient underwent the Pirani scoring system before and after treatment. The Pirani scoring system scores the severity of three features in each of the mid and hind feet. Each feature is scored 0, 0.5, or 1, where 1 indicates the most severe for each feature **[9].**

Table (1): Patients' enrollment data.

Data	Findings
Age:	
<4 years	20 (69%)
≥4 years	9 (31%)
Mean (±SD)	3.6 (1.2)
Gender:	
Males	15 (51.7%)
Females	14 (48.3%)
Laterality:	
Bilateral	6 (20.7%)
Unilateral	23 (79.3%)
Affected foot:	
Right	18 (51.4%)
Left	17 (48.6%)
Number of Ponseti trials:	
One	5 (14.3%)
Two	30 (85.7%)
Age at the ^{1st} Ponseti trial:	
<6m	14 (40%)
6-12m	18 (51.4%)
12-24m	3 (8.6%)
Age at the ^{2nd} Ponseti trial:	
6-12m	6 (17.1%)
12-24m	6 (17.1%)
>24m	18 (51.4%)

Preoperative Radiological assessment:

The preoperative radiological assessment entails determination of the anterior talocalcaneal angle for varus of the hindfoot, the anterior talo-first metatarsal angle for adduction of the midfoot, the lateral talocalcaneal angle for varus of the hindfoot, the lateral talo-first metatarsal angle for cavus of the midfoot, and the lateral tibio-calcaneal angle for equinus of the hindfoot.

Surgical procedures:

The surgical procedures were performed under general anesthesia with a high thigh tourniquet applied after commencement of anesthesia. The choice of the surgical procedure depended on the type of residual deformity, the rigidity of the deformity, and the patient's age. Patients younger than 4 years who had flexible deformity received soft tissue procedures, and patients older than 4 years who had rigid deformity underwent bony procedures. Soft tissue procedures included tibialis anterior tendon transfer (TATT), tendo-Achillis lengthening (TAL), posterior capsulotomy (PC), plantar fasciotomy (PF), or posteromedial release. Bony procedures were either double column osteotomy (DCO) or calcaneal osteotomy (CO). Detailed procedure descriptions with representative photos are shown in Figs (1-5).

Appendix (1): *The surgical procedures:*

1- *Tibialis anterior tendon transfer (TATT):*

Fig. (1-A): A dorsolateral incision was centered on the lateral cuneiform or over the insertion of the tibialis anterior tendon.

Fig. (1-B): The TAT was exposed without too far distal dissection to guard the growth plate of the 1st metatarsal. TAT was detached at its insertion.

Fig. (1-C): The position of the lateral cuneiform was identified radiologically, and a drill hole (3.8–4.2) large enough to accommodate the tendon was made in its middle.

Fig. (1-D): An anchoring suture using #0 absorbable material was inserted through multiple passes for the TAT fixation. The tendon was transferred laterally deep to the extensor tendons, and the extensor retinaculum was pulled into the drill hole, and the suture was tied securely with the foot in mild eversion and the ankle in neutral position.

PO Care:

A long-leg cast was applied while keeping the foot abducted and dorsiflexed. No bracing was required; the cast and the gauze were removed at 6 weeks, and the child was allowed to mobilize weight-bearing as tolerated. Occasionally, physical therapy was indicated to regain strength and normalize gait.

2- *Open tendo-Achilles Z-lengthening and posterior capsulotomy:*

Fig. (2-A,B): A straight longitudinal incision is made over the medial aspect of the Achilles tendon, the Achilles tendon is identified, dissected, and a Z-plasty is performed to lengthen it by releasing the medial half distally and the lateral half proximally for a distance of 2.5 to 4cm.

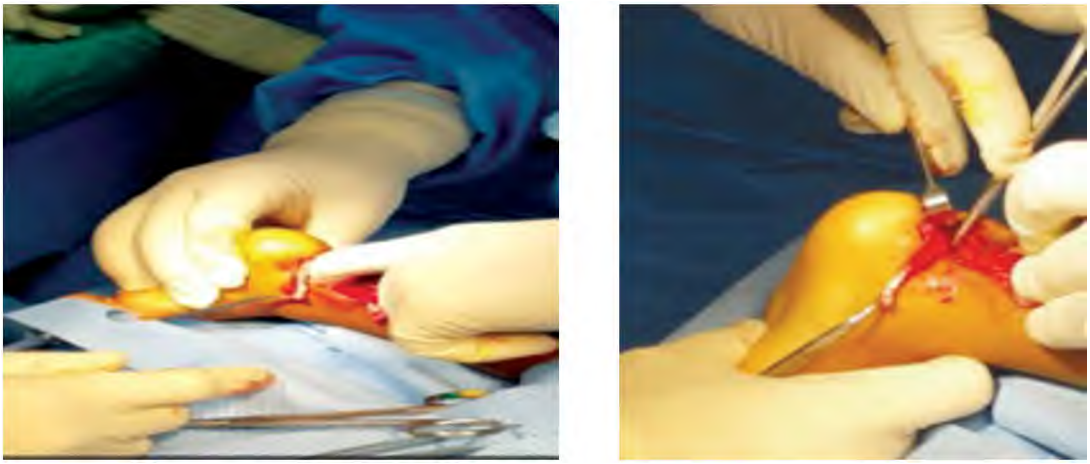

Fig. (2-C): The posterior aspect of the ankle joint was identified by gentle plantar flexion and foot dorsiflexion. A transverse capsulotomy was performed at the most medial aspect, stopped at the sheath of the posterior tibial tendon, and the most lateral articulation of the tibio-fibular joint. If required, posterior subtalar capsulotomy was made at the most proximal aspect of the sheath of the flexor halluces longus tendon, and the capsulotomy was extended medially and laterally as necessary.

Fig. (2-D): The foot was placed in 10o dorsiflexion, the Achilles tendon ends were approximated to assess tension, and then the overlapping ends of the tendon were repaired under moderate tension.

PO Care:

A long-leg, bent-knee cast with the foot in 5o dorsiflexion for 6 weeks after surgery. PO bracing with an ankle-foot orthosis was used for 6-9 months longer, especially at night, to prevent relapse of equinus.

3- *Calcaneal osteotomy (CO; DWYER, MODIFIED):*

Fig. (3-A): Skin incision for modified Dwyer CO to expose its lateral surface subperiosteally.

Fig. (3-B): A wedge of bone was resected with a wide osteotome (or electric saw) based laterally large enough.

Fig. (3-C): The wedge was removed, the osteotomy was fixed with a Kirschner wire, and the incision was closed with interrupted sutures. A short-leg cast was applied with the foot in the corrected position to allow the correction of the heel varus.

Fig. (3-D): Radiologic ascertaining of osteotomy fixation with K-wire, and the cast was applied.

PO Care: The Kirschner wire was removed at 6 weeks, and casting was at 8 to 12 weeks.

4- *Double column osteotomy (DCO):*

Fig. (4-A): A 2-cm incision was made on the cuboid bone to approach the medial cuneiform.

Fig. (4-13): An osteotomy was made in the cuneiform, leaving the anterior tibial tendon attached to the distal piece of bone. The medial cuneiform osteotomy was spread with a smooth spreader, and the cuboid bone wedge was inserted in it, with the base of the wedge directed medially. After clinical judgment of correction, two smooth Kirschner wires were used to fix the foot in the corrected position; one was inserted through the cuboid, starting in the calcaneus and exiting through the base of the 5th metatarsal, and the other was inserted through the 1st web space, through the medial cuneiform and tarsal navicular, and into the talus.

PO Care: The position of the pins and the correction of the bony deformity were confirmed with radiographs. A short-leg cast with thick padding to allow for swelling. The wounds were checked at 2 weeks, and a more form-fitting, non-weight-bearing cast was applied. The pins were removed at 6 weeks, and a weight-bearing cast was applied until bony union was evident on radiographs, usually at 8-12 weeks.

5- *One-stage Posteromedial release:*

Fig. (5-A): A Turco-shaped posteromedial incision was made.

Fig. (5-13): After blunt dissection of the skin, it was elevated as a full-thickness flap. The fascia overlying the muscles was opened. The neurovascular bundle was identified and retracted.

Fig. (5-C): The tibialis posterior tendon was identified and divided for a Z-plasty.

Fig. (5-D): The sheath of the flexor digitorum longus was opened and followed distally to the master knot of Henry, where the flexor hallucis longus was identified.

Fig. (5-E): A medial capsulotomy of the talonavicular joint was performed. A blunt periosteal elevator was introduced in the joint space, and the navicular bone was gently reduced to allow easy reduction of the forefoot and the varus of the hindfoot. Then, the posterior tibiotalar joint capsule was opened for reduction of the equinus. Z-plasty lengthening of the Achilles tendon was performed.

Fig. (5-F): The wound was closed.

PO Care:

The wound was checked after two weeks, the sutures were removed, and the back slab was exchanged to a full above-knee plaster of Paris cast with the foot in dorsiflexion with valgus stress for 4 weeks, and follow-up was performed at two months and every 6 months thereafter.

Postoperative care:

A long-acting local anesthetic was injected into the wound to reduce immediate PO pain. Immediate postoperative (PO) care was provided in the intermediate care unit after patients had fully recovered from anesthesia. PO analgesia was provided to keep patients pain-free. As long as there was no postoperative nausea and vomiting, oral fluids were allowed after two hours of recovery, and oral feeding was provided after six hours, and patients were home-discharged.

PO follow-up:

All patients were followed-up for at least 12 months. Following cast removal, gait training was provided for 6 weeks. During regular follow-up visits, patients were clinically assessed for pain in the operated foot, the resolution of preoperative complaints, stiffness, particularly in cases with extensive soft tissue release, and the appearance of the foot. Clinical follow-up for gaining PO complications, including skin complications, slipped graft, foot stiffness, PO residual deformity, or other complications. Radiological follow-up to detect the correction of the residual deformities by PO measurements of the preoperatively determined angles, assess the position of the K-wires, detect PO complications, if any, especially flat-topped talus, talus avascular necrosis, or slipped graft after double column and calcaneal osteotomies. At the end of the follow-up, PO Pirani scores were determined and compared with the preoperative scores. Details of case presentations with illustrative photos are shown in Figs (6-9).

Case presentation:

Case (1): Female child age 42 months, presented with residual left CF deformity and had previous 2 Ponseti trials at ages of 6 and 12 months. Complaint: pain, discomfort with wearing shoes, and difficulty in walking and running. Preoperative clinical examination showed a residual forefoot dynamic supination with a Pirani score of one. Radiographic assessment: TCA1: 32°, TFMA1: 10°, TCA2: 35°, TFMA2: 8°, TIB.CA: 90°. Operative procedure: Tibialis anterior tendon transfer. Follow-up period: 24 months. Result: excellent with no residual deformity, pain, or difficulty in walking, running, and shoe wearing, and Pirani score: 0, and no PO complications. Radiographic assessment: TCA1: 30°, TFMA1: 6°, TCA2: 32°, TFMA2: 5o, TIB.CA: 85° (Fig. 6A,B).

Fig. (6-A): Preoperative.

Fig. (6-B): 6-m PO.

Case (2): Female child aged 39 months, presented with right CF residual deformity after two previous Ponseti trials at the ages of 10 and 30 months. This time lag was secondary to the neglect of parents, and the second trial was incomplete until the age of presentation. The child had pain in her right foot, with difficulty in walking, running, and wearing shoes, and an unsightly appearance of the foot. Preoperative clinical examination detected residual cavus and adduction of the midfoot and residual varus and equinus of the hindfoot, and a Pirani score of 6. Radiographic assessment detected a TCA1 of 10°,TFMA1: 30°,TCA2: 8°,TFMA2: 23°, TIB.CA: 110°. The child underwent posteromedial soft tissue release (PMR), and the PO follow-up period was extended for 24 months. At 6-month PO, there was still mild adduction of the midfoot foot but the parents and the patient were satisfied due to the correction of the deformity. At the last visit, there were no difficulties in walking, running, and shoe wearing due to correction of the shape of the foot, but there was pain due to foot PO rigidity, and a mild residual adduction deformity. The PO Pirani score was 1.5, and the result is fair. Radiologically, the TCA1: 25°, TFMA1: 14°, TCA2: 28°, TFMA2: 7°, TIB.CA: 90°. Stiffness of the foot and mild residual adduction is the procedural complication (Fig. 7A-C).

Fig. (7-A): Preoperative.

Fig. (7-B): 6-mPO [Ant view].

Fig. (7-C): 6-m PO [Lat view].

Case (3): A male child aged 5 years and 11 months, presented with right foot residual deformity after 2 previous Ponseti trials at the ages of 8 and 26 months due to parental neglect, and the second trial was incomplete with neglect to seek advice till the age of presentation. Complaints included pain in the foot, especially on the lateral aspect, difficulty and discomfort with wearing shoes and difficulty in walking and running. Clinically, there was residual dynamic supination of the forefoot and rigid hindfoot varus with a Pirani score of 2. Radiographic assessment: TCA1: 10°, TFMA1: 12°, TCA2: 6º, TFMA2: 8º, TIB.CA: 90º. Patient received lateral closing wedge calcaneal osteotomy (CO) and tibialis anterior tendon transfer (TATT) and follow-up for 20 months. At 6-month PO, there was no residual deformity, pain, or difficulty in walking, running, or shoe wearing. However, one year later, the patient came with relapsed hindfoot varus with mild pain, but no marked difficulty in walking, running, and shoe wearing, and the Pirani score was 1.5, and a fair result. Radiographic assessment: TCA1: 15º, TFMA1: 6º, TCA2: 18º, TFMA2: 5º, TIB.CA: 85º. Residual varus of the hindfoot is the procedural complication (Fig. 8A-C).

Fig. (8-A): Preoperative.

Fig. (8-B): PO X-ray [Lat view].

Fig. (8-C): 6-m PO [Lat view].

Case (4): A male child aged 5 years and 8 months presented with bilateral residual deformities after two Ponseti trials at ages of 10 and 26 months, but the casting courses were incomplete, and the child was neglected till the age of presentation. Complaints included foot pain, difficulty with wearing shoes and difficulty walking and running. Clinically, there was residual rigid adduction of the midfoot of the right and residual rigid adduction and cavus of the midfoot of the left foot, and Pirani scores of 2.5 and 3, respectively. Radiographic assessment: TCA1: 30o, TFMA1: 28o, TCA2: 27°, TFMA2: 10°, TIB.CA: 90° on the right and TCA1: 24°, TFMA1: 40°, TCA2: 27°, TFMA2: 22°, TIB.CA: 90° on the left. The right foot had a double-column osteotomy, and 3 months later, the left foot received a double-column osteotomy and plantar fasciotomy. Follow-up was continued for 20 and 24 months for the left and right feet. Postoperatively, no pain, difficulty in walking, running, and shoe-wearing in both feet, and no marked residual deformity in both feet. The Pirani scores were 0 and 1 with excellent and good results for the right and left feet, respectively. The Right radiographic assessment: TCA1: 26o, TFMA1: 10°, TCA2: 28°, TFMA2: 5°, TIB.CA: 90°, and the left: TCA1: 25°, TFMA1: 15°, TCA2: 25°, TFMA2: 8°, TIB.CA: 90°. No complication was encountered in either foot (Fig. 9A,B).

Fig. (9-A): Preoperative.

Fig. (9-B): 6-m PO.

Statistical analysis:

The data are presented as mean, standard deviation (SD), numbers, and percentages. The data were compared using the paired *t*-test, while data presented as percentages were compared using the Chi-square test. Statistical analyses were conducted by the IBM® SPSS® Statistics software (Version 26, 2019; IBM Corporation; Armonk, USA). The significance of the analysis was evaluated at $p<0.05$.

Results

The preoperative evaluation excluded 8 feet in five patients, and 35 feet had the appropriate surgical procedure. All surgeries were completed uneventfully for the thirty-five feet, and all patients were home-discharged as a day-case. During follow-up visits, 28 feet (80%) were pain-free. Seven feet (20%) were rigid, despite being nearly fully corrected in shape; examination of the flexibility detected deformities of the different segments. These patients were still complaining of pain during walking and running, despite being of lower severity. However, these patients were satisfied because they could walk on plantigrade feet without problem in shoe-wearing.

Complete wound healing was achieved at two weeks postoperatively in 33 feet (94.3%), while soft tissue wound complications were encountered in two feet (5.7%). One foot showed a superficial wound infection that was eradicated within two weeks with daily dressing after suture removal and receiving antibiotics. The other case developed a deep wound infection that was treated by local wound debridement under general anesthesia and antibiotic administration according to culture and sensitivity test, without recurrence during follow-up for 18 months (Fig. 10).

The residual deformities were corrected, and 29 feet (82.9%) were completely free of deformities; however, 6 feet (17.1%) still had residual deformity. Two cases (5.7%) still had residual hindfoot varus deformity; one patient underwent lateral closing wedge osteotomy of the calcaneus, which was adequate and corrected the deformity until 6 months after the surgery. During the following visits, the varus deformity started to recur due to overgrowth of the lateral aspect of the calcaneus at the site of the osteotomy. At the last visit, the patient complained of mild pain but not from recurrence of the hindfoot deformity, and was satisfied because the associated tibialis anterior transfer successfully corrected the forefoot supination and the position of the foot during gait (Fig. 11). The other foot of residual hindfoot deformity, had PO wound infection, which necessitated early removal of the cast for wound dressing led to skin tethering after healing (Fig. 12) with mild relapse of the hindfoot varus deformity.

Two feet showed residual adduction of midfoot; one foot had a sever preoperative midfoot adduction, that was managed by double column osteotomy but the size of the wedge was under estimated for the cuneiform leading to under correction with residual midfoot adduction (Fig. 13). The other food had residual midfoot adduction due to slipped bone graft that was inserted at the medial cuneiform osteotomy as diagnosed through PO radiographic follow-up. The slipping of the bone graft was iatrogenic because no K-wire had been inserted at the time of surgery to fix the graft in position, relying on the fitness of the graft in the wedge, resulting in residual adduction deformity of <5º (Fig. 14).

Another two feet showed residual cavus deformity; one foot had posteromedial release and showed no residual deformity for 6 months PO, but later on, mild cavus appeared in the midfoot and reached a maximum at 12 months postoperatively (Fig. 15). This might be attributed to the development of soft tissue contracture after extensive surgery. The second foot had tibialis anterior tendon transfer surgery for correction of dynamic supination of the forefoot, but cavus deformity appeared postoperatively, mostly due to missed preoperative midfoot cavus (Fig. 16).

Preoperative difficulty in walking, running, or jumping, easy fatigability, and shoe-wear difficulty disappeared completely, even for the seven cases that still have pain, because the feet became plantigrade. Fortunately, no cases with PO neuro-vascular injury were defined, and muscle strength and skin sensations were preserved (Table 2).

Table (2): PO clinical outcomes.

Parameter	Outcome	Frequency
Pain	Pain-free	28 (80%)
	Residual minimal pain	7 (20%)
Foot flexibility	Flexible	28 (80%)
	Rigid	7 (20%)
Wound healing	Complete infection-free wounds	33 (94.3%)
	Infected wound	2 (5.7%)
Residual deformity	No	29 (82.9%)
	Yes	
	Residual hindfoot varus	2 (5.7%)
	Midfoot adduction	2 (5.7%)
	Residual cavus	2 (5.7%)
Other complaints	Disappeared	35 (100%)
Neurovascular injuries		0

Fig. (10): Shows the right foot of a case complicated by deep soft tissue wound infection that was managed surgically and completely healed during follow-up.

Fig. (11): Shows residual varus of the right hindfoot.

Fig. (12): Shows skin tethering resulting in residual varus of the hindfoot.

Fig. (13): Shows residual adduction of the midfoot.

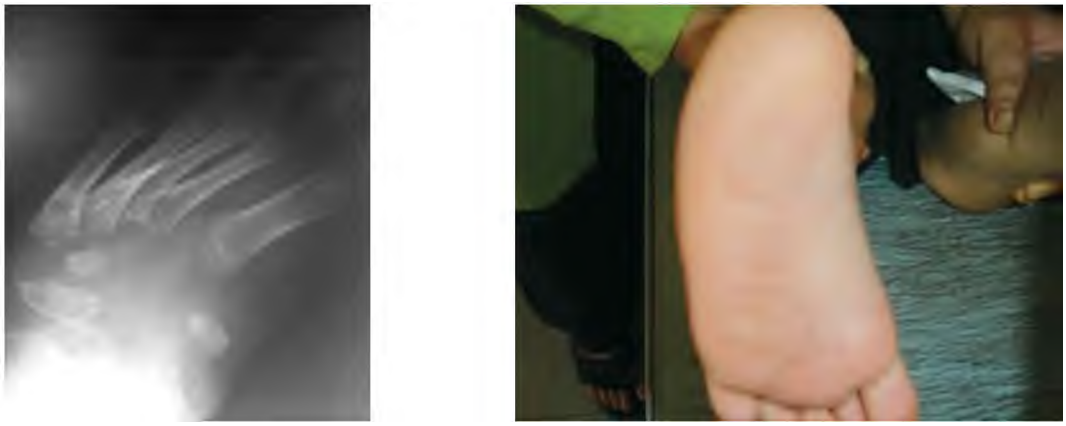

Fig. (14): Shows a foot with slipping of the bone graft as evident radiographically and clinically.

Fig. (15 & 16): Shows the residual cavus.

According to the Pirani score, preoperatively, 23 feet were scored by >2.5, 4 feet were scored by 1.5-2, and 8 feet were scored by either 0.5 or 1, while no case had a score of zero. PO Pirani scoring defined 17 feet (48.6%) as scored by zero, and the outcome was defined as excellent. PO outcome was good in 10 feet (28.5%) with a Pirani score of 0.5-1, and fair in 7 feet (20%) with a score range of 1.5-2, while it was poor in only one foot (2.9%), which was scored by 3. The PO feet distribution among the Pirani scores was significantly (p<0.001) different than the preoperative distribution (Fig. 16). The mean value for the PO Pirani score was significantly (p<0.001) lower than the preoperative score (Table 3, Fig. 17).

Postoperative radiologic estimation of various angles of the operated feet showed significant differences in comparison to the preoperatively estimated angles. The anterior talo-calcaneal and lateral talo-calcaneal angles were significantly increased with a p-value of 0.001 and 0.003, respectively. On the contrary, the anterior and lateral talo-first metatarsal angles significantly (p<0.001) decreased. The lateral tibio-calcaneal angle was also significantly (p<0.001) decreased relative to the preoperative angle (Table 3). No complications were detected on radiologic assessment regarding slipped graft after double column and calcaneal osteotomies, the position of the K-wires, the flat-topped talus, or talus avascular necrosis.

Table (3): The Pirani scorings.

Items	Score	Grade	Preoperative	Postoperative	p-value
Frequency	0	Excellent	0	17 (48.6%)	
	0.5 – 1	Good	8 (22.9%)	10 (28.5%)	<0.001
	1.5 – 2	Fair	4 (11.4%)	7 (20%)	
	2.5 – 6	Poor	23 (65.7%)	1 (2.9%)	
Pirani score	Mean (± SD)		2.95 (1.65)	0.64 (0.81)	<0.001
	Range (minimum-maximum)		1-6	0-3	

- Data are shown as mean, standard deviation (SD), numbers, and percentages. Analysis for the significance of the difference was assessed using the Chi-square test and the Paired t-test*.

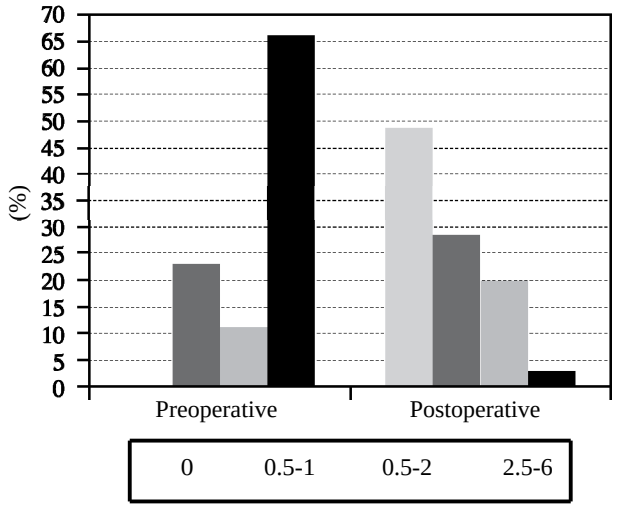

Fig. (16): Shows the feet distribution according to the Pirani score.

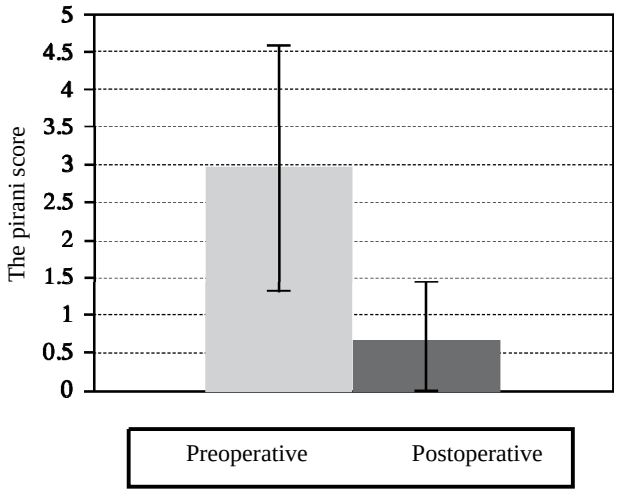

Fig. (17): Shows the mean (+SD) value of preoperative and postoperative Pirani score.

Table (3): The PO radiologic assessment of the correction of the residual deformity.

The angle	Significance	Preoperative	Postoperative	*p*-value
Anterior talocalcaneal	Varus of hindfoot	23.12±10.232 (5-35)	28.6±5.083 (15-35)	0.001
Anterior talo-first metatarsal	Adduction of midfoot	21.28±12.364 (8-38)	9.04±2.993 (6-15)	<0.001
Lateral talocalcaneal	Varus of the hindfoot	23.04±11.901 (5-38)	29.68±3.923 (18-35)	0.003
Lateral talo-first metatarsal	Cavus of midfoot	12.24±7.282 (3-28)	5.28±1.429 (4-8)	<0.001
Lateral tibio-calcaneal	Equinus of the hindfoot	104.56±14.866 (85-125)	88.16±2.954 (85-98)	<0.001

- Data are shown as mean, standard deviation, and range (minimum-maximum). Analysis for the significance of the difference was assessed using the Paired *t*-test.

Discussion

At the end of follow-up, pain, which is the principal complaint that limits, in addition to the deformity, patients' activities and deleteriously impacts their quality of life was completely disappeared in 80% of feet and was reduced in the remaining 20% of feet. In line with the impacts of the deformity-induced pain, Smythe et al. **[1]** ensured that untreated clubfoot deformity causes pain and reduced mobility, with subsequent activity limitations and disability.

Additionally, the residual deformity was corrected in 82.9% of feet; a figure coincident with that of pain-free outcomes. These findings, with the disappearance of the deformed foot shape and the difficulty in wearing shoes, alleviated the psychological burden on these children and their parents. In line with the psychological burden of the clubfoot deformity, Agarwal et al. **[10]** documented that mothers of children with clubfoot were subjected to early psychological stress, which can extend even post correction of deformity, and this requires periodic reinforcements during the treatment. Regarding the immediate surgical outcomes, only two feet developed wound infection that necessitated intervention in one foot, while the remaining 33 feet showed complete wound healing.

The current study aimed to determine the outcomes of selective surgical procedures based on residual foot deformity. The tibialis anterior tendon transfer (TATT) was performed on nine feet (25.7%) that exhibited dynamic forefoot supination, either as the sole deformity or combined with hindfoot varus, midfoot cavus, or adduction deformities. The results were satisfactory, with correction achieved in eight feet (88.9%), but the ninth foot showed PO cavus deformity, which may have been missed during preoperative assessment and not considered a procedure failure. The reported effectiveness of TATT for such residual deformities aligns with Ayub et al. **[11]**, who noted no recurrence in 98.7% of their series of residual dynamic supination deformities after correction with the Ponseti method, and no revision surgery was needed following TATT. Additionally, Ayub et al. **[11]** regarded bone anchors as a consistently reliable, reproducible, safe fixation method, providing a quick

and straight forward alternative to traditional techniques. Moreover, Boble & Samargandi *[12]* documented the effectiveness of Split TATT in treating CF residual deformities. Retrospectively, Haile et al. *[13]* found that children who underwent TATT for residual dynamic supination deformity exhibited higher clinical and functional scores than those who did not undergo TATT, indicating better outcomes and recommending the TATT procedure, especially for children younger than three years old.

Open tendo-Achilles Lengthening (TAL) and posterior capsulotomy (TAL & PC) were performed on 12 feet (34.8%) with equinus of the hindfoot in patients who had plantigrade feet at the end of follow-up. These findings align with Afridi et al. *[14]*, who reported a 100% success rate with plantigrade feet after Achilles tenotomy in children with persistent residual equinus deformity after Ponseti serial casting and recommended combined Ponseti casting and tendo-Achilles tenotomy to achieve plantigrade feet in 100% of patients with equinus deformity that present in over 60% of the patients after Ponseti serial casting.

In support of the effectiveness of the TAL procedure, Seidel et al. *[4]* found that TAL and limited posterior release, with subsequent splinting for a reduced period of splinting. Also, Garg et al. *[15]* reported that treatment of CF before one year of age by the Ponseti protocol with percutaneous Achilles tenotomy and bracing protocol for 2-4 years causes minimal scarring and does not interfere with the general functioning of the child with well-accepted aesthetic scar characteristics.

Calcaneal osteotomy was performed as the only procedure to correct residual varus of the hindfoot, and in combination with TATT for children who had residual hindfoot varus and dynamic forefoot supination after the Ponseti protocol in two patients, respectively. One patient developed a PO infection that required surgical wound debridement and responded well to treatment. Consistent with choosing these procedures for children with residual deformity older than four years, Al-Hilli[16] used the Ponseti method to treat relapsed clubfeet after previous posteromedial soft tissue surgical release in 25 feet of patients aged 1-10 years, with casts applied until only hindfoot equinus and/or dynamic supination remained, which were managed by calcaneal osteotomy with TATT for residual dynamic supination.

Conclusion:

The study outcomes indicated the appropriateness of selective surgical procedures for residual deformities after the Ponseti method for management of clubfoot deformity. Further, the provided treatment is effective with a success rate of more than 80% and a minimum complication rate.

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التصحيح الجراحى للتشوهات المتبقية بعد علاج بونسيتى للقدم الحنفاء عند الأطفال القادرين على المشى

الخلفيـة: تشـوه القـدم الحنفـاء ليـس تشـوهًا غيـر شـائع، ويصاحبـه قصـر الطـول الـذى يصيـب غالبيـة الأطفـال المصابـين بالقـدم الحنفـاء. تعـد طريقـة بونسـيتى لعـلاج تشـوه القـدم الحنفـاء بالجبـس التسلسـلى طريقـة فعالـة للغايـة. ومـع ذلـك، مـن الصعـب الالتـزام بسـت سـنوات مـن التجبيـس الليلـى مـع احتماليـة اسـتمرار أو تكـرار الإصابـة بالتشـوه.

الأهـداف: تقييـم نتائـج العمليـات الجراحيـة الانتقائيـة للأطفـال المصابـين بتشـوه القـدم الحنفـاء فـى المشـى وتـم علاجهـم سـابقًا بطريقـة بونسـيتي للجبـس التسلسـلى.

المرضـى والطـرق: شـملت الدراسـة ٣٥ قدمًـا حنفـاء مصابـة بتشـوهات متبقيـة بعـد إجـراء طريقـة بونسـيتى للجبـس التسلسـلى للأطفـال الذيـن تقـل أعمارهـم عـن ٧ سـنوات. المرضـى الذيـن تقـل أعمارهـم عـن ٤ سـنوات ويعانـون مـن تشـوه فـى المرونـة خضعـوا لعمليـات اصـلاح الأنسـجة الرخـوة. خضـع المرضـى الذيـن تزيـد أعمارهـم عـن ٤ سـنوات ولديهـم تشـوه صلـب لعمليـات عظميـة. اسـتلزمت المتابعـة بعـد الجراحـة تقييـم شـكاوى مـا قبـل الجراحـة، ومضاعفـات مـا بعـد الجراحـة، وتحديـد مواضـع أسـلاك K. تـم تحديـد درجـات شـدة تشـوه القـدم الحنفيـة باسـتخدام مقيـاس بيرانـى ومقارنتهـا بدرجـات مـا قبـل الجراحـة.

النتائـج: اختفـى الألـم والتشـوه المتبقـي تمامًـا فـى ٨٠٪ و٨٢,٩٪ مـن الأقـدام علـى التوالـى. تـم الكشـف عـن بقايـا مـن التشـوهات لتجويـف القـدم فـى ٦ أقـدام. حدثـت الالتهابـات لجـروح قدمـين بعـد الجراحـة تمـت معالجتهـا بشـكل متحفـظ فـى إحداهمـا، لكـن الأخـرى تطلبـت تدخـلاً لتنظيـف الجـرح وتطهيـره. كانـت جميـع الأقـدام قـادرة علـى المشـى، مـع اختفـاء كامـل للصعوبـات التـى كانـت موجـودة قبـل الجراحـة. كانـت درجـات مقيـاس بيرانـى أقـل بشـكل ملحـوظ بعـد الجراحـة، وتحسـن التقييـم بالأشـعة للزوايـا المختلفـة بشـكل ملحـوظ عـن مقاييـس مـا قبـل الجراحـة.

الاسـتنتاج: تُعـد الجراحـة الانتقائيـة للتشـوهات المتبقيـة مـن تشـوه القـدم الحنفـاء بعـد اتبـاع طريقـة بونسـيتى للجبـس التسلسـلى سياسـة علاجيـة مناسـبة وفعالـة وآمنـة مـع نسـبة نجـاح تزيـد عـن ٨٠٪ ومعـدل مضاعفـات أقـل.