

Comparative Study Between Arthroereisis Versus Calcaneal Lengthening In Planovulgus Foot In Cerebral Palsy Children

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Abstract

Background: Planovalgus deformity of the foot is common among cerebral palsy patients. There is no true consensus about the best way of treating this common deformity especially when surgical interference is required. Treatment options range from orthotics to complex surgical procedures.

Patient and Methods: The current study is a randomized prospective comparative study designed to evaluate and compare the effectiveness of 2 different procedures in the correction of symptomatic flexible pes planovalgus in ambulatory CP patients by comparing the clinical outcomes, radiographic outcomes, patients (or parents) satisfaction and tolerance to shoes or braces 6 months after each procedure. The study was divided into 2 groups: Group 1: subtalar arthroereisis using the prostop screw technique was done for 18 feet in 9 cases, group 2: lateral column calcaneal lengthening using iliac bone graft was done for 18 feet in 11 cases.

Results: There was a statistically significant improvement after both procedures in comparison to the preoperative parameters. No statistically significant differences were observed between the two groups regarding the aforementioned outcomes except for TNCA denoting more power of Evans osteotomy in the correction of forefoot abduction. In addition, neither procedure caused any loss of hindfoot mobility. Therefore, both procedures are valid options for the surgical management of PPV in ambulatory spastic CP patients.

Conclusion: The study is designed to evaluate the power of correction of the symptomatic pes planovalgus in ambulatory spastic CP patients by subtalar arthroereisis (prostop technique) in comparison to lateral column calcaneal lengthening technique.

Keywords: Arthroereisis, Calcaneal Lengthening, Planovulgus Foot, Cerebral Palsy Children

INTRODUCTION

Pes planovalgus is the most common foot deformity in all ages of children with cerebral palsy (CP) ^[1], specifically among diplegic and quadriplegic patients ^[2,3]. In this deformity, the foot is in valgus, external rotation, and dorsiflexion relative to the talus. The equinus drives the calcaneus to displace posteriorly and rotate into valgus, causing the talar head to sublunate medially and inferiorly. The forefoot tends to abduct, leading to sublaxation of the calcaneocuboid joint with dorsal sublaxation of the cuneonavicular joint in the medial column. Consequently, the navicular and the head of the talus become the weight-bearing areas, which is often painful ^[4].

There is general consensus and evidence that within the first years of life a flat shape of the foot has to be considered physiological, often spontaneously correcting by the age of ten years. ^[5]

Despite this, the abnormal foot shape can often become a reason for concern for parents and triggers subsequent medical referral. ^[6,7] Usually children are able to walk without symptoms, but sometimes they may complain of pain located over the medial aspect of the heel, the sinus tarsi, the distal fibula and the medial aspect of the midfoot. ^[8]

The radiographic evaluations consist of many angles; however, there are variations in these measurements. Gait analysis for ambulatory patients gives quantitative data, specifically, foot pressure, which measures the distribution of forces acting on the foot. ^[9]

Subtalar arthroereisis Derived from the fusion of the Greek roots arthro- (joint) and -ereisis (the action of sustaining, supporting, pushing against something), 'arthroereisis' is a surgical option in the treatment of planovalgus foot with the aim of re-establishing a medial foot arch and limiting the movement of the subtalar joint without blocking it. ^[10]

Calcaneal lengthening osteotomy has been used most commonly to correct the deformity and not sacrifice joint motion in

patients with CP. Calcaneal lengthening for symptomatic planovalgus deformity in children and adolescents was introduced by Evans in 1975 [11]. Subsequently, numerous studies have reported the success of calcaneal lengthening for treatment of symptomatic flatfoot deformity in patients with CP [12].

Both treatment options have been reported for treatment of symptomatic planovalgus deformity of feet in ambulatory patients with CP with varying degrees of success and some complications [13]

The goal of this study is to compare the short term results benefits, complications and advantages of correction of planovalgus foot deformity by arthroereisis versus calcaneal lengthening osteotomy, aiming at identifying if there is any difference between both, and trying to formate some recommendations to choose one method or the other.

Patients and Methods

Patients:

The current study is a Prospective randomized study using closed envelope technique, It was conducted on 36 feet (20 patients) admitted both in Abolreesh Children's University Hospital. (18 feet in 9 patients underwent arthroereisis and 18 feet in 11 patients underwent calcaneal lateral column lengthening). All cases presented by symptomatic CP spastic flexible pes planovalgus. The current study started in Sep 2019 and ended in May 2021. Written detailed informed consents were obtained from parents.

To compare the clinical and radiological outcomes of subtalar arthroereisis using prostop screw and calcaneal lengthening osteotomy for the management of planovalgus feet in ambulatory patients with spastic cerebral palsy.

▪ Inclusion criteria:

Diagnosis of spastic cerebral palsy, age between 4 and 15 years at time of surgery, ambulatory patients (GMFCS I, II), planovalgus feet correctable by manipulation (flexible deformity), progressive deformities, despite the conservative treatment for at least six months.

▪ Exclusion criteria:

Rigid flatfoot (irreducible), asymptomatic flatfoot condition, patients with a history of bony foot surgery, poorly or non-ambulatory patients (GMFCS III, IV&V).

The patients were randomly assigned into 2 groups: **Group 1:** Subtalar arthroereisis (prostop implant) was done for the first group: 18 feet in 9 patients (all cases bilateral), **Group 2:** Lateral column lengthening (iliac bone graft) was done for the second group: 18 feet in 11 patients (7 bilateral and 4 unilateral).

Simple randomization was carried out in the operating suite using a sealed-envelope system containing a piece of paper written either subtalar arthroereisis or lateral column lengthening -the envelope was opened at the time of the first case and the written procedure was performed, with the following case treated with other procedure.

Methods:

▪ Preoperative assessment was done similarly for both groups:

All of the 20 patients had history of difficult delivery and/or were incubated at birth. Of these patients 16 were spastic diplegic (for whom surgery performed for both feet in 16 cases and for one foot in 4 cases), and 4 were spastic hemiplegic (three right sided and one left-sided), but no patient was of the total body involvement (TBI) type. Each of them received some forms of non-operative treatment as physical therapy programs, orthoses, and skeletal muscle relaxant but no previous foot surgery.

Presentation complaints:

Foot Pain with ambulation, foot Deformity, skin problems and frequent tripping when ambulating and abnormal gait.

Clinical assessment:

Neurological Assessment, orthopedic Assessment (Foot deformity and functional Disabilities).

Radiographic assessment:

Weight bearing anteroposterior and lateral X-ray views of ankles and feet were taken for all patients. Ankle anteroposterior radiography excluded the possibility of valgus at the tibiotalar joint evidenced by talar tilt in the ankle mortise. The following angles were measured on both pre-and postoperative radiographs of feet:

On the weight-bearing foot AP view: Talo-navicular coverage angle (TNCA), Talo-first metatarsal angle (AP T-1ST), Talo-calcaneal angle (AP TCA), **On the weight-bearing foot lateral view:** Talo-first metatarsal angle (LAT T- 1ST), talo-calcaneal angle (LAT TCA), calcaneal pitch angle (CPA).

▪ Surgical Approaches

All patients underwent surgery under general anaesthesia with endotracheal intubation. Perioperative antibiotic prophylactic doses were routinely used tourniquet is applied proximally to the lower limbs.

Patient Positioning:

All patients were positioned supine on a radiolucent operating table and image intensifier was tested ensuring ease of taking intraoperative radiographs. Tourniquet wasn't used in arthroereisis groups being non bloody procedure. Sterilization and draping were performed as ordinary.

A- Subtalar arthroereisis (prostop implant):

Operative procedure:

Incision for arthroereisis. A slightly curved 2-cm skin incision was made on the lateral side of the hindfoot centered over the sinus tarsi, just anterior and plantar to the tip of the lateral malleolus. Fig1A

Direct approach to the sinus tarsi was obtained. The sinus tarsi was debrided to remove its contents; fatty tissue with abundant nerve endings, Fig1B.

A guide pin was inserted from lateral to medial across the sinus tarsi, perpendicular to the longitudinal axis of the calcaneus, Fig1C.

The cannulated sizer was placed onto the guide pin and advanced from lateral to medial until the tip abutted the medial margin of the sinus tarsi then the range of motion of the subtalar joint was assessed. Fig1.



Figure 1: Intraoperative photographs showing surgical steps of the calcaneostop technique.

B- Calcaneal lengthening:

- An approximately 5-cm straight lateral **incision** is made parallel to the foot's plantar aspect just above the peroneal tendons, avoiding the sural nerve and exposing anterior half of the calcaneus Fig2A
- The periosteum is incised in line with the planned osteotomy. A vertical osteotomy is made in the neck of calcaneus 1.5 cm proximal to calcaneocuboid joint using an oscillating saw or osteotome. Fig2B
- Two or more 2-mm smooth K-wires are inserted antegrade, in the foot after the osteotomy is distracted and graft introduced, from the back of the foot passing through the osteotomy, across the center of the calcaneocuboid joint, to prevent dorsal displacement of the distal calcaneal fragment and maintain graft Fig2C

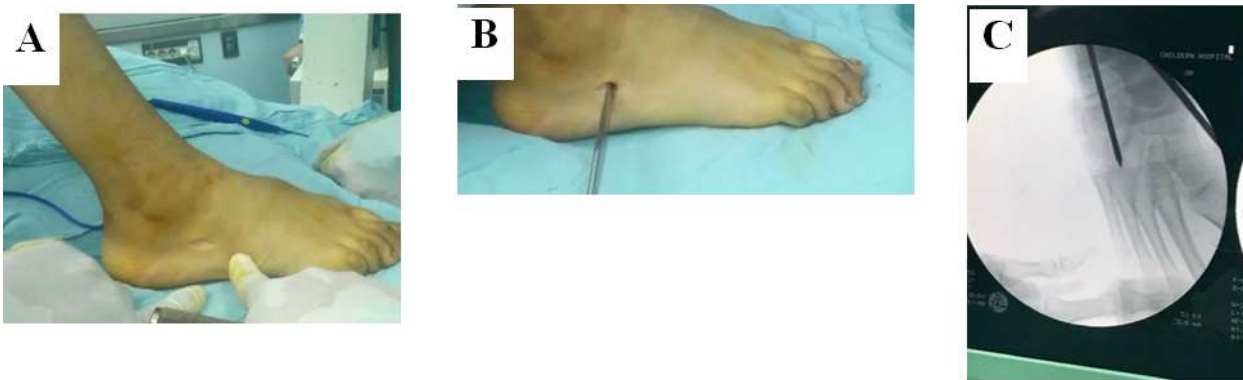


Figure 2: Intraoperative photographs showing surgical steps of the Evans osteotomy technique.

Following both techniques (both groups):

The foot was assessed intraoperatively for improved talonavicular coverage and recreation of a satisfactory medial arch, for equinus deformity, Achilles tendon lengthening was performed, peroneus brevis lengthening or intramuscular tenotomy was performed in all cases, wound closure, procedures for associated deformities (e.g. adductor tenotomy, hamstrings lengthening, osteotomies for angular or rotational malalignment, etc) were addressed during the same setting as single.

Postoperative:

A- Subtalar arthroereisis:

Patients were placed in below-knee walking cast for 3 weeks to minimize possible implant loosening. Following cast removal, unrestricted activities were encouraged using an ankle-foot orthosis, above knee cast for 6 weeks was applied when Achilles tendon lengthening was performed, there was no intention to remove screws unless there are complications requiring that removal.

B- Calcaneal lengthening:

Postoperatively, a below knee cast (above knee cast if Achilles tendon lengthening was performed) was applied and retained for 8 weeks. K-wires were removed after 6 weeks and weightbearing was allowed after 8 weeks using an ankle-foot orthosis.

Subsequently, patients of both procedures were referred to a local rehabilitation center to continue muscle strengthening exercises and gait training.

- **Postoperative assessment and follow-up regime:**

The follow-up period ranged from **6 months to 18 months (Average 11.5 months)**. All cases were assessed clinically and radiographically **6 months postoperatively**, comparing between the 2 groups regarding the following outcomes:

1- Primary outcomes (Most important outcomes that were assessed):

A-Improvement in **clinical** outcome by the clinical score proposed by **Yoo et al (17)** (**6 months postoperatively**) in the 2 techniques (comparing both techniques):

- **For forefoot abduction and hindfoot valgus**, the results were assessed as:

"Normalized" when the normal neutral alignment of the forefoot or hindfoot developed in weight-bearing position, "Improved" when the corrected amount of each parameter reached 50% or more of the preoperative angular deformity, "Minimal" when less than 50%.

- **For symptomatic relief**, it was assessed by the subjective report of the patients or their parents.

- **For the longitudinal arch**, the results were assessed as:

"Normalized" when a marked longitudinal arch developed in weight-bearing position, "Improved" when the medial aspect of the foot was off the ground in weightbearing position, "Minimal" when the arch developed only in non-weight-bearing position. When the total score is 8 or more, the results were considered satisfactory.

B- Improvement in postoperative radiographic measurements (comparing both techniques):

Arthroereisis group: Patients were followed up on the first postoperative day then after 2, 4, and 6 months by standing foot x-rays. **Calcaneal lengthening group:** Patients were followed up on the first postoperative day then at 6 weeks (after change of the cast and removal of K-wires), 8 weeks (after cast removal), 4, and 6 months by standing foot x-rays. Same angles which were measured preoperatively were measured at the **6-month-follow up** X-rays, to be compared with the preoperative ones. Secondary outcome parameters (other outcomes that were assessed 6 months postoperatively): patient satisfaction and tolerance to brace or shoes.

Statistical analysis

Statistical analysis was carried out using the SPSS computer package version 25.0 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp., USA). The statistical methods were verified, assuming a significant level of $p < 0.05$ and a highly significant level of $p < 0.001$.

Results

Table 1: Correction power of arthroereisis pre and post procedure showing significant improvement of all angles.

		Group A		Change	P-value	Sig.
		Pre	Post			
TNCA	Median (IQR)	46.5 (42 – 50)	32.5 (25 – 37)	14.94 ± 4.81	0.000	HS
	Range	38 – 65	16 – 50			
APT-1stT	Median (IQR)	35 (30 – 38)	25 (20 – 30)	9.78 ± 4.40	0.000	HS
	Range	25 – 45	10 – 25			
APTCA	Mean ± SD	32.89 ± 5.60	22.72 ± 6.69	10.17 ± 4.12	0.000	HS
	Range	22 – 45	12 – 37			
LTT-1STT	Median (IQR)	33.5 (30 – 36)	13.5 (12 – 20)	16.67 ± 5.52	0.000	HS
	Range	25 – 43	10 – 25			
LTC angle	Mean ± SD	48.39 ± 5.12	39.67 ± 4.63	8.72 ± 2.85	0.000	HS
	Range	42 – 60	32 – 50			
CPA	Median (IQR)	2 (1 – 4)	9 (4 – 12)	6.83 ± 3.96	0.000	HS
	Range	-10 – 6	-5 – 15			

(Mean pre= preoperative mean value of angle. Mean post= postoperative mean value of angle, change=mean correction power of angle, *: Significant.)

Therefore, subtalar arthroereisis showed a statistically significant improvement of all angles with the change (power of correction) shown in **table 2**.

Table 2: Correction power of Calcaneal lengthening pre and post procedure showing significant improvement of all angles.

		Group B		Change	P-value	Sig.
		Pre	Post			
TNCA	Median (IQR)	40 (34 – 45)	20 (15 – 26)	20.89 ± 11.04	0.000	HS
	Range	30 – 52	-12 – 35			
APT-1stA	Median (IQR)	26 (20 – 29)	15 (10 – 20)	12.33 ± 8.74	0.000	HS
	Range	18 – 35	-16 – 27			
APTCA	Mean ± SD	34.72 ± 8.80	23.61 ± 8.51	11.11 ± 4.43	0.000	HS

	Range	25 – 49	12 – 40			
LT1STA	Median (IQR)	29 (25 – 32)	10 (9 – 11)	19.83 ± 4.27	0.000	HS
	Range	14 – 38	-12 – 15			
LTC angle	Mean ± SD	44.33 ± 6.81	33.89 ± 7.46	10.44 ± 5.15	0.000	HS
	Range	35 – 58	19 – 45			
CPA	Median (IQR)	4.5 (2 – 6)	10 (10 – 15)	8.72 ± 3.80	0.000	HS
	Range	-13 – 10	-9 – 20			

(Mean pre= preoperative mean value of angle, Mean post= postoperative mean value of angle, diff=mean correction power of angle

*: Significant).

Therefore, Calcaneal lengthening showed a statistically significant improvement of TNCA (power of correction) shown in **table 3**.

Table 3: Transient and persistent complications of both groups.

Complication	Arthroereisis	Calcaneal lengthening
Transient (<6 months):		
▪ Pain	7 (sinus tarsi)	6 (2 donor site & 4 lateral foot)
▪ Temporary supination	0	0
▪ Superficial wound infection	1	2
Persistent (≥6 months):		
▪ Pain	2 sinus tarsi	0
▪ Undercorrection	(2 feet all component undercorrection)	(2 feet arch and hind foot undercorrection)

Sinus tarsi pain in 7 cases (no.6, 12, 13, 15, 16, 17 and 18): resolved within 4 months postoperative except (no 15 and 16) persistence.

Table 4: Comparison between changes in radiographic angles between the 2 groups

Change		Group A	Group B	Test value	P-value	Sig.
		No. = 18	No. = 18			
LTC angle	Mean ± SD	8.72 ± 2.85	10.44 ± 5.15	-1.242•	0.223	NS
	Range	0 – 12	0 – 20			
LT1STA	Mean ± SD	16.67 ± 5.52	19.83 ± 4.27	-1.924•	0.063	NS
	Range	5 – 25	12 – 26			
CPA	Mean ± SD	6.83 ± 3.96	8.72 ± 3.80	-1.460•	0.153	NS
	Range	0 – 14	4 – 17			
TNCA	Mean ± SD	14.94 ± 4.81	20.89 ± 11.04	-2.094•	0.044	S
	Range	5 – 22	5 – 46			
APT-1stA	Mean ± SD	9.78 ± 4.40	12.33 ± 8.74	-1.108•	0.276	NS
	Range	5 – 21	4 – 34			
APTCA	Mean ± SD	10.17 ± 4.12	11.11 ± 4.43	-0.662•	0.512	NS
	Range	1 – 17	5 – 21			

Mean 1: Mean correction (change) in Arthroereisis group, Mean 2: Mean correction (change) in Calcaneal lengthening group, Diff: the difference in correction between the 2 groups. *: Significant.

- The difference between the 2 groups regarding the power of radiographic angles correction wasn't statistically significant for all angles except the talo navicular cover angle (TNCA).
- Regarding TNCA, the mean correction power of Calcaneal lengthening is (20.89 ± 11.04°) was significantly higher than that of arthroereisis (14.94 ± 4.81°) (p value =0.044),denoting more power of Evans osteotomy in the **correction of forefoot abduction**.

Discussion

The current study is a randomized prospective comparative study designed to evaluate and compare the effectiveness of 2 different procedures in the correction of symptomatic flexible pes planovalgus in ambulatory CP patients. The study was divided into 2 groups: group 1: subtalar arthroereisis using the prostop screw technique, group 2: lateral calcaneal lengthening using iliac bone graft.

Patients were assessed clinically by the clinical score proposed by Yoo et al⁽¹⁷⁾ 6 months postoperatively. Also, they were assessed radiologically by measuring the important angles (6 angles) in both AP and lateral standing foot views both preoperatively and 6 months postoperatively. Patients' (or parents') satisfaction and their tolerance to braces or shoes were assessed 6 months after surgery as secondary outcome parameters. During the follow up visits, patients were monitored for

complications. Statistically the P value was assessed for these criteria to detect if there were statistical significant differences between the 2 groups.

There was marked improvement in both primary and secondary outcome parameters of our study in the 2 groups.

Regarding the clinical results, there were no statistically significant differences between the 2 groups regarding the total score except in pain improved 16 feet (88.8%) in arthroeresis group while improved in 18 feet (100%) in calcaneal lengthening with (p value=0.034).

In group 1: 12 feet (66.6% of cases) showed excellent results, 3 feet (16.6%) showed good results and 1 foot (5.5%) showed fair results and 2 foot (11.1%) unsatisfactory results.

In group 2: 15 feet (83.3%) of cases showed excellent results, 1 feet (5.5%) showed fair results and 2 feet (11.1%) showed unsatisfactory results.

The difference was not statistically significant in such sample size (p value= 0.343).

Regarding the radiological results the difference between the 2 groups regarding the power of radiographic angles correction wasn't statistically significant for all angles except the talo navicular cover angle (TNCA), for which the mean correction power of Calcaneal lengthening ($20.89 \pm 11.04^\circ$) was significantly higher than that of arthroeresis ($14.94 \pm 4.81^\circ$) (p value =0.044), denoting more power of calcaneal lengthening is in the correction of forefoot abduction.

The patient satisfaction rate was 88.8% (16 of 18 feet) in group 1 compared to 88.8% (16 of 18 feet) in group 2 without statistically significant difference between the 2 groups (P value=1.000).

In group 1, 2 cases (11.1%) experienced difficulty in using the AFO and the other 16 cases (88.8%) showing good tolerance to AFO, while all cases demonstrated good tolerance to AFO

in group 2. all cases demonstrated good tolerance to AFA with no statistically significant difference between the 2 groups (P value=0.146).

Statistical analysis of complication rates showed that there was no statistically significant difference between the 2 groups in such sample size. Regarding undercorrection rate and persistent pain in arthroeresis group with 2 feet showing undercorrection of all components of the deformity and persistent pain while in calcaneal lengthening 2 feet suffered undercorrection.

Few studies are available in the literature presenting the results of calcaneal lengthening or subtalar arthroeresis, of which fewer studies are available as treatment options of PPV foot deformity in children with CP.

Silva et al.⁽¹⁹⁾ (in 2010) used Pisani screw to treat PPV in 29 children (57 feet) with spastic Cerebral Palsy; the mean age was six years. The mean follow-up period was eight years and nine months. They studied 12 radiographic parameters and found that eight (table 6).

Table 4: Comparison between change of the angles in our study (arthroeresis group) and their corresponding angles in Silva et al ⁽¹⁹⁾. study

Study	Silva et al. ⁽¹⁹⁾				Arthroeresis (our study)			
	Mean PRE	Mean POST	Diff	P value	Mean PRE	Mean POST	Diff	P value
TNCA	35°	10°	25°	0.0132	46.5 (42 – 50)	32.5 (25 – 37)	14.94 ± 4.81	0.000
APT T-1stT	21°	7°	14°	0.0017	35 (30 – 38)	25 (20 – 30)	9.78 ± 4.40	0.000
AP TCA	27°	17°	10°	0.7699	32.89 ± 5.60	22.72 ± 6.69	10.17 ± 4.12	0.000
LAT T-1stT	38°	15°	23°	0.0000	33.5 (30 – 36)	13.5 (12 – 20)	16.67 ± 5.52	0.000
LAT TCA	47°	34°	13°	0.0004	48.39 ± 5.12	39.67 ± 4.63	8.72 ± 2.85	0.000
CPA	6°	13°	8°	0.0011	2 (1 – 4)	9 (4 – 12)	6.83 ± 3.96	0.000

Table 5: Comparison between change of the angles in our study (calcaneal lengthening) and their corresponding angles in Silva et al ⁽¹⁹⁾ study

Study	Silva et al. ⁽¹⁹⁾				calcaneal lengthening (our study)			
	Mean PRE	Mean POST	Diff	P value	Mean PRE	Mean POST	Diff	P value
TNCA	35°	10°	25°	0.0132	40 (34 – 45)	20 (15 – 26)	20.89 ± 11.04	0.000
APT T-1stT	21°	7°	14°	0.0017	26 (20 – 29)	15 (10 – 20)	12.33 ± 8.74	0.003
AP TCA	27°	17°	10°	0.7699	34.72 ± 8.80	23.61 ± 8.51	11.11 ± 4.43	0.000
LAT T-	38°	15°	23°	0.0000	29 (25 –	10 (9 –	19.83 ±	0.000

1stT					32)	11)	4.27	
LAT TCA	47°	34°	13°	0.0004	44.33 ± 6.81	33.89 ± 7.46	10.44 ± 5.15	0.000
CPA	6°	13°	8°	0.0011	4.5 (2 – 6)	10 (10 – 15)	8.72 ± 3.80	0.000

They claimed that the satisfactory result of only 65% of the feet in Their study (based on exclusively clinical criteria) was influenced by factors such as: longer follow up time, feet more subject to deformations, greater acquisition of weight of the child in the growth spurt period, the need to meet all the criteria for satisfactory result, high degree of aimplication by paralysis in the patient studied (reflected by the percentage of associated dermorities and of surgeries performed during the follow up time). Six feet (11%) presented screw extraction (considered as one of the causes of high unsatisfactory result, which can be reduced by the learning curve with the technique).⁽¹⁹⁾

They concluded that the calcaneal lengthening is a better alternative in pain satisfaction clinically and TNCA radiologically in comparison to arthroereisis and arthrodesis for treatment of reducielbe palnovalgus feet in spastic cerebral palsy.

As study by Wen et al (in 2017)⁽²⁴⁾, comparing the mid-term efficacy (average follow up 30.2±9.5 months) between subtalar arthroereisis and Dennyson-fulford subtalar arthrodesis in the treatment of spastic flatfoot in ambulant children with cerebral palsy, had the following results among the 12 children (20 feet) in the subtalar arthroereisis group:

Radiographic improvement: Postoperative **AP TCA** was decreased from preoperative 35° (20°-50°) to 19° (12°-25°); lateral X-ray films showed that the **Meary's angle** was decreased from preoperative 20° (15°-40°) to postoperative 0° (0°-3°). The differences in both findings were statistically significant (P value< 0.05).

These results confirm the mid-term efficacy of subtalar arthroereisis in the treatment of pes planovalgus in children with CP and **were similar to the outcomes of our study, both clinically and radiologically (regarding AP TCA and LAT T-1stT) (Table 8), however our results were only for the short-term efficacy.**

Table 6: Comparison between the radiographic results of current study and arthroereisis group of Wen et al study⁽²⁴⁾.

Procedure	Angle	No.of feet	Mean pre	Mean post	Diff	P-value
calcaneal lengthening (our study)	APTCA	18	34.72 ± 8.80	23.61 ± 8.51	11.11 ± 4.43	0.000
	LAT T-1stT	18	29 (25 – 32)	10 (9 – 11)	19.83 ± 4.27	0.000
Subtalar arthroereisis (our study)	APTCA	18	32.89 ± 5.60	22.72 ± 6.69	10.17 ± 4.12	0.000
	LAT T-1stT	18	33.5 (30 – 36)	13.5 (12 – 20)	16.67 ± 5.52	0.000
Subtalar arthroereisis (Wen et al study) ⁽²³⁾	APTCA	20	35°	19°	16°	0.000
	LAT T-1stT	20	20°	0°	20°	0.000

Evans⁽¹⁵⁾ (in 1975) recommended elongation of the lateral column as a treatment for planovalgus or calcaneovalgus foot. He stated at that time that the operation was inappropriate for children with spastic paresis because of high prevalence of overcorrection, or in other paralytic children because of osteopenia and muscle imbalance deteriorating the results. More recently, **Mosca**⁽¹⁴⁾ (in 1995), **Andreacchio et al**⁽²⁵⁾ (in 2000) **Hanna et al**⁽²⁶⁾ (in 2004) and **Aboelenein et al**⁽¹⁶⁾ (in 2018), modified the procedure described by Evans and reported the ability of the lateral foot column lengthening to correct the abnormal anatomy of the deformity while preserving the subtalar joint (STJ) motion in children with cerebral palsy. **Mosca**⁽¹⁴⁾ (in 1995) reported at an average of 2 to 3 years of follow-up, satisfactory results in 29of 32 feet, and failure in the tow feet with the most severe deformity. Eight feet had the addition of either cuneiform wedge osteotomy or talocalcaneal arthrodesis.

Aboelenien et al⁽¹⁶⁾ (in 2018), reported the following results at the average of 31 months of follow-up: Clinical results, according to **Dogans scale**⁽²³⁾ were perfect in 18 feet (82%),good in 2 feet (9%),and fair in 2 feet (9%). Radiological results showed improvement in 20 feet,while 2 feet showed no improvement. The improvement was significant in **LAT T-1stT (P<0.001)**, **AP T1stT (P<0.05)**, **AP TCA (P<0.001 for each)**, whereas it was insignificant in **LAT TCA (P>0.05)**.

In our study we saw **no calcaneocuboid subluxation, because the distal calcaneal fragment was transfixed as proposed by Mosca**⁽¹⁴⁾.

Zeifang et al⁽¹⁸⁾ found calcaneal lengthening to be effective for the correction of severe, flexible flatfoot deformity in children with cerebral palsy in the short and midterm, but not for longterm follow up **Also my studies support theses result at the short and midterm follow up from 6 to 18 months. However in my study we didnot follow up the patients long priods.**

Yoo et al⁽¹⁷⁾ studied the outcomes of calcaneal lengthening for the treatment of planovulgus foot deformity in ambulatory children with cerebral palsy. This is the largest study to date with 92 feet in 56 children. The mean age at surgery was 9.2 years. 69 cases (75%) showed satisfactory clinical outcomes at an average follow up of 5.2 years (4.0-17.2 years). They described a

marginal significance between the ambulatory status of the patients and clinical outcomes, they also found a significant risk of unsatisfactory results if the deformity was too severe with a preoperative **talocalcaneal angle greater than 35°, a talo-first metatarsal angle greater than 25° and a calcaneal pitch on weightbearing lateral radiographs less than 5°**. The operation could be performed safely under these limits.

Our results were similar to a study by **Chong et al** ⁽²⁰⁾ who prospectively compared subtalar arthroereisis with lateral column calcaneal lengthening for the treatment of painful flatfeet in 15 patients (24 feet) **without underlying neuromuscular diagnoses**. Kinematic motion analysis, pedobarometry, and radiography were performed, and the Oxford Ankle-Foot Questionnaire for Children was administered for each patient before surgery and at the 1-year follow-up.

Statistically significant improvements in both groups, with no difference in their outcomes. Both groups showed significantly improved hindfoot and midfoot motion and positioning. Hindfoot range of motion was preserved. Radiography and pedobarometry also revealed significant improvements.

The difference in the outcomes of the two groups was found to be statistically significant only for an **increase in calcaneal pitch in the lengthening group (p value= 0.01)**; However, **in our study** there was no statistically significant difference in the change of **CPA** between the 2 groups (p value=0.153). On the other hand, the difference in our study regarding the outcomes of the two groups was found to be statistically significant only for a decrease in **TNCA** in the Calcaneal lengthening group (p value=0.044).

The two treatments that they studied may affect the flatfoot complex differently; arthroereisis may only minimally affect midfoot transverse plane deformities, which may be better addressed with lateral column lengthening or medial column shortening. If a patient's forefoot has significant varus, then a subtalar arthroereisis may push the forefoot into even more varus deformity. **In our study**, we found that Evans osteotomy was more powerful in correcting hindfoot valgus also to be more powerful in correcting forefoot abduction; however, that difference was not statistically significant in such sample size (p value=0.545). There were no significant changes seen between the two groups to recommend one over the other.

Conclusion

The study is designed to evaluate the power of correction of the symptomatic pes planovalgus in ambulatory spastic CP patients by subtalar arthroereisis (prostop technique) in comparison to lateral column calcaneal lengthening technique. As shown by the results and statistics there was a statistically significant improvement in both **primary** and **secondary** outcome parameters after both procedures in comparison to the preoperative parameters.

No statistically significant differences were observed between the two groups regarding the outcomes of both procedures except for the **talo navicular cover angle (TNCA)**, for which calcaneal lengthening was significantly more effective in correction compared to arthroereisis, denoting more power of Calcaneal lengthening in the **correction of forefoot abduction**. Clinically, calcaneal lengthening was more effective in correcting forefoot abduction; however, this was not statistically significant in such sample size.

Neither procedure caused any loss of hindfoot mobility. Therefore, both procedures are valid options for the surgical management of PPV in ambulatory children with spastic CP. The less-invasive nature and lower potential morbidity suggest that judicious use of arthroereisis is appropriate for some patients, especially in the context of SEMLS. However, further investigation and long-term outcome studies are warranted to demonstrate the efficacy and safety of arthroereisis, as compared with the more accepted method of calcaneal osteotomy and iliac crest bone graft.

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