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Double calcaneal osteotomy in treatment of flexible planovalgus foot deformity in ambulatory cerebral palsy. A case series study

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ABSTRACT

Background: The aim of this prospective non randomized case series study was to assess the intermediate-term outcomes of double calcaneal osteotomy (lateral column lengthening and medial slide calcaneal osteotomy) use in ambulatory cerebral palsy with flexible planovalgus feet.
Methods: 16 cases with planovalgus feet were surgically treated by double calcaneal osteotomy and observed over an average of 33.5 months. The mean age at the time of surgery was 10.74 years. The functional outcomes were assessed clinically and radiologically.
Results: There were a statistical improvement of clinical heel valgus and all radiological parameters as regard talar head uncoverage, calcaneal pitch, talo-calcaneal angle, and talus 1st metatarsal angle at the end of follow up period.
Conclusion: Double calcaneal osteotomy is a good option in the treatment of flexible planovalgus feet in ambulatory cerebral palsy patients.

1. Introduction

Foot deformities are common in children with cerebral palsy (CP). While equinovarus foot deformities are common in patients with hemiplegic CP, planovalgus foot deformity are common in diplegic ones. Planovalgus foot deformity is mostly a consequence of muscle imbalance and abnormal forces on skeletally immature foot. Pain with weight bearing, ulcerative lesions because of prominent talar head and gait disturbances resulting from irreducible talo-navicular joint subluxation are frequently occurred [1,2].

Foot biomechanics are altered in spastic planovalgus CP patients. The talus is plantar flexed along with excessive eversion of the subtalar joint during weight bearing, the calcaneous is in valgus deformity with eversion and equinus and the navicular bone is abducted and dorsiflexed on the head of the plantar flexed talus. These relationships lead to midfoot breakage with loss of medial longitudinal arch, relatively shorter lateral column compared to the medial column and supinated forefoot in relation to the hindfoot. Tendon achilles and peroneal muscles contractures are common association with symptomatic planovalgus. The deformity remains flexible until adolescence before being a fixed bony deformity [3].

The appropriate treatment of planovalgus in CP is a complicated issue and should be tailored to each case; there is no single procedure could be done to all of them. Early deformity control is essential to prevent progression to a more severe foot condition. Treatment options are foot orthosis and surgeries that include fusion of one or more of foot joints, arthroereisis of the sinus tarsi and corrective osteotomies [4].

Attempts should be made to preserve foot and ankle joints mobility for children who are ambulators (Gross Motor Functional Classification System "GMFCS" I, II, and most III), their feet deformities are flexible and less severe, and presented earlier due to high force demands on feet during walking [2]; that could be achieved by corrective osteotomies. While severely deformed stiff feet with more disabilities are treated generally by fusion for pain relief [5].

Lateral column lengthening, Evans osteotomy, is a widely accepted option to deal with flexible planovalgus feet with good results [6–8]. It relieves the pressure on the prominent talar head by restoring the anatomical position of the calcaneus under the talus [9], inverting the subtalar joint and dorsiflexing the talus. Consequently, symptoms improvement, better orthosis tolerance, and prevention of ulcer formation are achieved [3].

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However, lateral column lengthening has its limits. Sees and Miller recommended additional procedures for patients with talus-first metatarsal angle (TMT1 angle) more than 23° in anteroposterior (AP) view and 36° in lateral view and 72% naviculo-cuboid overlap. These procedures included tibialis posterior (TP) tendon advancement to provide medial arch support, medial plantar-based wedge resection of the naviculo-cuneiform joint (Cotton osteotomy) if the forefoot is still in supination with elevated first ray and peroneal tendons lengthening [2].

The major problem with lateral column lengthening is the recurrence of deformity which usually necessitates subtalar fusion. Failure to correct the associated deformities such as medial column collapse, tibial torsion or plantar flexor contractures are among the factors that increase the risk of recurrence [2].

Our hypothesis was to add medial slide calcaneal osteotomy to the lateral column lengthening, double calcaneal osteotomies (DCO), in order to correct the more severe flexible planovalgus feet deformities (determined clinically by heel valgus >30° and radiologically by calcaneal pitch angle ≤0 and talar head uncoverage ≥30% in standing X-rays) in the transverse, frontal and sagittal planes at both the midtarsal and subtalar joints as well as to decrease the risk of recurrence [10]. The DCO gain benefits of the medial slide calcaneal osteotomy in correction of heel valgus and the lateral column lengthening in correction of forefoot abduction.

2. Materials and methods

In the period between January 2013 and December 2017, 16 patients with 24 symptomatic planovalgus feet in Spastic diplegic CP (or mixed with predominant spasticity) were treated by double calcaneal osteotomies. Nine patients in this study were males and seven were females. The mean age of the patients at the time of surgery was 10.74 years (range: 6–16 years). The mean follow-up period was 33.5 months (range: 24–48 months). Equal number of procedures were performed on the right foot and on the left (12 procedures for each). All patients were ambulatory (GMFCS I: one case = 6.25%, GMFCS II: three cases = 18.75%, and GMFCS III: 12 cases = 75%).

Patients involved in this study had clear indications for surgery like pain and callosities from prominent talar head, lever arm dysfunction and shoe or brace unfitness.

Complete preoperative lower limb evaluation of CP patients was done including evaluation of gait, hip abduction range of motion, hip Thomas test, popliteal angle, hamstring shift test, and rotational profile of the entire lower limb. As a part of Single Event Multi-level surgery (SEMLS), we corrected all the existing deformities (e.g. rotational malalignment and flexion knee deformity) in the same stage with DCO without affecting the outcome.

Local examination was done preoperatively to estimate the degree of motion around the subtalar joint, Silfverskiöld test to determine Gastro-soleus complex tightness, presence or absence of peroneal spasm, integrity of tibialis posterior tendon, degree of heel valgus (Fig. 1), and forefoot pronation. Accordingly, associated procedures were chosen. They included gastrocnemius muscle (GC) lengthening (14 patients) in patients with positive Silfverskiöld test and equinus heel resulted in mid-foot breakage preoperatively, TP advancement (5 patients) in whom TP integrity was assessed preoperatively and revealed insufficiency especially in severe foot deformity and in elder patients, peroneal tendons lengthening (5 patient) which determined intraoperatively when there was tight peroneal tendons after deformity correction, and Cotton osteotomy (3 patients) when forefoot supination was increased intraoperatively after performing DCO to prevent recurrence of heel valgus.

Fig. 1. Left side planovalgus with increased clinical heel valgus angle.

Fig. 2. Angles measured on standing lateral plain X-ray foot.

The heel valgus was measured clinically in both preoperative and during follow up postoperatively using the goniometer to measure objectively the angle formed by 2 lines, first line was the axis of the leg and second line was the axis of calcaneus (Fig. 1).

AP and lateral feet standing views were done pre- and postoperatively to assess 4 radiological outcomes: calcaneal pitch, talo-calcaneal angle, TMT1 angle and the percentage of talar head uncoverage (Fig. 2).

Cases with radiological osteoarthritic changes (2 patients), stiff feet deformities (3 patients), non-ambulatory cases (5 patients) and dystonic CP (3 patients) were excluded from this study.

2.1. Surgical technique

The patient was placed supine on a radiolucent table, with an ipsilateral hip bump, and the foot was extended off the end of the table to provide access to the medial, lateral, and posterior sides of calcaneus. The medial slide calcaneal osteotomy is completed after usual lengthening of gastro-soleus complex to prevent proximal migration of the posterior capital fragment of calcaneus after the osteotomy. A 45-degree oblique incision just behind peronei

Fig. 3. Intra-operative photo showing the double incisions for DCO.

Fig. 4. Intra-operative photo showing improvement in heel valgus and restoration of foot longitudinal arch.

Fig. 5. Intra-operative photo showing tibialis posterior advancement.

tendons was utilized to get access to the calcaneous, deep dissection with care not to injury the sural nerve, the periosteum was sharply dissected and reflected dorsally and plantarily, and then an osteotomy was done in line with the skin incision starting from the lateral to medial surface using small blade electric saw with cautions not to injure the medial structures. The posterior capital fragment of the calcaneus was moved medially to reduce the calcaneal valgus and improve the hindfoot alignment in relation to the leg. Fixation was done using K-wires or cannulated screws crossing perpendicular to the osteotomy site. The Size and number of screws were dependent on patient's age and the size of the posterior capital fragment of the calcaneus.

Evans calcaneal osteotomy followed utilizing a horizontal skin incision starting just behind calcaneo-cuboid joint, a skin island of 3 cm should be left between both incisions to avoid any skin necrosis (Fig. 3). Deep dissection was done, and the osteotomy was performed approximately 1.5 cm proximal to the calcaneo-cuboid joint. A preliminary K wire was used to fix calcaneo-cuboid joint before opening the osteotomy to avoid joint subluxation. The anterior capital fragment of the calcaneus was distracted to the desired position with the aid of a lamina spreader to reduce forefoot abduction and to align the forefoot and midfoot with the hindfoot (Fig. 4). An appropriate custom-size trapezoidal wedge composed of a tricortical cancellous bone graft (autograft from iliac crest in 12 patients or xenograft in 4 patients as the allograft was not available in our country) was inserted with the base oriented laterally. We stabilized the graft in its position by Staples in 3 cases but recently we no longer have fixed the osteotomy and depend on the inherent stability of the graft.

Additional procedures performed in the same session were common. They included gastrocnemius muscle (GC) lengthening (14 patients) in patients with positive Silfverskiöld test, TP advancement (5 patients) (Fig. 5) in whom TP integrity was assessed preoperatively and revealed insufficiency especially in severe foot deformity and in elder patients, peroneal tendons lengthening (5 patient) which determined intraoperatively when there was tight peroneal tendons after deformity correction, and Cotton osteotomy (3 patients) when forefoot supination was increased intraoperatively after performing DCO to prevent recurrence of heel valgus.

As a part of Single Event Multi-level surgery (SEMLS), we corrected all the existing deformities (e.g. rotational malalignment and flexion knee deformity) in the same stage with DCO.

Below knee cast (if no concomitant knee surgery was needed) was applied postoperatively for 2 weeks. Then, suture removal and cast change in corrected position for another 4 weeks. After that, physiotherapy was started aiming for ankle range of motion and invertors strengthening. Weight bearing was allowed 2 months postoperatively. Regular follow up of patients was done at 2 months intervals in the 1st year then at 4 months intervals after that.

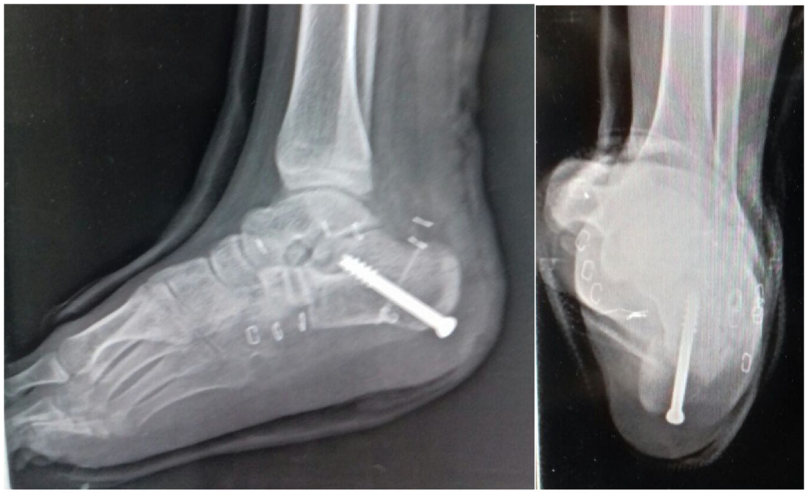

Fig. 6. (A and B) Immediate post-operative PXR of DCO, notice medial translation of calcaneus in axial view (B).

3. Results

Nine boys and seven girls ambulatory diplegic CP with planovalgus feet underwent double calcaneal osteotomies. The average age at the time of surgery was 10.74 years (range 6–16) with average follow up period 33.5 months (range: 24–48 months). Clinical and radiological assessment was done preoperatively and at the end of follow up period. They include clinical heel valgus, plain AP foot X-ray to measure the percentage of talar head uncoverage, and lateral foot X-ray to determine calcaneal pitch, talo-calcaneal angle, and TMT1 angle.

There was a statistically significant improvement of the clinical heel valgus from preoperative mean of 34.45 (range: 20.75–47.38) to postoperative mean of 16.03 (range: 11.25–20). Radiologically, there were a statistically significant improvement of all parameters (Fig. 6).

The percentage of talar head uncoverage reduced from preoperative mean of 31.64% (range: 16.6%–66.6%) to postoperative mean of 8.32% (range: 0%–33.3%) (Fig. 7), lateral talo-calcaneal angle reduced from 36.85 preoperatively (range: 22.81–51.36) to 17.11 postoperatively (range: 12.08–20), calcaneal pitch angle was improved from mean −1.08 (range: −5 to 5) to mean 28.58 (range: 24–33) (Fig. 8), and lateral TMT1 Improved from 33.91 (range: 17.67–47.14) to 17.73 postoperatively (range: 14.25–20) (Table 1).

Fig. 7. Postoperative AP PXR of DCO demonstrating lateral column lengthening with graft, notice talar head coverage percentage after correction is 100%.

Procedures were performed in concomitant with double calcaneal osteotomies were GC lengthening in 14 patients (87.5%), TP advancement in 5 patients (31.2%), peroneal tendon lengthening in 5 patients (31.2%), and Cottons osteotomy in 3 patients (18.8%) (Table 2).

All cases were corrected completely apart two cases who were under-corrected (12.5%) in form of mild heel valgus which was improved by foot insole with complete coverage of talar head and the pain from prominent talar head completely disappeared, one case showed heel ulcer (6.25%) and one case had chronic heel pain (6.25%) which improved after heel screw removal.

4. Discussion

In patients with spastic CP, planovalgus foot may develop. The hindfoot is in valgus, forefoot is in abduction and pronation, and the medial arch is lost. These could result in pain, callosities, ulceration, lever arm dysfunction, and shoe unfitness [7]. The natural history of the disease is variable; however, it commonly tends to progress to be fixed and painful especially in late childhood and adolescent periods [5]. So, treatment of it with a regular follow up is indicated.

Surgical correction of planovalgus foot in CP falls into one of three groups: fusion of one or more of foot joints, arthroereisis of the sinus tarsi, and corrective osteotomies [5]. The surgery chosen depends on GMFCS level and the severity [11]. Generally, those presented with flexible planovalgus feet are treated by corrective osteotomies while triple fusion is spared to the severe fixed cases [5].

Joint fusion is a surgical option used in spastic planovalgus CP. Subtalar fusion was described either extra-articular or intra-articular after subtalar reduction to maintain a corrected hindfoot. Extra-articular subtalar fusion (Grice procedure) was utilized by several authors for young children with flexible planovalgus with reasonable results [5,12–14]. Bourelle et al. used Grice procedure in 23 children with mean age 5 years and 5 months and mean follow up 20 years period. Thirteen patients were satisfied by the procedure and had no pain and 15 were still able to walk [12]. Yoon et al. utilized it for 50 feet with mean age 9 years and mean follow up 3 years. Talonavicular subluxation and hindfoot valgus were corrected significantly but not the calcaneous pitch [13]. However, clinical failure was not uncommon owing to graft

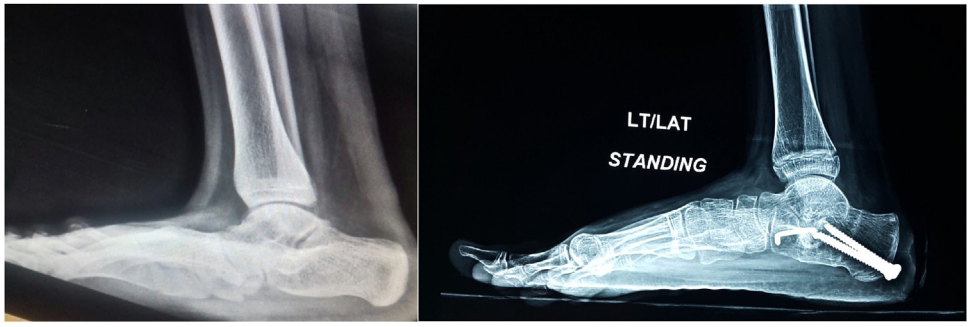

Fig. 8. Pre-and postoperative PXR demonstrating improvement in foot arch, lateral Talo-calcaneal angle, and calcaneal pitch after DCO.

Table 1
Results of DCO at the end of follow up period.

		Pre-operative average	Post-operative average	Paired t-test	
				t	P-value
Talus head coverage	Mean	34.67 % ± 13.8	8.32 % ± 14.7	6.402	0.000
	Range	16.6%–66.6 %	0%–33.3 %		
Clinical heel valgus	Mean ± SD	34.45 ± 9.59	16.03 ± 3.01	9.466	0.000
	Range	20.75–47.38	11.25–20		
Lateral TMT1	Mean ± SD	33.91 ± 10.67	17.73 ± 2.10	6.981	0.000
	Range	17.67–47.14	14.25–20		
Calcaneal pitch angle	Mean ± SD	−1.08 ± 4.21	28.58 ± 3.48	−15.812	0.000
	Range	−5 to 5	24–33		
Lateral talo-calcaneal angle	Mean ± SD	36.85 ± 10.41	17.11 ± 2.95	9.006	0.000
	Range	22.81–51.36	12.08–20		

resorption, independent of its source, in 6%–33% of the cases and late ankle valgus in 23%–50% of the cases [15,16].

Another option to stabilize the subtalar joint after reduction was to put an insert in the sinus tarsi (subtalar arthroeresis) [5]. It was a simple procedure with less pain and rapid postoperative recovery compared to osteotomy and fusion, but it was limited to flexible mild cases and usually associated with soft tissue procedures [17,18].

Dennyson and Fulford described intra-aricular fixation of subtalar joint by a screw and fusion using autogenous bone graft in 29 patients with correctable planovalgus. 93.7% of the cases had bony fusion but the assessment was solely dependant on the clinical appearance rather than the radiological parameters [19].

Other fusion options in the treatment of flexible planovalgus include talonavicular fusion utilized by Turriago et al. in 59 feet with mean age 13.9 years and mean follow up 3 years. There was statistically improvement in terms of clinical and radiological findings with no significant changes in gait. However, the patient group was not restricted to flexible cases and pseudoarthrosis was not uncommon [20]. Naviculo-cuneiform fusion was described by Ajis and Geary on 33 feet with high patient satisfaction (96.9%) but the radiographic data had not improved significantly, and the patient group was not essentially CP [21].

Triple arthrodesis was used as an option in treatment of severe non-ambulatory cases [22–25] rather than ambulatory ones to relieve pain on expense of motion with good results.

Lateral column lengthening is a widely used surgical option especially in mild and moderate ambulatory cases with good results [6–8,26]. Yoo et al. used it in 92 feet with mean follow up 5.2 years. 75% showed satisfactory outcomes with significant improvement of radiographic data. However, the limitation for lateral column lengthening to be performed safely were established to be $\leq 35^\circ$ talocalcaneal angle, $\leq 25^\circ$ talo-1st metatarsal angle, and $>5^\circ$ calcaneal pitch on standing lateral radiographs [26]. Another drawback was the high recurrence rates (17–5%) that were reported in some studies [7,27].

Medial slide calcaneal osteotomy was published by some surgeons without clarifying its benefit in CP patients [5]. Our study is the first to describe the use of double calcaneal osteotomies in ambulatory CP with planovalgus feet. It is hypothesized that adding medial sliding calcaneal osteotomy would correct more the hindfoot valgus, decreased the impingement of tibialis posterior between fibula and calcaneous, and tighten the plantar fascia. So, it can be used in more severe ambulatory cases compared to the lateral column lengthening alone with better results.

In comparison to Yoo et al. study [26], we use double calcaneal osteotomies in cases with talo-calcaneal angle up to 80°, −5° of calcaneal pitch, and 70° TMT1 angle with satisfactory results. All radiological parameters are significantly improved including the calcaneous pitch, unlike Grice Green procedure that does not necessarily correct the plantarflexed calcaneus and hence the clacaneous pitch angle [12].

A long term follow up is needed for the cases treated by double caclaneal osteotomies in order to detect the recurrence

Table 2
Additional procedures performed with DCO.

		No.	%
GC	Negative	2	8.33%
	Positive	22	91.66%
TP advancement	Negative	16	66.6%
	Positive	8	33.3%
Peroneal lengthening	Negative	16	66.6%
	Positive	8	33.3%
Cotton osteotomy	Negative	21	87.5%
	Positive	3	12.5%

and the necessity of comparative studies with other surgical techniques.

5. Conclusion

The clinical and radiological parameters were significantly improved by double calcaneal osteotomies performed in ambulatory cerebral palsy patients with flexible planovalgus feet. The DCO gain benefits of the medial slide calcaneal osteotomy in correction of heel valgus and the lateral column lengthening in correction of forefoot abduction. More number of patients with longer follow up period will definitely be included in further studies.

Conflict of interest

All authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.fas.2018.07.003.

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