



Functional and Radiological Outcomes Following Calcaneo-Cuboid-Cuneiform Osteotomy for the Treatment of Planovalgus Feet: A Short-Term Analysis

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Abstract

Introduction Flexible flatfoot refers to the loss of the medial longitudinal arch of the foot on weight bearing and is associated with excessive heel eversion or forefoot abduction. Unless symptomatic, flexible flatfeet are best managed non-operatively. The calcaneo-cuboid-cuneiform osteotomy is a procedure that restores the anatomical shape of the foot without arthrodesis of the joints. Our study aims to evaluate the functional and radiological outcomes of patients treated with calcaneo-cuboid-cuneiform osteotomy in patients with planovalgus feet.

Methodology A retrospective review of records and radiographs of patients with symptomatic flexible planovalgus feet, who were operated with the calcaneo-cuboid-cuneiform osteotomy by a single senior surgeon in a time period between April 2016 and July 2017 was done. The clinical and radiological outcomes were evaluated in 12 feet in 8 children.

Results A total of 12 feet in 8 children were operated (6 males and 2 females). Average age of patients was 11 ± 1.27 years; average follow up was 14.7 months ± 2.7 months. Two patients had planovalgus feet secondary to spastic diplegia and 6 had idiopathic planovalgus feet. There was a statistically significant improvement in the pain score as well as the radiographic parameters in all the operated patients.

Conclusion The calcaneo-cuboid-cuneiform osteotomy has potential to give good results for symptomatic planovalgus feet with minimal complications.

Keywords Children · Paediatric · Idiopathic · Symptomatic · Planovalgus · Flatfeet · Triple C osteotomy · Calcaneo-cuboid-cuneiform osteotomy

Background

Flat foot is a common foot deformity [1–3] and it refers to the loss of the medial longitudinal arch of the foot on weight-bearing and is associated with excessive heel eversion or forefoot abduction [2, 3]. The planovalgus foot may be idiopathic; associated with neuromuscular diseases (Cerebral Palsy [CP], meningomyelocele), tarsal coalitions, over-corrected clubfoot, vertical talus, and the accessory navicular syndrome [4]. Joseph et al. has studied the effect of use

of shoes in children and implicated role of early shoe wear in the development of flatfeet [5].

Though most children with flexible flatfeet are asymptomatic, some may go on to develop foot pain or lower limb pain as adults [6, 7]. Treatment should be individualised since everyone may not require intervention. Unless symptomatic, flexible flatfeet are best managed non-operatively and can be observed [4]. Orthotics are frequently used for painful flatfoot, although, long-term benefit is controversial and has not been proven by any prospective study [4, 7]. Surgical indications of flexible flatfeet include children with intractable pain not relieved with activity modification or orthotic use and which significantly affects their daily activities.

Surgical options for the treatment of valgus foot deformity span from soft tissue releases to triple arthrodesis [4]. Since arthrodesis is associated with long-term complications, the focus is now towards doing surgeries not involving even limited arthrodesis. The calcaneo-cuboid-cuneiform

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osteotomy (Triple C osteotomy) which involves medial sliding osteotomy of the calcaneum, cuboid lengthening, and plantar-based closing wedge osteotomy of the medial cuneiform [8], is one such procedure that restores the anatomical shape of the foot without arthrodesis of the joints. There are very few studies discussing the outcomes of calcaneo-cuboid-cuneiform osteotomy in the paediatric age group, and data of results of this modality of treatment from the Indian population are lacking. Our study aims to evaluate the functional and radiological outcomes of patients treated with Calcaneo-Cuboid- Cuneiform osteotomy in patients with planovalgus feet.

Materials and Methods

The study was approved by the institutional ethics committee. It was an observational study involving a retrospective review of medical records and radiographs of patients, operated between April 2016 and July 2017. The study was conducted in the department of Paediatric Orthopaedics in a tertiary level hospital. Inclusion criteria comprised of patients aged 8–18 years old with symptomatic flexible planovalgus feet, who were not relieved of their symptoms after a trial of conservative treatment for 4–6 months in the form of arch support footwear and physiotherapy (involving weekly sessions with the therapist and regularly at home), and those, who completed 1 year follow-up period following the surgery. Patients with rigid planovalgus feet, and those, who were lost to follow-up were excluded from the study. The University of California Biomechanics Laboratory (UCBL) insert was tried in a few patients but, the children were more uncomfortable with a rigid orthosis inside the shoe and hence it was not prescribed to all patients.

The pre-operative assessment was done clinically and radiologically. Clinical assessment included assessment and recording of the patient's symptoms, pain, deformity, difficulty in weight-bearing, or cosmesis and presence of contracture of Tendo-Achilles. Grading of pain was done using a visual analogue scale. The radiographic assessment included talo-1st metatarsal angle, talo-navicular coverage, talo-calcaneal angle in the AP radiograph and talo-1st metatarsal angle, calcaneal pitch and talo-calcaneal angle in the lateral radiograph (Fig. 1a–f) both preoperatively and at each follow-up to identify any loss of correction at follow-up. The values at their latest follow-up were included for analysis.

Operative Protocol: (Fig. 2)

All patients were operated in the floppy lateral position under general and epidural anaesthesia. Under tourniquet control, the calcaneum was exposed through a lateral incision (Fig. 2a), after retracting the sural nerve and peroneal

tendons an oblique extra-articular osteotomy of the Calcaneus was performed, beginning posterior to the posterior articular facet and extending distally and anteriorly to the inferior surface of the calcaneum. The osteotomy was done with an oscillating saw from the lateral cortex leaving a medial cortex intact which was later osteotomised with an osteotome. Completeness of osteotomy was checked clinically using osteotome and mediolateral mobility of posterior fragment was checked.

Cuboid was exposed by a separate lateral incision through the interval between extensor digitorum brevis and peronei. An osteotomy was made in the middle third of Cuboid and the osteotomy was opened with a lamina spreader to allow placement of wedge of bone (Fig. 2b). Care was taken to avoid violating the calcaneo-cuboid or cuboid- metatarsal joints.

Medial Cuneiform was exposed through a third longitudinal incision centred over it. A medial and plantar-based wedge of the Medial Cuneiform was removed from the middle third of the Medial Cuneiform taking care to remove the wedge in toto (Fig. 2c, d). This allowed pronation of the forefoot and recreation of the medial arch of the foot (Fig. 2e).

The wedge of bone removed from the Medial Cuneiform was inserted into the opening wedge osteotomy of the Cuboid to lengthen the lateral column (Fig. 2f). The Cuneiform osteotomy was closed manually and fixed with a Kirschner wire (K-wire). A second K-wire was passed from the 5th Metatarsal passing through the Cuboid and all the way back till the calcaneum. The Calcaneal osteotomy was then displaced medially by around 8–10 mm (Fig. 2g) and fixed with 2 K-wires. Radiological confirmation of 1st talo-metatarsal angle in AP and lateral views, talo-calcaneal angle in AP and lateral views, talo-navicular coverage angle and calcaneal pitch was done using C-arm (Fig. 2h, i). The size of K-wires was between 1.8 mm and 2.5 mm, depending on the size of the bone as well as the number of wires to be put (two wires were inserted in the calcaneal osteotomy-hence 2, 1.8 mm wires were used in the calcaneum). The pins were bent outside the skin, and closure was done in a routine manner. The patient was given a below-knee well-padded slab.

Post-Operative Protocol

The Epidural anaesthesia provided pain relief in the immediate post-operative period. The epidural catheter was removed on the second post-operative day. The post-operative dressing was done on day 3 and after confirmation of healthy sutures, a below-knee cast was applied for 6 weeks. At the 6 weeks follow-up K-wires were removed after a check X-ray, and a custom-made non-articulated

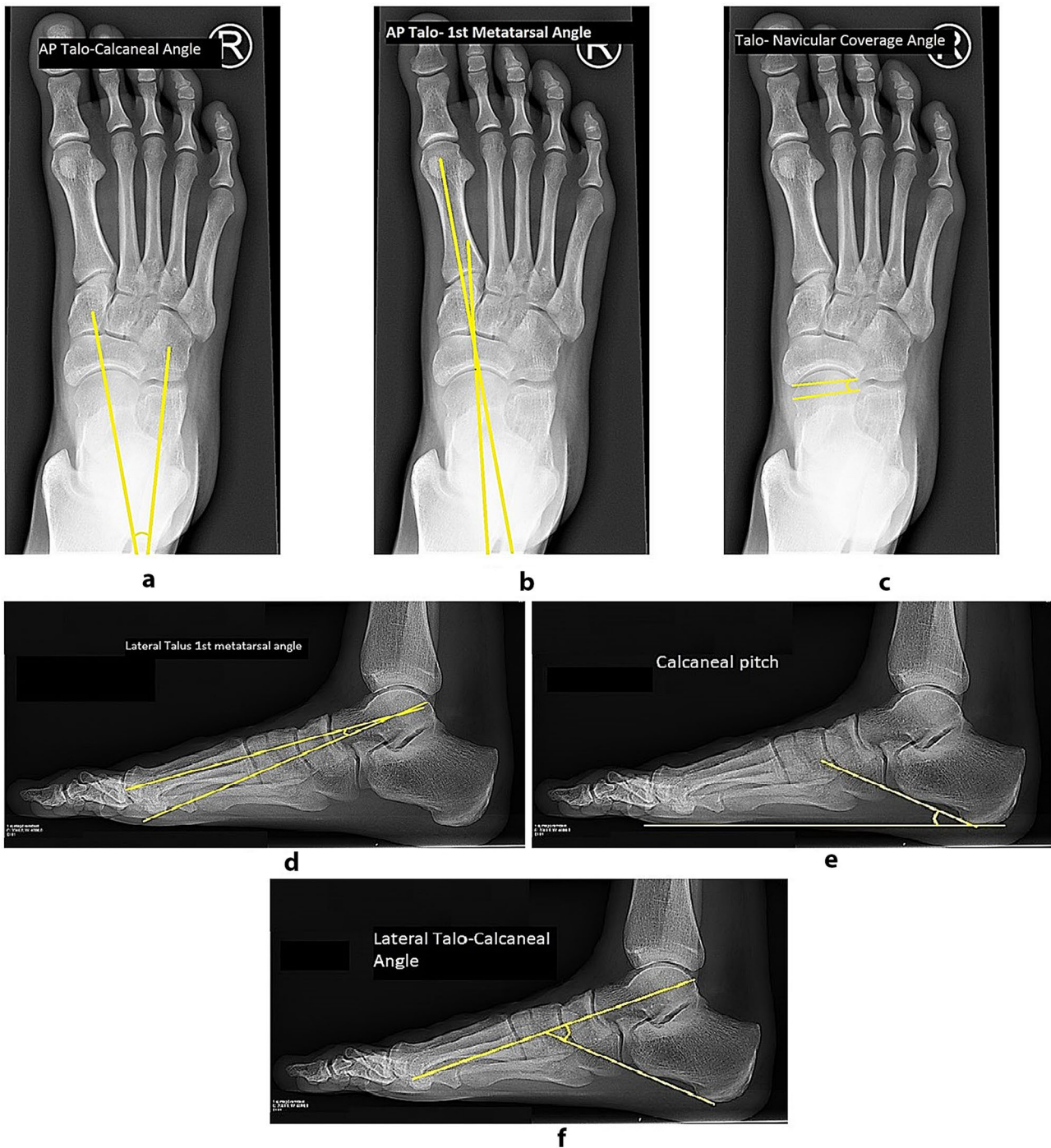


Fig. 1 **a** AP talo-calcaneal angle: angle between the long axis of the talus and calcaneus. **b** AP Talo-1st metatarsal angle: angle between the long axis of the talus and the 1st metatarsal. **c** Talo-navicular coverage angle: angle between the articular surface of the talar head and the proximal articular surface of the navicular. **d** Lateral talo-

1st metatarsal angle: angle between the long axis of the talus and 1st metatarsal in the lateral radiograph. **e** Calcaneal pitch: angle between the calcaneal inclination axis and the supporting horizontal surface. **f** Lateral talo-calcaneal angle: angle between the long axis of the talus and the calcaneal inclination axis

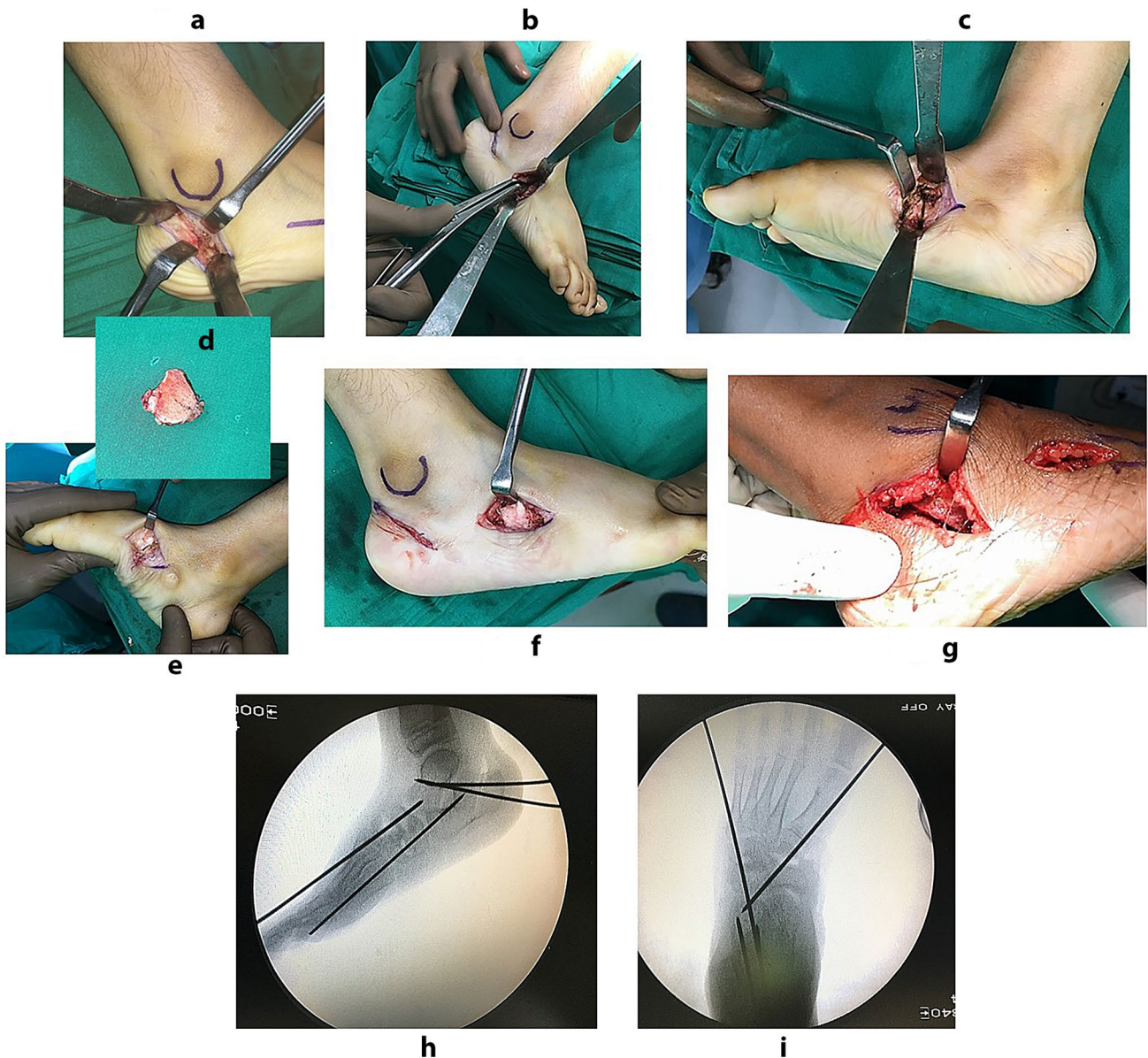


Fig. 2 a–g Depicting surgical steps of Triple C osteotomy. **h, i** Intra-operative C-arm picture showing fixation of the osteotomies

ankle foot orthosis (AFO) was made for the child and the child was allowed weight-bearing to tolerance in an AFO.

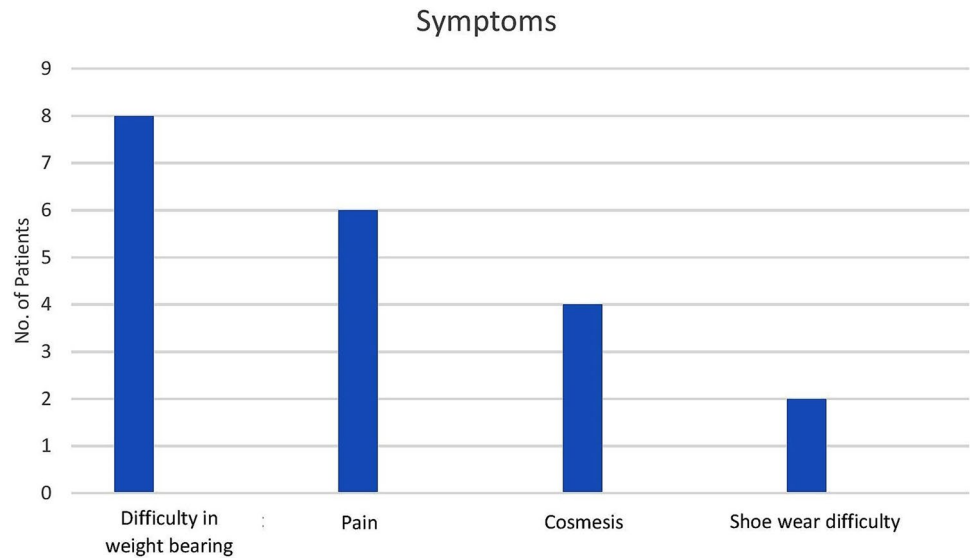
Statistical Analysis

Patient data were maintained, and statistical analysis was performed using Microsoft® Excel® 16 for Office 365. The difference between the pre-operative and post-operative radiological parameters was performed using the Paired *T* test. *P* value of <0.05 was considered statistically significant.

Results

A total of 12 feet in 8 children were operated (6 males and 2 females). 4 patients were bilateral and 4 were unilateral. 2 patients (4 feet) had planovalgus feet secondary to spastic diplegia and 6 patients (8 feet) had idiopathic planovalgus feet. The average age of the patients was 11 ± 1.27 years (range, 10–13 years). Mean follow-up was 14.7 ± 2.7 months (range, 12–20 months). A few patients required additional procedures like lengthening of the Triiceps-Surae complex in the form of Gastrosoleus recession in three feet to correct ankle equinus secondary to cerebral

Fig. 3 Presenting symptoms of patients



palsy and 1st metatarsophalangeal joint fusion in one foot with hallux valgus.

All patients presented with difficulty in walking which affected their daily routine and social participation. This was associated with corns and callosities on the medial border of the foot with skin breakdown in some patients. 6 out of 8 children (75%) had pain as their primary complaint. 4 out of 8 children (50%) had cosmesis as their chief complaint and 2 children (25%) had difficulty in wearing shoes (Fig. 3).

Post-operative assessment of deformity correction was done clinically by assessment of hindfoot valgus, restoration of the longitudinal medial arch of the foot and reduction of the prominence of the talar head and improvement in pain score. Patients who had achieved all of these were considered to have satisfactory results. 11 out of 12 patients had satisfactory outcomes. One patient had a residual mild heel valgus after surgery suggesting that there was an under correction of the deformity. However, he had complete relief of pain and improvement in his ambulatory capacity. There was no overcorrection of the feet leading to heel varus. All patients had improvement in pain score and ambulatory

status post-surgery and had improved tolerance to shoes. There were no gait deviations after surgery.

The VAS score improved from 2.09 ± 2.42 to 0 ($p < 0.005$).

There was a statistically significant change in all but one radiological parameter (Table 1; Fig. 4). The AP Talo-calcaneal angle was the only radiological parameter which despite improvement did not show a statistically significant improvement.

There was no evidence of subsidence or displacement of graft in the post-operative period, or, after the removal of k wires. All grafts and osteotomies had united within 3 months after surgery.

A few patients required additional procedures like Tendo-Achilles lengthening in 3 feet to correct ankle equinus secondary to cerebral palsy and 1st metatarsophalangeal joint fusion in 1 foot with hallux valgus.

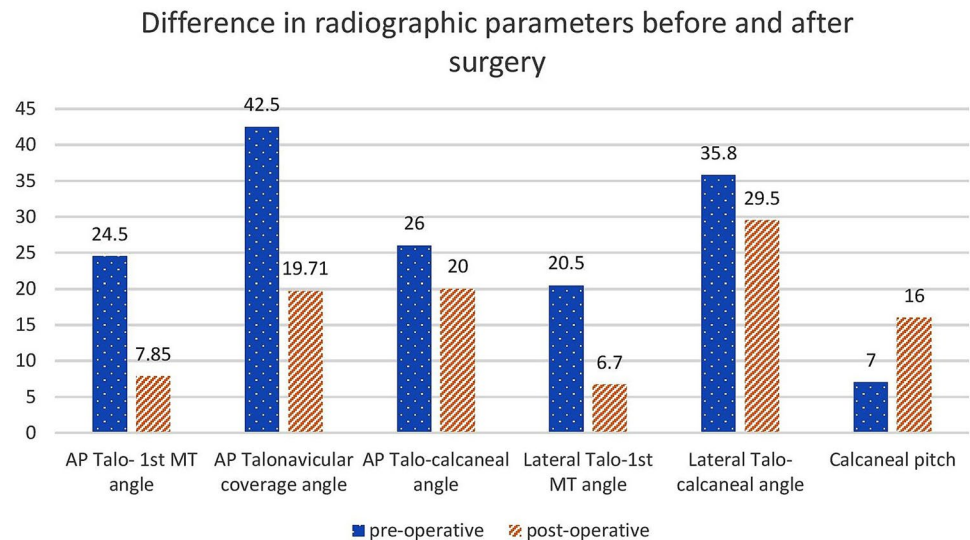
Children with idiopathic planovalgus feet were allowed to discontinue the AFO 3 months after surgery followed by routine shoe wear and no special shoes were prescribed for them later; 2 children with cerebral palsy continued the use of AFOs as a part of their routine orthotic treatment. Although this is a short-term follow-up, there was no

Table 1 Difference in the radiological parameters before and after surgery

Radiological parameter	Normal range [16]	Preoperative	postoperative	T test
AP talo-calcaneal angle	10–56°	26° ± 4	20° ± 2.44	$p = 0.01^a$
AP talo 1st metatarsal angle	– 20 to 15°	24.5° ± 5	7.85° ± 2.4	$p = 0.0003$
AP talo-navicular coverage	5–39°	42.5° ± 13.6	19.71° ± 4.85	$p = 0.001$
Lateral talo 1st metatarsal angle	1–35°	20.5° ± 3.7	6.7° ± 1.6	$p = 0.0003$
Calcaneal pitch	11–38°	7° ± 1.8	16° ± 1.4	$p = 0.003$
Lateral talo-calcaneal angle	15–60°	35.8° ± 3.2	29.5° ± 2.3	$p = 0.003$

^aOnly radiological parameter which did not show statistically significant improvement

Fig. 4 Difference in radiographic parameters before and after surgery



recurrence of deformity at the final follow-up in any of the feet (Fig. 5a–l).

The only complication we encountered in our study was superficial skin necrosis around the calcaneal suture lines in 2 feet (16.6%) which responded well to change of dressings and no additional procedure was required in any of the patients. There were no other complications.

Discussion

Surgery for flexible planovalgus feet is indicated for intractable pain not subsiding with conservative management [7]. Surgical procedures can be either soft tissue reconstruction procedures, realignment osteotomies, and non-fusion motion limiting techniques (arthroereisis) or arthrodesis which may be extra-articular or triple arthrodesis.

Soft tissue procedures in isolation are associated with poor results as the pathological bony anatomy is not rectified and thus these procedures are performed in conjugation with osteotomies [9, 10]. It is recommended to preserve as much functional range as possible in paediatric patients and thus, arthrodesis is not recommended in flatfoot in the paediatric age group as it limits motion and growth in children, and increases stress in the adjoining joints which eventually leads to degenerative changes in the adjacent joints in the long-term follow-up [4, 7].

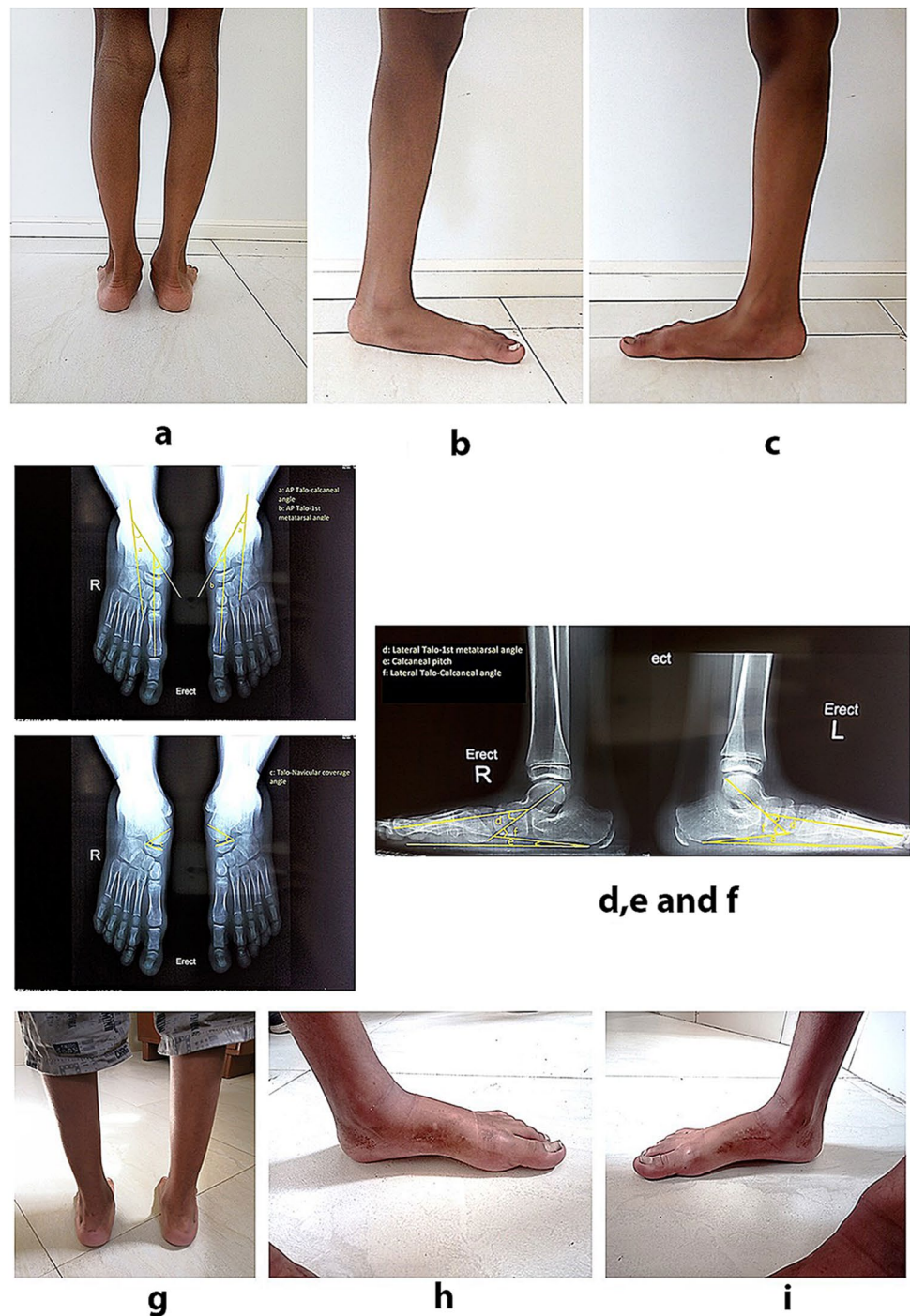
The calcaneal lengthening osteotomy (CLO) was introduced by Evans in 1975 [11] and was later modified by Mosca et al. in 1995 [12]. In his study, he described the lateral column of the foot to be a foundation structure of the foot, and that its length relative to the medial column influences the shape of the foot. It is widely used as it is a single procedure and provides extra-articular correction of the deformity by an osteotomy in the anterior process

of the calcaneus which corrects the external rotation of the acetabulum pedis around the talar head at the site of the deformity at the same time preserving motion of the subtalar joint [2]. The calcaneal lengthening osteotomy relies on the windlass effect of the tight plantar fascia to achieve correction [12]. However, calcaneal lengthening is also associated with complications including calcaneo-cuboid joint subluxation, wound complications, under correction, need for bone grafting with donor site morbidity, graft subsidence, recurrence, and also, it is not a suitable procedure in patients with a talo-navicular subluxation of more than 24° or a calcaneal pitch less than 5° [11].

A double calcaneal osteotomy has been used in cases where hindfoot valgus correction falls short with the CLO [13]. The procedure is a combination of medial calcaneal slide and CLO. Another advantage of using a double calcaneal osteotomy is that it reduces the increased lateral plantar pressures associated with CLO [14]. However, double calcaneal osteotomy has been scarcely reported in literature for paediatric flat feet. Mourkus et al. [13] has reported double calcaneal osteotomy through minimally invasive surgical technique as he reported wound healing problems with the traditional two incision or extended lateral approach. Whereas we did not have significant wound issues with the triple C procedure.

Xu et al. [14] has described the use of cotton osteotomy an opening wedge osteotomy of the medial cuneiform, which they used in nine of their 13 patients. The cotton osteotomy helps to restore the tripod of the foot, [15] and has been successfully used by others as an adjunctive procedure for the same. The use of a closing wedge osteotomy of the cuneiform in the Triple C procedure has the same effect of restoring the tripod of the foot, with an additional advantage of providing a graft for lengthening the cuboid, thus preventing the use of allografts or autografts from another location.

Fig. 5 a–c Clinical appearance of the feet before surgery in a 10-year-old child showing heel valgus loss of medial longitudinal arch of the feet. **d** Preoperative talo-1st metatarsal angle and AP talo-calcaneal angle were 22° and 26° for the right foot and 19° and 26° for the left foot, respectively. **e** Talonavicular coverage angle was 61° and 54° for the right and left foot, respectively. **f** Lateral X-ray showing lateral talo-1st metatarsal angle, calcaneal pitch and lateral talo-calcaneal angle with preoperative values for the right foot being 24°, 7° and 38°, respectively while that for the left foot being 23°, 6° and 38°, respectively. **g–i** Showing clinical appearance of the foot after surgery with reduction in heel valgus and reconstitution of the medial arch of both feet. **j** Showing postoperative talo-1st metatarsal angle and AP talo-calcaneal angle for the right foot being 8° and 22° and for the left foot being 9° and 19° respectively. **k** Postoperative talonavicular coverage angle of 28° for the right foot and 24° for the left foot. **l** Postoperative X-ray showing lateral talo-1st metatarsal angle, calcaneal pitch, and lateral talo-calcaneal angle of 5°, 13° and 30° on the right side and 5°, 14° and 33° on the left side

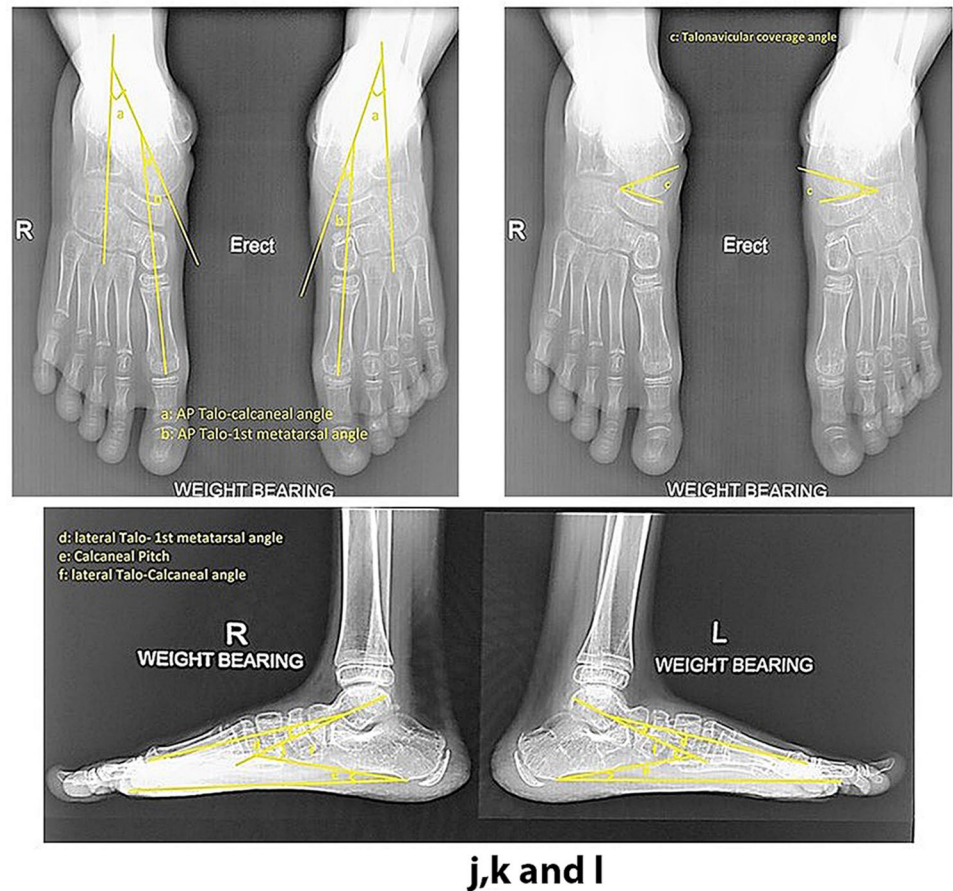


The Triple C osteotomy was described by Karl Rathjen et al. in 1998 to overcome the shortcomings of calcaneal lengthening osteotomy and problems associated with arthrodesis of feet in children [8]. It consists of correction of the deformity at 3 places to achieve a more anatomically sound correction. Rathjen et al. stated that the Calcaneal osteotomy corrects the valgus hindfoot, whereas the Cuboid opening wedge lengthens the lateral column and helps to realign the talo-navicular joint and dorsiflex the talus. Finally, the

Cuneiform osteotomy allows pronation and plantar flexion of the forefoot. This helps to recreate the longitudinal arch of the foot.

Our study involved analysis of short-term results of calcaneo-cuboid-cuneiform osteotomy in conjugation with soft tissue procedures in selected patients with symptomatic flexible flatfoot not responding to conservative treatment. The foot being a complex structure poses some difficulties with respect to clinical assessment of

Fig. 5 (continued)



deformity correction. We used the visual analogue scale to determine the improvement of pain following surgery. None of the foot developed cavo-varus deformity due to overcorrection.

Rathjen in their study reported minor complications 3 patients with scar hypergranulation, 1 superficial infection and 1 delayed union, of the 24 patients, 7 and 16 had excellent and good results, respectively. These results corroborate with our study. We had satisfactory results in all patients with an under correction in 1 patient and superficial skin necrosis in 2 patients.

Mosca et al. [12] in their series had 2 cases in which graft slipped from its position and 3 feet with dorsal subluxation of the distal fragment of the calcaneum and the calcaneocuboid joint. There have been no graft related complications or subluxations in our series. The Triple C also has the advantage of using local grafts, thus, avoiding the need for a separate incision to harvest bone graft and the complications of donor site morbidity.

Moraleda et al. in their study comparing Triple C osteotomy with CLO [16] have described better radiological and clinical correction of the deformity with Triple C osteotomy and has described a higher complication rate with CLO. In their study, they had only one wound dehiscence with the

Triple C osteotomy which is comparable to the results of our study.

Limitations

There are a few limitations of our study. Our study has a small sample size with a relatively short follow-up. This short follow-up can be explained by the fact that ours is a tertiary care institute in which most of the patients travel from distant places. Though the patients are counselled for regular follow-ups, it is difficult to enforce them, especially after one year or so, when they are asymptomatic and painless. We usually discharge them from active follow-up after a year and ask them for routine follow-up every six months or so. Secondly, we have not compared our study population with a comparative population for another representative procedure like the Mosca's CLO. However, it is one of the first few studies of the Calcaneo-Cuboid Cuneiform osteotomy done on the Indian population. We recommend a long-term follow-up to see for any recurrence of the deformity or symptoms as well as a comparative study between the two procedures.

We achieved satisfactory clinical results and statistically significant correction of radiological parameters and a fairly

small percentage of complications along with results comparable to previous literature.

Conclusion

Thus, the calcaneo-cuboid-cuneiform osteotomy is a simple procedure with minimal complications. It has the potential to give good results even in severe planovalgus feet. It gives good radiological and functional outcomes with results comparable to those in literature.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they or their immediate family members have no conflicts of interest regarding this study.

Ethical standard statement All procedures performed in the study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individuals included in the study.

References

- Harris, E. (2010). The natural history and pathophysiology of flexible flatfoot. *Clinics in Podiatric Medicine and Surgery*, 27(1), 1–23.
- Kim, J. R., Shin, S. J., Wang, S.-I., & Kang, S. M. (2013). Comparison of lateral opening wedge calcaneal osteotomy and medial calcaneal sliding-opening wedge cuboid-closing wedge cuneiform osteotomy for correction of planovalgus foot deformity in children. *Journal of Foot and Ankle Surgery*, 52(2), 162–166.
- Caravaggi, P., Sforza, C., Leardini, A., Portinaro, N., & Panou, A. (2018). Effect of plano-valgus foot posture on midfoot kinematics

- during barefoot walking in an adolescent population. *Journal of Foot and Ankle Research*, 11(1), 1–9.
- Carr, J. B., Yang, S., & Lather, L. A. (2016). Pediatric Pes planus: a state-of-the-art review. *Pediatrics*, 137(3), e20151230.
- Rao, U., & Joseph, B. (1992). The influence of footwear on the prevalence of flat foot. A survey of 2300 children. *The Journal of Bone and Joint Surgery. British*, 74-B(4), 525–527.
- Uden, H., Scharfbillig, R., & Causby, R. (2017). The typically developing paediatric foot: how flat should it be? A systematic review. *Journal of Foot and Ankle Research*, 10(1), 1–17.
- Sachini, N. K., Kodithuwakku, A., Chander, H., & Knight, A. (2019). Flat feet: Biomechanical implications, assessment and management. *Journal of Foot*, 38, 81–85.
- Rathjen, K. E., & Mubarak, S. J. (1998). Calcaneal-cuboid-cuneiform osteotomy for the correction of valgus foot deformities in children. *Journal of Pediatric Orthopedics*, 18(6), 775–782.
- Mosca, V. S. (2010). Flexible flatfoot in children and adolescents. *Journal of Children's Orthopaedics*, 4, 107–121.
- Sullivan, J. A. (1999). Pediatric flatfoot: evaluation and management. *Journal of American Academy of Orthopaedic Surgeons*, 7(1), 44–53.
- Luo, C., Kao, H., Lee, W., Yang, W., & Chang, C. (2017). Limits of calcaneal lengthening for treating planovalgus foot deformity in children with cerebral palsy. *Foot and Ankle International*, 38(8), 863–869.
- Mosca, V. S. (1995). Calcaneal lengthening for valgus deformity of the hindfoot: results in children who had severe, symptomatic flatfoot and skewfoot. *Journal of Bone and Joint Surgery American*, 77, 500–512.
- Mourkus, H., & Prem, H. (2018). Double calcaneal osteotomy with minimally invasive surgery for the treatment of severe flexible flatfeet. *International Orthopaedics*, 42(9), 2123–2129.
- Xu, Y., Cao, Y., Li, X., Zhu, Y., & Xu, X. (2017). Double calcaneal osteotomy for severe adolescent flexible flatfoot reconstruction. *Journal of Orthopaedic Surgery and Research*, 12(1), 153.
- Cohen, B. E., & Ogden, F. (2007). Medial column procedures in the acquired flatfoot deformity. *Foot and Ankle Clinics*, 12(2), 287–299.
- Moraleda, L., Salcedo, M., Bastrom, T. P., Wenger, D. R., Albiñana, J., & Mubarak, S. J. (2012). Comparison of the calcaneo-cuboid-cuneiform osteotomies and the calcaneal lengthening osteotomy in the surgical treatment of symptomatic flexible flatfoot. *Journal of Pediatric Orthopedics*, 32(8), 821–829.

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