# Osteotomies combined with soft tissue procedures for symptomatic flexible flatfoot deformity in children

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# Abstract

**Background:** The indications for surgery, timing, and procedure in children with flexible flatfoot deformity remain controversial. For marked deformities, combined procedures are preferred to correct multiple plane deformities. Thus, this study aimed to evaluate the outcomes of osteotomies combined with soft tissue procedures in children with flexible flatfoot aged 9-14 years.

**Methods:** From July 2014 to October 2017, 28 children (47 feet) with flexible flatfoot with an average age of 11.7±2.1 (range 9-14) years underwent osteotomy combined with soft tissue surgery. The American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score and Foot and Ankle Outcome Score (FAOS) were used to evaluate the preoperative and postoperative clinical outcomes. The talo-navicular coverage angle (TNCA) and talar–first metatarsal angle (T1MA) on the foot anteroposterior view, calcaneal pitch angle and Meary's angle on the foot lateral view, and calcaneus valgus angle (CVA) on the Saltzman view were also observed.

**Results:** All patients were followed up for an average duration of 29.7±8.6 months. Mean AOFAS and FAOS significantly improved from 56.6±8.0 and 47.4±9.5 preoperatively to 88.4±3.9 and 83.2±6.8 at final follow-up (P<0.001). respectively. There were statistically significant differences between preoperative and postoperative scores in all FAOS subscales (P<0.001). Radiographic parameters, such as TNCA (P<0.001) and T1MT (P<0.001) on foot AP views, calcaneal pitch angle (P=0.014) and Meary's angle (P<0.001) on foot lateral views, and CVA (P<0.001) on Saltzman views, were significantly improved. All patients and their parents were satisfied with the functional outcomes.

**Conclusion:** Osteotomies combined with soft tissue procedures are an effective strategy for flexible flatfoot deformity in children, as it results in favorable radiographic and functional outcomes.


# Background

Most children with flexible flatfoot frequently encountered in clinical practice are asymptomatic. Clinicians should alleviate worry in their parents and examine patients every 6 months. However, severe flexible flatfoot deformities in children cause pain and functional limitations in activities of daily living [1]. Conservative procedures include in foot orthoses, physiotherapy, weight control and medications for pain relief. Children who are symptomatic but have not well responded to the management with conservative methods will require surgical interventions [2, 3]. The aim of the surgery is to alleviate symptoms and prevent permanent deformity. However, the indications for surgery, timing, and procedure in children with flexible flatfoot deformity remain controversial.

There are various procedures for flexible flatfoot in the adolescents and young adults, including arthrodesis, arthroereisis, lateral column calcaneal lengthening (LCL), medial displacement of calcaneal osteotomy (MDCO), medial cuneiform opening wedge (Cotton) osteotomy, and soft tissue procedures [4, 5]. Arthrodesis can restore the alignment, but it usually inhibits foot mobility and increases the risk of developing degenerative arthritis of the adjacent joints. Thus, arthrodesis should be avoided in children.

Arthroereisis is a minimally invasive procedure that temporarily blocks the subtalar joint in the corrected position [6, 7]. The rate of complications, including under-correction, over-correction, implant resorption, inflammatory reactions, and persistent pain, has been as high as 30% [8].

Flexible flatfoot, especially with a marked deformity, including hindfoot and forefoot deformities, requires a meticulous operative plan. For example, the heel is in a far more valgus position, for which a subtalar arthroereisis does not provide sufficient correction; thus, osteotomies and additional soft tissue procedures are required [9]. Failure to correct the associated deformities, such as forefoot abduction and gastrocnemius contracture, increases the risk of recurrence [10].

The osteotomies combined with soft tissue interventions can achieve complete correction, which can avoid deformity progression and consequent premature degenerative changes [11]. Osteotomies combined with soft tissue surgery in children aged 9–14 years have been rarely reported before. Limited researches reported the outcomes of this strategy for the management of adolescent and young adult flatfoot, and the average age of studied patients was > 14 years [9]. The purpose of this study was to evaluate the outcomes of the combined procedure for children with flexible flatfoot aged 9–14 years. The present hypothesis was that the combined procedure was an effective method for correcting flexible flatfoot in children.

# Methods

This retrospective study was approved by the institutional review board. Informed consent was obtained from all patients. Twenty-eight patients (47 feet) with symptomatic flexible flatfoot deformities underwent reconstructive surgery from July 2014 to October 2017. There were 16 boys (26 feet) and 12 girls (21 feet) with an average age of 11.7 ±2.1 (range 9-14) years at the time of surgery.

Patients with symptomatic, flexible, idiopathic flatfoot were included in this retrospective study. The exclusion criteria were neuromuscular disease, tarsal coalition, traumatic flatfoot, congenital vertical talus, and over-correction of cavus foot. Patients underwent conservative methods involving the use of orthotics and ankle brace as well as physical therapy at a minimum of 12 months before operation. If the pain still persisted, the surgery was recommended.

### Preoperative management

The detailed history and physical assessment were taken before the surgery. Flexible flatfoot is characterized by a flat arch during weight bearing, but the arch recovers when the individual is sitting with the foot dangling. It was important to note the appearance of the forefoot when the heel was reduced to a neutral position during the examination. The Silfverskiold test was used to identify the contracture of the gastrocnemius-solues complex or Achilles tendon. The dorsiflexion of <10º indicated contracture of the Achilles tendon, regardless of whether the knee was flexed or extended. If the dorsiflexion was >10º with knee flexed but <10º with knee extended, it implied contracture of the gastrocnemius complex. The

Coleman block test or heel rise test was used to assess the hindfoot flexibility. The “too-many-toes” sign could show the extent of forefoot abduction.

Radiographic evaluation should include weight-bearing AP and lateral views of the foot, ankle AP view, and hindfoot alignment view. Advanced imaging is rarely indicated for the assessment of flatfoot deformity. Computed tomography (CT) and magnetic resonance imaging (MRI) were usually employed to identify the extent and exact location of the coalition and soft tissue changes, respectively. The talonavicular coverage angle (TNCA) and talar–first metatarsal angle (T1MT) were assessed on foot AP views. The calcaneal pitch angle and Meary’s angle were recorded on foot lateral views. The calcaneus valgus angle (CVA) was assessed on hindfoot Saltzman views.

## Surgical technique

The patients with a thigh tourniquet were placed in the supine position on operation table under general anesthesia in addition to the regional nerve block. First, we performed gastrocnemius recession or percutaneous Achilles lengthening according to the preoperative Silfverskiold test. Then, an incision is made below the tip of the fibula along with the peroneal tendon. The sural nerve should be protected. After the subperiosteal dissection, a 45º osteotomy was performed with an oscillating saw. The posterior aspect of the calcaneus was translated medially at approximately 0.5-1.0cm to realign the hindfoot. The K-wire was used to fix the fragment temporarily. We raised the lower limb and evaluated the heel alignment under direct vision. It was exactly determined with an intraoperative Saltzman view. The MDCO was fixed with two 4.0-mm cannulated screws. If the epiphysis was open, a contoured mini-plate or K-wire was used for fixation (Fig. 1a).

Following the MDCO procedure, midfoot abduction was evaluated clinically. Then, we extended the incision over the calcaneocuboid joint for the LCL procedure. The osteotomy cut was made 1 cm posterior to the calcaneocuboid joint. With the osteotomy distracted, the position of the talus relative to the navicular is checked clinically and radiographically. Once the position is corrected, the allograft with an appropriate size was used to maintain the reduction. Fixation was performed with K-wire, cannulated screw or plate (Fig. 1f).

After completing the hindfoot osteotomy, medial soft tissue reconstruction was performed. A medial incision was made over the posterior tibial tendon (PTT). We debrided and repaired the mild or moderate PTT tear. If the PTT presented a large, extensive and degenerative lesion, repair and flexor digitorum longus (FDL) transfer were adopted. FDL was harvested from the Henry's knot and passed from the plantar to dorsal direction through a drill hole and sutured to itself in mild inversion. The deltoid and spring ligaments were evaluated. Imbrication suturing before FDL transfer was performed with appropriate tension. In children with a painful accessory navicular bone, which was more prevalent among this age group, we always tried to use screw for fixation of the accessory bone, if the bone fragment was large enough. The excision of the entire accessory navicular bone and reattachment with the suture anchor were necessary if the bone was small (Fig. 1b-d).

At the completion of the soft tissue procedures, Cotton osteotomy was performed with residual forefoot supination . An incision was made over the medial cuneiform. Then, a laminar spreader was inserted, and a structural allograft was wedged into the osteotomy site after evaluation with intraoperative fluoroscopy. The plate was used to fix the osteotomy (Fig. 1e).

### Postoperative management

The sutures were removed at 14 days postoperatively. A short cast was used, and weight bearing was avoided in the first 6 postoperative weeks. During this period, patients were advised to undergo physical therapy for rehabilitation and to reduce the risk of deep vein thrombosis. Thereafter, the patients were allowed partial weight bearing as tolerated. At 8 weeks postoperatively, X-ray examination was performed to assess the consolidation of the osteotomies. The patients were allowed to perform full weight bearing after achieving complete bone healing. Outpatient visits at 6 months and 1 year postoperatively were required. The hardware was removed at 1 year postoperatively. The American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot (100 point scale) scores and Foot and Ankle Outcome Score (FAOS) (100 point scale) were employed to evaluate the clinical outcome. The FAOS consists of 5 separate subscales: pain, symptoms, activities of daily living, sports activities and quality of life. These were each scored separately on a scale from 0 (poor outcome) to 100 (best outcome) [12].  Radiographic parameters included TNCA, T1MT, calcaneal pitch angle, Meary's angle, and CVA. All data were assessed preoperatively and at the final follow-up visit.All of the included parameters on the weight-bearing views were underwent by two observers independently.

### Statistical analysis

Statistical analysis was performed using SPSS (version 23.0; SPSS Inc, IBM company, Chicago, IL, USA), and Significance was set at $p < 0.05$. The data was demonstrated as the mean and standard deviation. Differences between preoperative and postoperative functional and radiologic outcome were analyzed using paired Student's t test.

## Results

Data of all of the patients were reviewed, and the average follow-up time was 29.7±8.6 (range 20 to 45) months. All patients achieved bony unions within 10 weeks. The AOFAS scores significantly improved from 56.6±8.0 preoperatively to 88.4±3.9 at final follow-up (P<0.001). A statistically significant difference was shown in the mean FAOS scores, which improved from 47.4±9.5 preoperatively to 83.2±6.8 at final follow-up (P<0.001). There were statistically significant differences between preoperative and postoperative scores in all FAOS subscales (P<0.001). Radiographic parameters, including TNCA (P<0.001) and T1MT (P<0.001) on foot AP views, calcaneal pitch angle (P=0.014), and Meary's angle (P<0.001) on foot lateral views, and CVA (P<0.001) in Saltzman views, were significantly improved at final follow-up. All the patients and their parents were satisfied with the functional outcomes (Table 1, Figs. 2-5).

The procedures performed in all patients were as follows: gastrocnemius recession in 29 feet (61.7%), percutaneous Achilles lengthening in 18 feet (38.3%), LCL in 16 feet (34.0%), MDCO in 42 feet (89.4%), FDL transfer in 5 feet (10.6%), Cotton osteotomy in 18 feet (38.3%), spring ligament imbrication suturing in 20 feet (42.6%), resection of accessory navicular in 11 feet (23.4%), and fusion of accessory navicular bone in 7 feet (14.9%).

Three patients had complications. One patient had sural nerve palsy, but the symptoms disappeared after neurotrophic drug treatment for 6 months. One patient had residual pain in the medial foot, which was relieved by using custom-made insole and gradually disappeared after 3 months. Another patient with diabetes had superficial infection. With careful wound care and oral antibiotic treatment, the incision healed at 1 month postoperatively. Nonunion and delayed union were not present in our cohort. All the patients returned to previous sporting activities without functional limitation and pain.

**Table 1** Comparison of the functional outcomes and radiographic parameters between preoperative and final follow-up time

| Parameters | Preoperative | Final follow-up | P-value |
|---|---|---|---|
| AOFAS scores | 56.6±8.0 | 88.4±3.9 | <0.001 |
| FAOS (mean) | 47.4±9.5 | 83.2±6.8 | <0.001 |
| Pain | 48.2±5.4 | 84.3±8.7 | <0.001 |
| Symptoms | 53.4±9.3 | 81.2±4.6 | <0.001 |
| Activities of daily living | 32.4±10.5 | 82.6±7.5 | <0.001 |
| Sports activities | 45.3±14.2 | 80.1±3.6 | <0.001 |
| Quality of life | 57.6±7.9 | 87.6±9.5 | <0.001 |
| T1MT (º) | 17.2±4.7 | 6.8±2.4 | <0.001 |
| TNCA (º) | 19.4±4.4 | 7.8±2.2 | <0.001 |
| Calcaneal pitch angle (º) | 16.9±5.2 | 21.1±4.3 | 0.014 |
| Meary's angle (º) | 14.2±3.6 | 4.3±2.4 | <0.001 |
| CVA (º) | 15.9±3.0 | 5.4±2.1 | <0.001 |

AOFAS:American Orthopaedic Foot and Ankle Society ankle-hindfoot Score, FAOS: Foot and Ankle Outcome Score, TNCA:talonavicular coverage angle, T1MT:talar–first metatarsal angle, CVA:calcaneus valgus angle.

# Discussion

Flexible flatfoot is a common disease in children. Most children experience spontaneous correction of the deformity or become asymptomatic. Conservative treatment is the first choice for flexible flatfoot in children. Surgery is indicated for patients with persistent pain despite conservative treatment [2-4,13-14]. The optimal surgical method and its timing still remain controversial. The surgical plan for severe flexible flatfoot is complex, because we should consider correction of the hindfoot valgus, forefoot abduction. Arthrodesis is not appropriate for children especially with open epiphysis. Subtalar arthroereisis is recommend for children aged 8-12 years, and it is not suitable for patients with severe deformities and those with a high risk of complication [8,15]. Some researchers reported that osteotomies combined with additional soft tissue procedures used in adults can solve adolescent flexible flatfoot. The present study demonstrated that osteotomies with soft tissue reconstruction can achieve foot realignment and result in satisfactory clinical and radiographic outcomes in the children.

MDCO is popularly used in the correction of flexible flatfoot. If we only focus on the forefoot deformity and neglect the hindfoot valgus, the operation failure rate is high. MDCO can translate the weight bearing alignment related to the lower limb, medialize the insertion of Achilles tendon to prevent subtalar joint degeneration and reduce the impingement of the lateral ankle. The MDCO is a significant procedure whenever hindfoot valgus exists. In addition, MDCO can eliminate the negative deformity effects of Achilles tendon and improve the outcome of FDL transfer [7,16]. In the present study, MDCO was performed in 42 feet (89.4%), and the CVA evaluated on Saltzman views improved from 15.9º preoperatively to 5.4º postoperatively, indicating that the heel alignment nearly normalized.

Some authors previously observed that LCL or double calcaneal osteotomy was optimal for severe forefoot abduction deformity and also better realigned the midfoot transverse plane deformities [5,9,17]. A cadaveric study also reported that LCL can restore 60% of hindfoot valgus deformities associated with 100% forefoot abduction deformity [18]. In the current study, there were 16 feet that underwent LCL and 13 feet that underwent double calcaneal osteotomy. They all obtained satisfactory outcomes except for one patient who had sural nerve palsy for 6 months. Thus, it is critical to expose the sural nerve under direct visualization and protect it carefully during operation. The most common complication of LCL was calcaneocuboid subluxation and increased risk of calcaneocuboid arthritis [15], which did not occur in our patients. The patients with an average age of 11.7 years had a strong growth potential to remodel the soft tissue balance. Furthermore, joint degenerative changes did not occur because of the short follow-up time.

Osteotomy and FDL transfer procedures are widely accepted in adults, and they have facilitated flatfoot reconstruction and resulted in excellent outcomes [19]. Accompanied with hindfoot osteotomies, soft tissue procedures maximally maintain the stability of the medial column and restore the foot arch. In this study, the decision to perform FDL transfer depended on the characteristics of PTT. FDL transfer was not performed in patients with normal PTT characteristics, and these patients still achieved hindfoot alignment. For cases with PTT accompanied with small- or moderate-sized lesions, we debrided and sutured the PTT. If the PTT had a considerable tear and extensive degenerative changes, we repaired the PTT and performed FDL transfer to strengthen further the medial soft tissue [20]. Most children have relatively healthy PTT compared to adults [4]. A previous biomechanical research had revealed that spring ligament appeared to have similar importance to PTT for supporting the medial arch [21]. Thus, we evaluated the quality of the spring ligament and repaired it with imbrication suture.

Great controversy exists about the relationship of accessory navicular and flatfoot. Senses et al. reported that there is no clear association between the accessory navicular bone and flatfoot [22]. Jacobs et al. argued that the accessory navicular bone changed the insertion and biomechanical characteristics of PTT. Symptomatic flatfoot can progressively occurred [23]. Cha et al. prospectively compared the outcomes between simple excision and the Kidner procedure for painful accessory navicular bone and concluded that two methods minimally restored the medial longitudinal arch [24]. Although still controversial, when a patient still has a symptomatic flatfoot with painful accessory navicular bone, overall foot alignment reconstruction should be performed rather than dealing with accessory bone alone. In addition, the large accessory navicular bone was fixed with a screw in this study, which differed from Cha's procedure [24]. We think that the bone-to-bone healing is easier than the tendon-to-bone healing.

The Cotton osteotomy is an excellent adjunct to hindfoot correction procedures. When the residual forefoot supination is present after restoring hindfoot alignment, Cotton osteotomy is indicated. Benthian et al. demonstrated that the LCL procedure may increase the lateral column pressure, resulting in uncomfortable and painful foot [25]. Cotton osteotomy can reduce the risk of this complication [20]. In the current study, 18 feet underwent Cotton osteotomy, and the patients obtained excellent outcomes without complaints of lateral discomforts. These results may be due to the utilization of Cotton osteotomy and the strong adaptative ability in children.

Our study showed that children who underwent osteotomies combined with soft tissue procedures achieved promising clinical and radiographic outcomes. However, this study has several limitations. Firstly, the patients underwent different combinations of corrective surgeries and had different preoperative conditions. It was difficult to assess objectively the efficacy of each procedure. Furthermore, the sample size was small, which can result in a statistical bias and preclude the definitive conclusion of the operative procedures. Finally, we did not analyze the outcome until the epiphysis closed. As children grew older, the reconstruction results will perhaps change gradually. Thus, a prospective randomized controlled study involving a larger number of patients and longer follow-up time is warranted to determine the efficacy of osteotomies combined with soft tissue procedures in children.

# Conclusion

The osteotomy method combined with additional soft tissue procedures is an effective treatment for flexible flatfoot in children, as they achieve significant improvement in functional and radiographic outcomes.

# Abbreviations

AOFAS:American Orthopaedic Foot and Ankle Society ankle-hindfoot score; FAOS: Foot and Ankle Outcome Score; PTT: posterior tibial tendon; FDL: flexor digitorum longus; TNCA: talonavicular coverage angle; T1MT: talar–first metatarsal angle; CVA: calcaneus valgus angle; LCL: lateral column calcaneal lengthening; MDCO: medial displacement of calcaneal osteotomy.

# Declarations

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Authors' contributions
WXD, LXJ, and LY designed the study, carried out statistical analysis and drafted the manuscript. LXJ and LY performed the all surgery procedures. NGH, LJQ and ZHM participated in statistical analysis and study design. GR, WXW, ZY and LJ collected the clinical and radiographic data and helped in manuscript preparation. All authors read and approved the final manuscript.

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Availability of data and materials
All datasets used during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
This study was approved by the ethical committee of Honghui Hospital, Xi'an Jiaotong University.We had obtained the consent to participate from the participants.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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## Figures

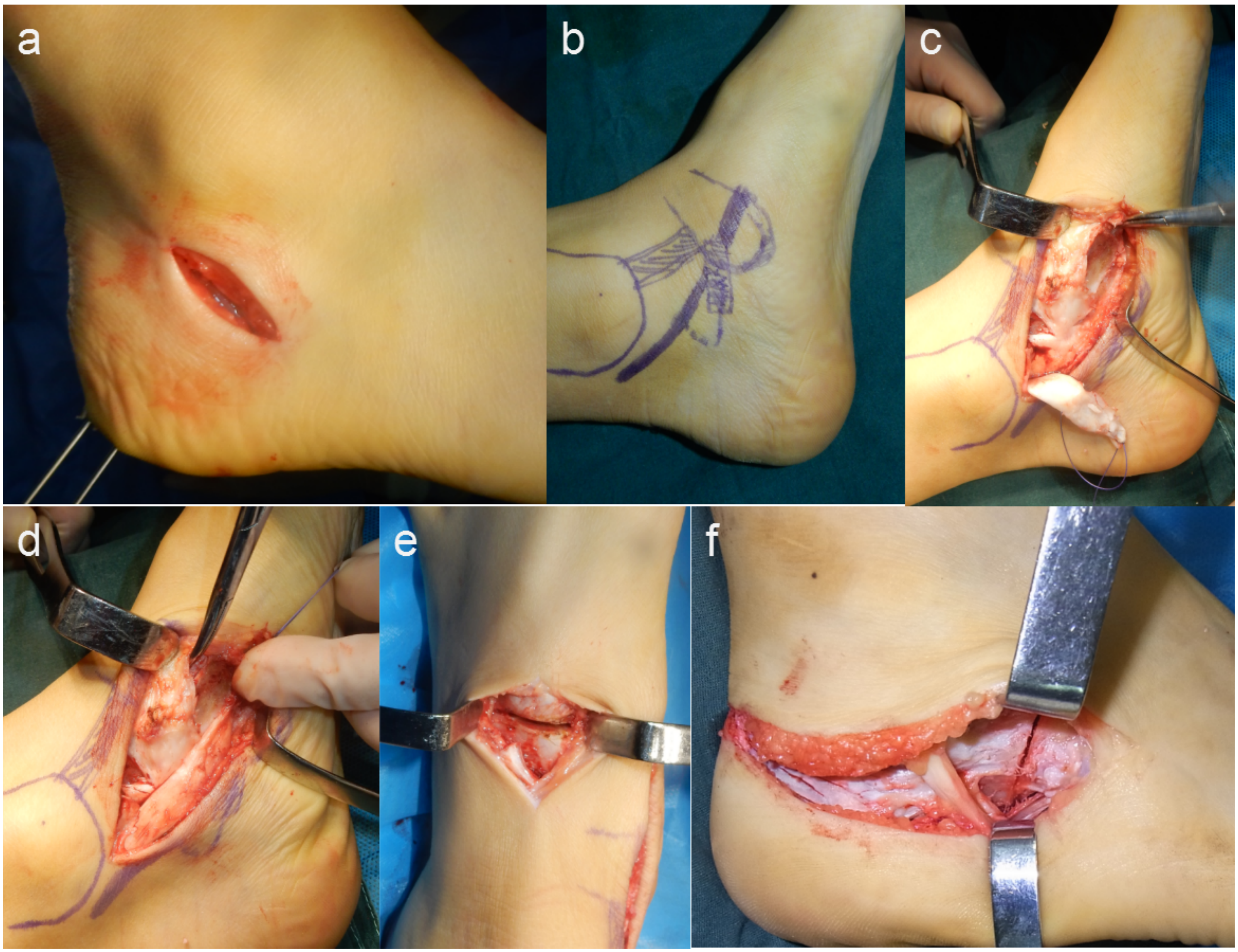



**Figure 1**

Operative procedures of osteotomies combined with soft tissue surgery. We performed MDCO with lateral mini incision (a). Medial anatomic mark and surgical incision (b). Degenerative PTT was debrided and prepared for repair (c). Reattachment of PTT to the navicular tuberosity (d). Cotton osteotomy was performed in a patient with redisual forefoot supination after restoring hindfoot alignment (e). The incision should been extended along the peroneal tendon because of the requirement for simultaneous performance LCL and MDCO (f).

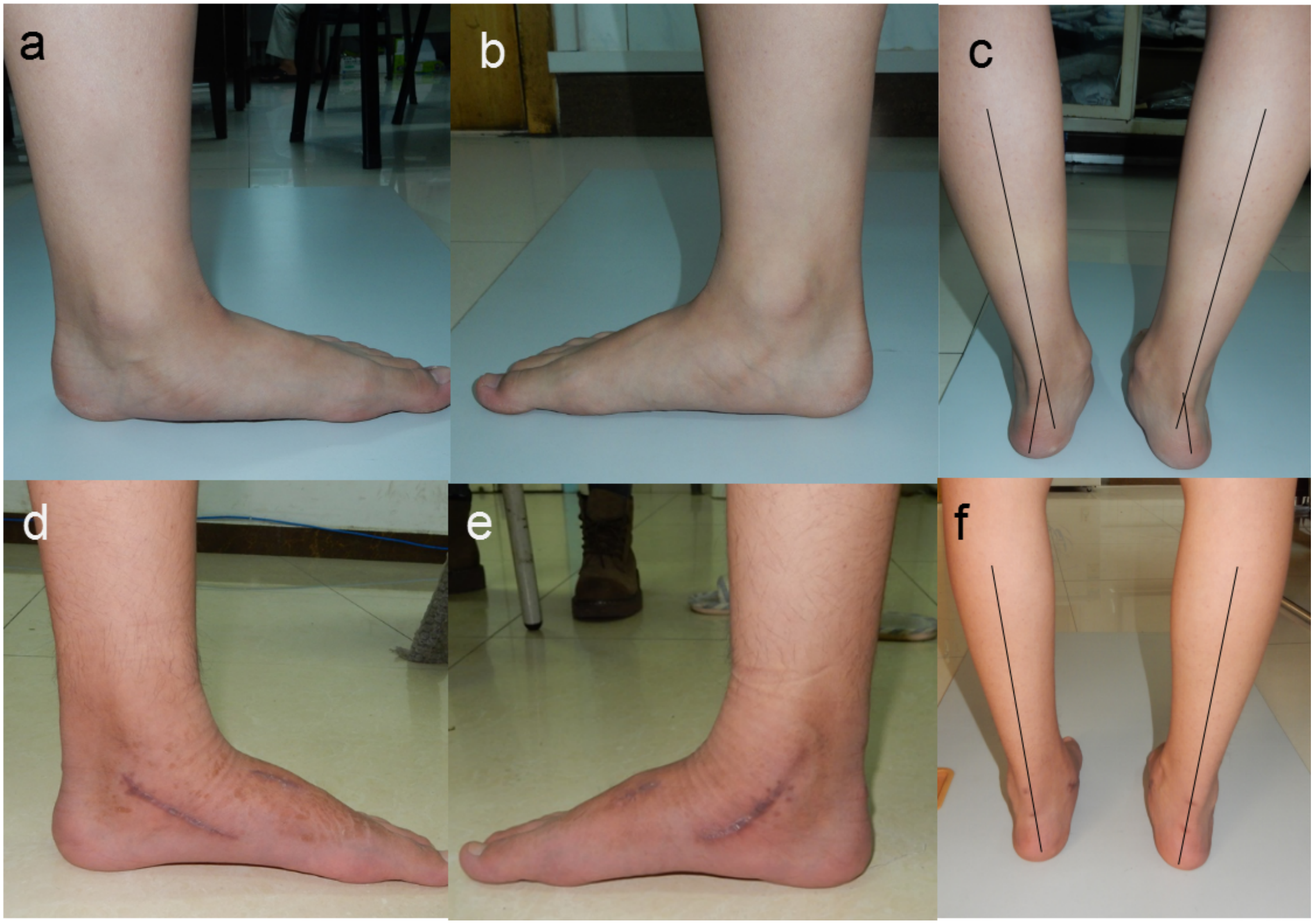
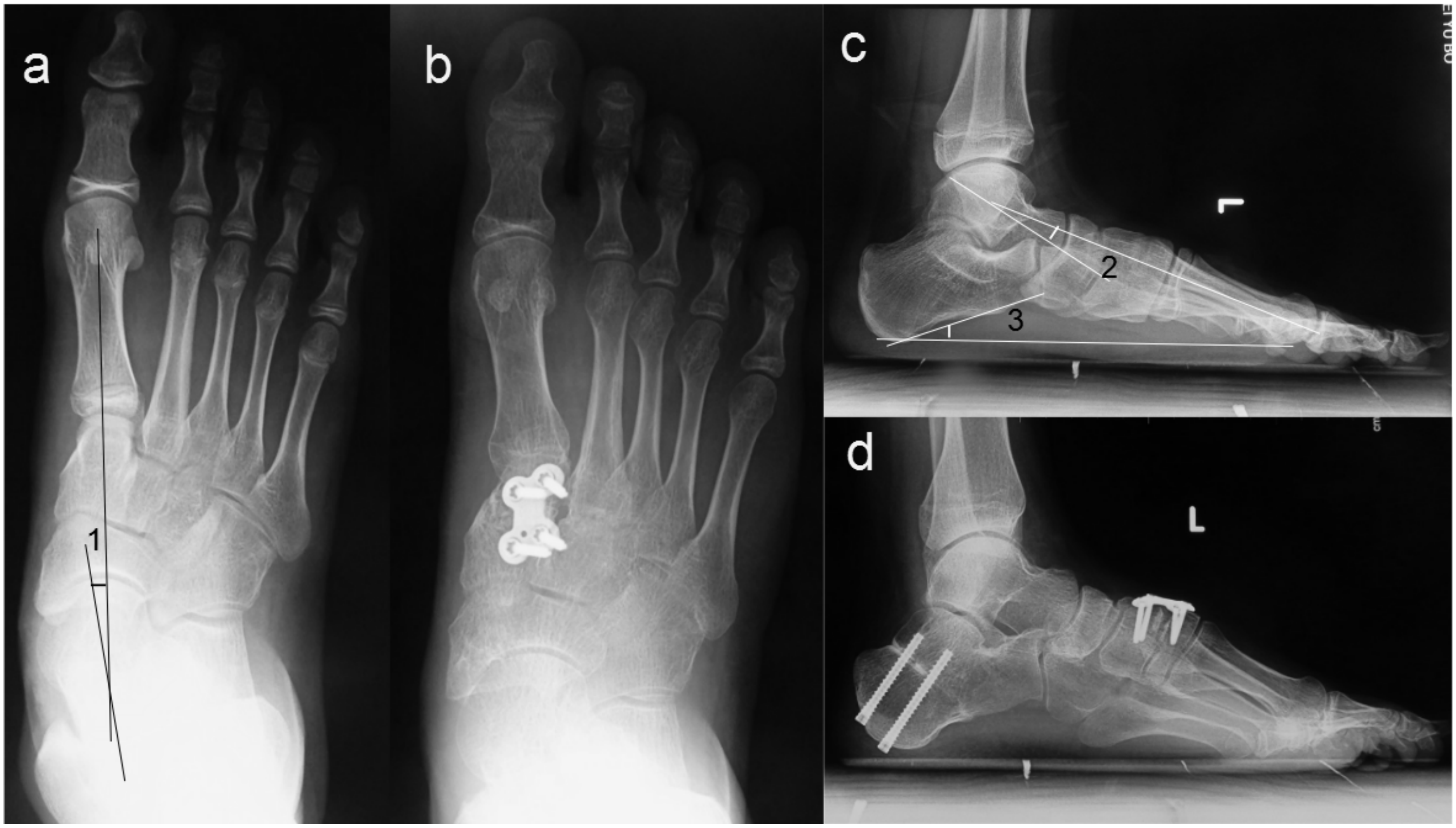



**Figure 2**

A 12-year-old boy with bilateral flexible flatfoot deformity who underwent osteotomies (MDCO and Cotton osteotomy) combined with soft tissue procedures (percutaneous Achilles lengthening and repair of PTT and spring ligament) simultaneously. Compared with the preoperative appearance (a-c), bilateral longitudinal arch and hindfoot alignment were restored at the final follow-up (d-f).




## Figure 3

Preoperative (a,c) and postoperative (b,d) weight bearing views in the left foot demonstrated that the forefoot and hindfoot alignment had been corrected. Numbers 1, 2, and 3 showed the talar–first metatarsal angle (T1MA) on the foot AP view, the calcaneal pitch angle and Meary,s angle on the foot lateral views, respectively.


**Figure 4**

Preoperative (a,c) and postoperative (b,d) weight bearing views in the right foot demonstrated that the forefoot and hindfoot alignment had been corrected. The number 4 showed the talo-navicular coverage angle (TNCA) on the foot AP view.

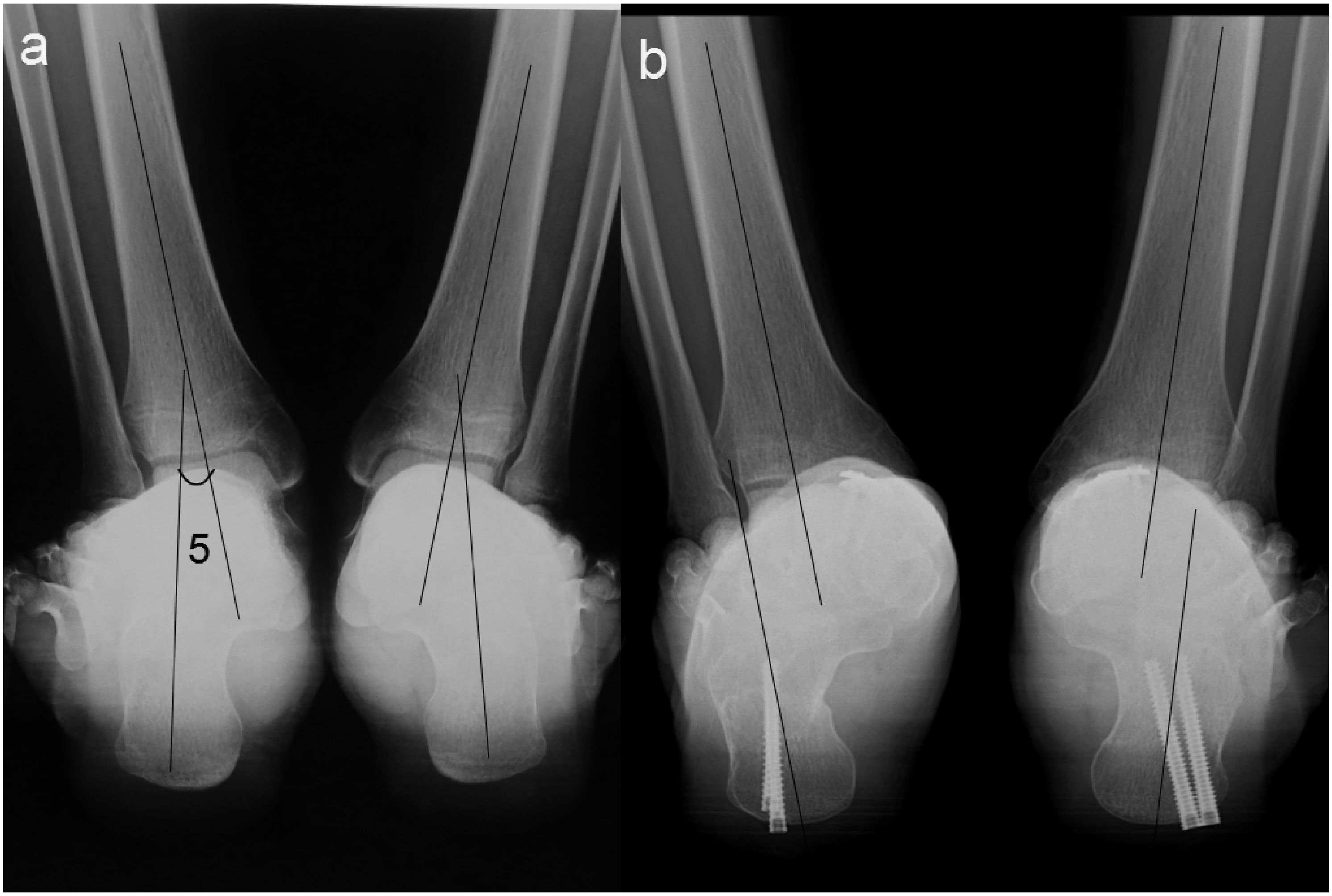



**Figure 5**

Preoperative Saltzman view (a) showed an obvious valgus in bilateral feet. The deformity was corrected after the combined surgery (b). The number 5 showed the calcaneus valgus angle (CVA) on a Saltzman view.