Clinical and radiographic results of the use of a titanium wedge in pediatric patients undergoing calcaneal lengthening osteotomy for symptomatic flat foot

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Flatfoot is a common condition in children; surgical treatment should be reserved for severe and symptomatic cases. Calcaneal lengthening osteotomy (CLO) has been associated with good results; the original technique considers the use of allografts or autografts. This study aimed to evaluate advantages of a titanium trapezoidal wedge (TTW) in a pediatric population, compared with traditional grafts. At our knowledge, there are no studies in pediatric patients. This is a retrospective study of 11 patients (14 feet) with severe flatfoot treated with CLO and TTW and a control group of nine patients (13 feet) treated with CLO and traditional grafts. The mean age of TTW group was 13.4 years, and the mean follow-up was 15 months. The mean age in the control group was 13.7 years, and the mean follow-up was 36 months. Pre- and postoperative clinical and radiographic measures were evaluated, as well as operative time and radiation exposure. At follow-up, feet treated with TTW showed an improvement in all radiographic parameters measured on weight-bearing radiographs and also an improvement in the American Orthopedic Foot and Ankle Society Score, comparable to the control group. The use of TTW significantly reduced radiation exposure and operating time. No cases of graft fracture or migration were observed. All TTW appeared osteointegrated at the last follow-up. CLO using TTW is an effective procedure, allows correction to be maintained over time and reduces operative time and radiation exposure. Despite the promising results, our findings should be considered as a preliminary report; more data are needed to confirm our results. *J Pediatr Orthop B* **XXX: XXXX–XXXX**

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Introduction

The calcaneal lengthening osteotomy (CLO), first described by Evans in 1975 and later modified by Mosca in 1995, is indicated in pediatric patients with severe and symptomatic flatfoot associated with shortening of the lateral column and midfoot abduction [1,2]. The technique has been shown to have good clinical and radiographic results in both idiopathic and neuromuscular flatfoot deformities, and the complication rate reported in the literature is relatively low [1,3–7]. In particular, several authors have reported a success rate ranging from 82.6 to 93.5% [1,4,7].

CLO consists of a complete open wedge osteotomy at the neck of the calcaneus to lengthen the lateral column of the foot. The correction of midfoot abduction is then achieved by moving the navicular bone, which acts as a unit with the cuboid, medially over the talar head, increasing its coverage and restoring the medial longitudinal arch of the foot. Thus, a single osteotomy simultaneously corrects the hindfoot, midfoot, and forefoot. This technique aims to restore the normal architecture of the foot and improve its biomechanical function [3,4,6]. The osteotomy is performed 10–15 mm proximally to the calcaneocuboid (C-C) joint and is away from the growth plate, minimizing surgical trauma in skeletally immature patients and allowing for growth and remodeling [1,3–5].

To maintain correction, the space created by the osteotomy is filled with a bone graft, and to prevent the graft from collapsing, the cortex of the graft is placed perpendicular to the osteotomy. Historically, autologous bone tissue from the tibia or iliac crest or allograft bone from similar harvested sites have been used as grafts [3,4,6]; however, in recent years, there has been increasing interest in the use of titanium wedges to reduce the complications and disadvantages associated with traditional grafts.

Although the clinical and radiologic outcomes of CLO have been widely reported, to date, there have been no studies in the literature that have exclusively evaluated the clinical and radiologic outcomes of the use of a titanium trapezoidal wedge (TTW) when performing CLO for symptomatic flatfoot in pediatric patients.

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A retrospective study was designed to evaluate the efficacy and benefits of using a TTW in pediatric patients with symptomatic flatfoot treated with CLO. A comparison to a control group of patients who underwent CLO with traditional grafts was performed.

Methods

From January 2023 to June 2024, 14 feet in 11 patients were treated at our institution with CLO and the use of a TTW instead of a bone graft to fill the space created by the osteotomy. Surgical indication was given in the presence of severe and symptomatic flatfoot unresponsive to conservative treatment, confirmed by radiographic evidence of lateral column shortening.

The following demographic and clinical data were collected from the medical records: age at diagnosis, sex, laterality, severity, treatment modality, and presence of complications (wedge displacement, lack of consolidation, infection, pain, recurrence of deformity, and others).

Inclusion criteria were as follows: (a) age less than 16.5 years at the time of treatment; (b) confirmed diagnosis of symptomatic flatfoot by clinical examination and plain radiographs, refractory to medical treatment and requiring surgical treatment; (c) minimum follow-up of 6 months; (d) surgical treatment at our Institution; and (e) complete radiographic and clinical data.

Exclusion criteria were: (a) age greater than 16.5 years at the time of treatment or patients with closed physis; (b) incomplete clinical and radiographic data; (c) patients initially treated at another Institution; and (d) follow-up less than 6 months.

A total of 11 patients (14 feet) met the inclusion criteria. There were seven boys and four girls with a mean age of 13.4 years (range: 10.1–16.1 years); eight patients underwent unilateral surgery and the remaining three ones underwent bilateral surgery. Eleven feet in nine patients were idiopathic, three feet were neurological in two cerebral palsy (CP) ambulatory patients with a diplegic pattern Gross Motor Function Classification System (GMFCS) grade II. Mean follow-up was 15 months (range: 7–23 months).

A control group of nine patients (13 feet) treated at our institution from March 2021 to January 2023 with CLO and a conventional graft was compared with the TTW group. Inclusion and exclusion criteria were the same as for the TTW group. All patients were boys with a mean age of 13.7 years (range: 12.6–16.5 years) and a mean follow-up of 36 months (range: 24–48 months). Overall, three patients underwent unilateral surgery and six underwent bilateral surgery. Seven feet of four patients were idiopathic, five feet were neurological in four ambulatory CP patients with a diplegic pattern GMFCS grade II. One patient, clubfoot-affected, had a surgical indication to correct hypercorrection as a result of his previous treatment.

Demographic and treatment-related data are summarized in Table 1.

Surgical titanium trapezoidal wedge procedure and postoperative protocol

The surgery was performed under general anesthesia with the patient in the supine position and a tourniquet applied. All surgical procedures were performed by only one senior surgeon with more than 20 years of experience in foot surgery. The steps of surgical technique as described by Evans and Mosca were followed [1,2].

The CLO was performed approximately 10–15 mm proximally to the C-C joint, between the anterior and middle subtalar articular facets, with a direction from proximal–lateral to distal–medial, first with a reciprocating saw and then manually completed with an osteotome [4,7]. It should be noted that, as reported in the literature, 46–69% of the articular facets are fused, making it sometimes difficult to identify the interval between them [4]. Two pins were placed on either side of the osteotomy to allow opening the osteotomy with a spreader instrument. At this point, trapezoidal wedge templates were inserted from the smallest to the largest, and each was checked for correction both clinically, by simulating a weight-bearing surface on the foot, and radiographically. Once the correct measurement for adequate correction was determined, the final TTW (OsteoSinter; Ames Medical Prosthetic Solutions, Barcelona, Spain) was inserted without additional stabilization. A final fluoroscopic check was then performed. The decision to add an adjunctive procedure was based

Table 1 Demographics and treatment details

	TTW group	Control group auto/allograft
Demographics		
Age (mean, range), year	13.4 (10.1–16.1)	13.7 (12.6–16.5)
Sex, *n* (%)		
Male	7 (63.6)	9 (100)
Female	4 (36.4)	0
Treatment details		
Laterality, *n* (%)		
Right	9 (64)	4 (30.8)
Left	5 (36)	9 (69.2)
Severity (AOFAS score)	46.1 ± 10.6	58.5 ± 15.3
Other procedures, *n* (%)		
Achilles tendon lengthening	10 (71.4)	10 (76.9)
Medial cuneiform plantarflexion osteotomy	1 (9.1)	0
Complications, *n* (%)		
Wedge displacement	0	0
Lack of consolidation	0	0
Infection	0	0
Recurrence of deformity	0	0
Pain	2 (18.1)	1 (11.1)
Wound dehiscence	1 (9.1)	0
Cutaneous dysesthesia	1 (9.1)	1 (7.7)

AOFAS, American Orthopedic Foot and Ankle Society; TTW, titanium trapezoidal wedge.

on the residual deformity after the primary procedure (Hoke Achilles tendon lengthening or Cotton osteotomy) [8–11].

During the entire surgical procedure, the C-C joint was not stabilized with wires or pins, as was done in the original Evans technique [2]. According to recent literature, joint fixation does not affect the final clinical or radiological outcome [4]. Any C-C joint subluxation recorded postoperatively is a temporary finding that undergoes remodeling over time.

At the end of the procedure, a weight-bearing cast was applied below the knee and worn for 5 weeks. Patients were then instructed to begin gradual weight bearing after 1 week. After 5 weeks, the cast was removed, and radiographs were taken. The patient was advised to gradually return to daily activities. Most patients were cooperative and followed all physical therapy rehabilitation programs; they were able to perform some exercises on their own to regain function and gait. Physical therapy to restore adequate proprioception, correct gait, and muscle strength, especially of the gastrocnemius, was recommended in only five patients because of significant hypotrophy of the posterior muscle compartment. Full return to sports activities was allowed 12–14 weeks after surgery.

Clinical evaluation

The follow-up protocol included preoperative and postoperative evaluations at 1, 3, 6, and 12 months, and then once a year (Figs. 1 and 2). This protocol was applied for both groups. Clinical assessment was performed using the American Orthopedic Foot and Ankle Society (AOFAS) scale, which consists of a 9-point scoring system divided into three domains: pain (40 points), functional appearance (50 points), and alignment (10 points), for a total of 100 points [4,12].

Radiographic assessment

For both groups, radiographic assessment was performed in all patients using weight-bearing radiographs of the feet in both anterior–posterior and lateral views, and the following radiographic measurements were noted:

1. Lateral talus-first metatarsal angle (Maery's angle) [3,13].
2. Calcaneal pitch [3,13].
3. Talocalcaneal angle (Kite's angle) [13].
4. Anterior–posterior talus-first metatarsal angle [3,14].
5. Talonavicular uncoverage percentage [3,14].
6. Lateral incongruity angle (Ellis angle) [3,15].

The TTW union was defined as the absence of lines of lucency around the implant on anterior–posterior and lateral radiographs at the last follow-up and no evidence of graft migration. Clinically, union was assessed as the absence of pain at the osteotomy site at the final follow-up [16–19].

Operative time and radiation exposure

A comparison of operative time and radiation exposure time between the TTW group and traditional grafts was extracted from the medical records (Table 2). In our institution, these data are required to be recorded in the operating room electronic program for each procedure.

Statistical analysis

Data are presented as means and SDs. Student's *t* test was used to compare preoperative and final follow-up radiographic measurements and to compare preoperative and final follow-up AOFAS clinical scores. Subsequently, clinical and radiological differences between the TTW and conventional graft groups were evaluated using an unpaired Student *t* test. The statistical significance level was set at 0.05.

Results

Eleven patients were treated according to the protocol reported in the current study (Figs. 1 and 2). All feet ($n = 14$) underwent a CLO osteotomy with the addition of a TTW. Ten feet underwent simultaneously to Hoke percutaneous Achilles tendon lengthening [10,11] and one foot underwent cotton first cuneiform osteotomy [8,9]. The decision to add an associated procedure was based on the residual deformity after the primary procedure.

Length of surgery

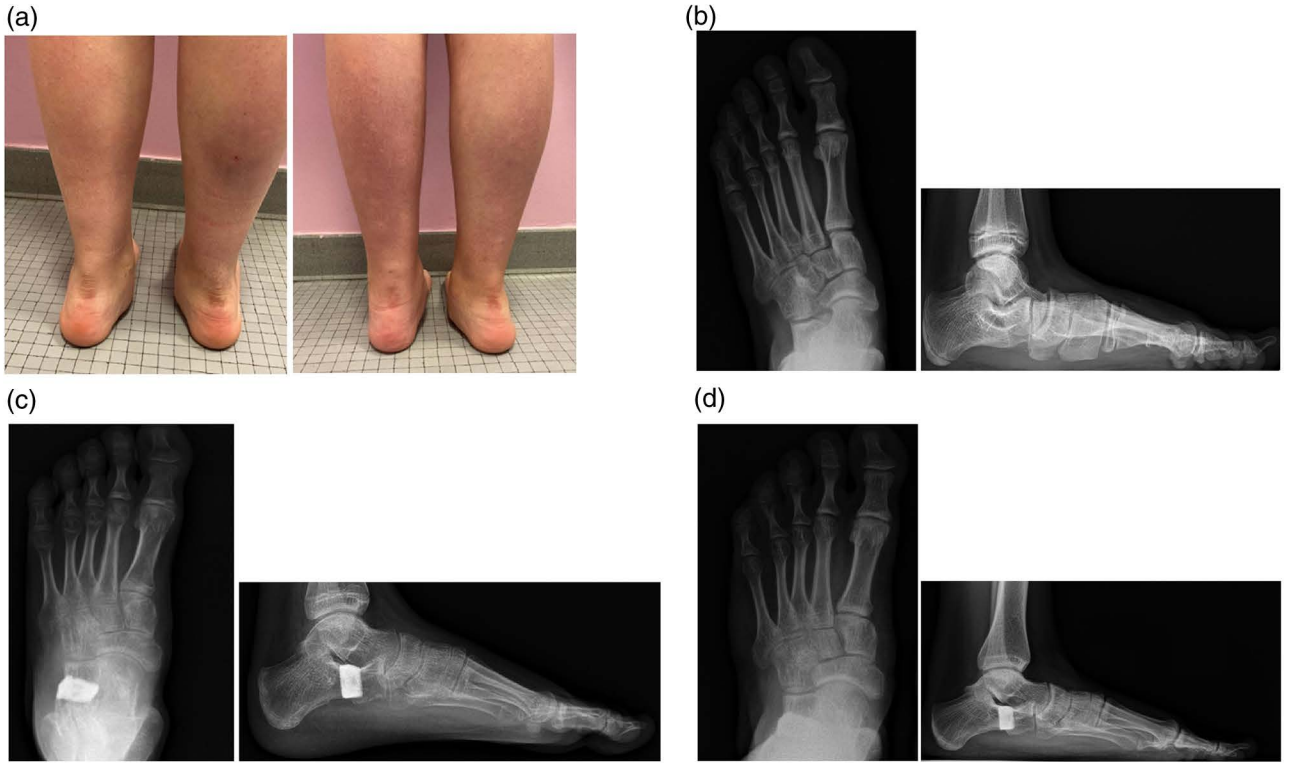
The operative time for CLO with the TTW was shorter compared with the operative time with autologous or allogenic bone graft. With the use of the TTW, the entire surgical procedure took an average of 51.2 ± 11.3 min, compared with an average of 89.5 ± 14.7 min with autograft or allograft. Specifically, the harvesting time for autograft was 28.8 min on average (range: 22–35), while the shaping time for allograft was 12 min on average (range: 9–15). Our results showed that the operating time with the TTW was on average, 38.3 min shorter than that with traditional grafts because of the elimination of the graft preparation time, including any thawing and graft shaping, and the time for harvesting was also saved in the case of autograft (Table 3).

Clinical outcome

In all cases, there was a statistically significant increase in the AOFAS score from preoperative to final follow-up. In particular, the mean preoperative AOFAS score in the TTW group was 46.1 ± 10.6, and the mean postoperative score was 96.1 ± 6.7; all but two patients (18.1%) were completely asymptomatic at the last follow-up.

In the conventional graft group, the mean preoperative AOFAS score was 58.5 ± 15.3, and the mean postoperative score was 94.2 ± 10.2; only one patient (11.1%) complained of pain at the last follow-up. Table 4 shows the comparison between preoperative and postoperative AOFAS scores in the two groups of patients.

Fig. 1



A 13-year-old boy with bilateral flatfoot. (a) Clinical appearance before and 6 months after surgical correction of the left foot. (b) Preoperative anterior–posterior and lateral weight-bearing radiographs. (c) Postoperative anterior–posterior and lateral weight-bearing radiographs (1 month). (d) Postoperative anterior–posterior and lateral weight-bearing radiographs (1 year).

Radiographic results and radiation exposure

A statistically significant improvement in radiographic parameters measured on weight-bearing radiographs in both anterior–posterior and lateral views was observed in all feet treated with TTW; comparison with the changes in radiographic parameters in the conventional graft group did not show a statistically significant difference ($P > 0.05$). These data show that the results of the two methods are comparable (Table 5).

Furthermore, the use of the TTW significantly reduced the radiation exposure time, which is an advantage for the surgeons as well ($P < 0.05$; Table 2).

Complications

Only one complication was recorded in the TTW group (1/11; 9.1%) in a patient who underwent bilateral surgery in two separate stages 1 year apart. The patient experienced superficial wound dehiscence in the left foot and cutaneous dysesthesia at the dorsolateral region of both feet.

There were no reported cases of graft fracture or migration. All TTW appeared to be well-integrated at the last radiographic follow-up.

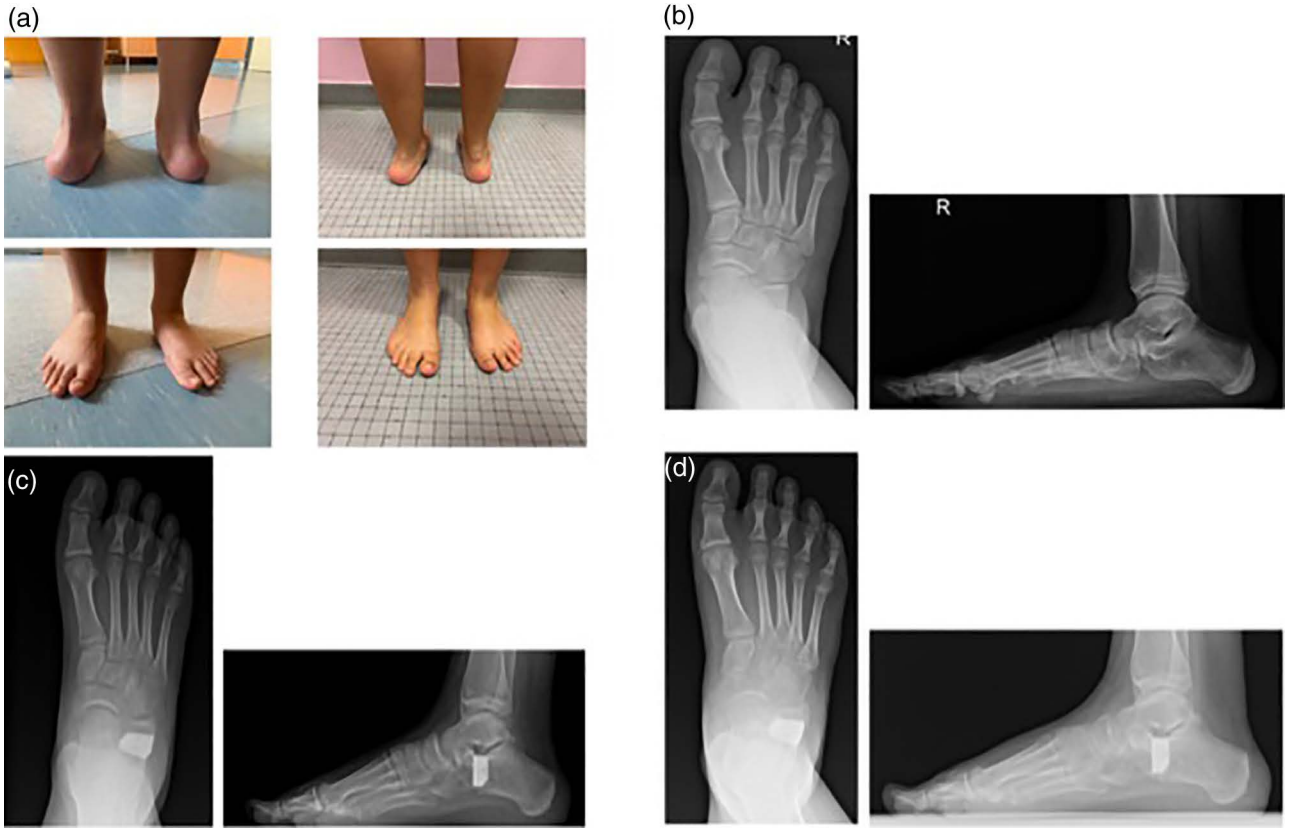
In the conventional graft group, only one patient complained of pain at the final follow-up. Another complication reported was cutaneous dysesthesia on the dorsolateral aspect of the foot in another patient.

Discussion

Surgical treatment of symptomatic flatfoot has been extensively discussed in the literature, and many different techniques have been reported in recent years [20–22]. The results of the present study demonstrate that the use of a TTW in patients undergoing CLO for the correction of symptomatic flatfoot provides similar clinical and radiographic results to procedures performed with bone autograft and allograft [1,3,4,7]; however, the use of a TTW allows for a shorter surgical procedure and less radiation exposure.

CLO is a well-established procedure known for its good clinical and radiologic results in the correction of symptomatic flatfoot, with a success rate of up to 93.5% reported by Mosca and a low risk of complications [1]. Marengo *et al.* [4] reported that the procedure was performed in 31 patients (38 feet) with flatfoot, with good to excellent results in 89% of cases, including patients

Fig. 2



A 12-year-old girl with bilateral flat feet. (a) Clinical appearance before and 6 months after surgical correction of the right foot. (b) Preoperative anterior–posterior and lateral weight-bearing radiographs. (c) Postoperative anterior–posterior and lateral weight-bearing radiographs (1 month). (d) Postoperative anterior–posterior and lateral weight-bearing radiographs (1 year).

Table 2 Radiation exposure

	Mean ± SD		
	Titanium wedge	Auto/allograft	*P* value
Radiation exposure time (min)	0.11 ± 0.04	0.15 ± 0.1	<0.05
DAP (mGy × cm²)	86.7 ± 39.4	89.41 ± 53.6	<0.05

DAP, dose area product.

Table 3 Length of surgery

	Mean ± SD		
	Titanium wedge	Auto/allograft	*P* value
Operating time (min)	51.2 ± 11.33	89.5 ± 14.7	<0.05
Graft harvesting and shaping time (min)	0	28.8 ± 4.7	<0.05

with various patterns of spasticity, contractures, and muscle weakness. Andreacchio *et al*. studied 15 ambulatory patients (23 feet) with moderate neurological flatfoot due to cerebral palsy who underwent CLO with iliac crest autograft. Consistent with other reports, Andreacchio *et al*. found that at a final follow-up of 4.1 years, 17 of 23 feet had good cosmetic appearance, improved walking distance or reduced use of bracing, and no pain, and only four feet had poor results and required revision surgery because of recurrence of the deformity. Andreacchio *et al*. [7] concluded that CLO provides good clinical results in 82.6% of cases, resolves painful symptoms, restores normal biomechanics, and provides good radiographic correction regardless of etiology. Our series predominantly included idiopathic flatfoot (n = 11), and all patients (n = 14) had good clinical and radiographic outcomes. Changes in the AOFAS score in the two groups are summarized in Table 4. The AOFAS score improved in the TTW group, increasing from a preoperative mean of 46.1 ± 10.6 to a postoperative mean of 96.1 ± 6.7. In our opinion, this means that there is a greater clinical satisfaction in patients with a statistically significant difference compared with the conventional graft group. A lower mean preoperative AOFAS score for the TTW group may have partially influenced these results.

In the original technique, Evans described the use of an autograft from the ipsilateral tibia [2]. Later, Mosca [1] reported the use of tricortical iliac crest autograft. Despite

Table 4 Clinical outcome

	Mean ± SD			
	Preoperative	Postoperative	*P* value	Variation preoperative/FU (delta)
AOFAS score TTW group	46.1 ± 10.6	96.1 ± 6.7	<0.05	49.9 ± 11.6 (*P* value 0.002)
AOFAS score auto/allografts group	58.5 ± 15.3	94.2 ± 10.2	<0.05	32.2 ± 14.9 (*P* value 0.002)

AOFAS, American Orthopedic Foot and Ankle Society; FU, follow up; TTW, titanium trapezoidal wedge.

Table 5 Radiographic outcome

	TTW group (mean ± SD)			Auto/allograft group (mean ± SD)			Variation preoperative/FU (delta)		
	Preoperative	Postoperative	*P* value	Preoperative	Postoperative	*P* value	Titanium wedge	Auto/allograft	*P* value
Maery's angle (°)	20.6 ± 7.33	8.2 ± 7.7	<0.05	14.5 ± 4.6	6.3 ± 4.5	<0.05	12.3 ± 6.6	8.2 ± 6.1	0.1
Calcaneal pitch (°)	13.1 ± 5.8	18.2 ± 4	<0.05	12.8 ± 3.9	20.7 ± 6.6	<0.05	5.6 ± 2.4	8.2 ± 3.8	0.06
Kite angle (°)	33 ± 5.2	23.6 ± 3.4	<0.05	30.2 ± 4.5	23.1 ± 4.1	<0.05	9.4 ± 6.1	7.1 ± 3.3	0.2
AP talus-first metatarsal angle (°)	24.6 ± 6.4	11.1 ± 7.7	<0.05	18.8 ± 9.1	8.8 ± 5.3	<0.05	13.5 ± 7.2	10.7 ± 6.9	0.3
Talo-navicular unvoverage percent (%)	30.7 ± 9.8	17.3 ± 6.7	<0.05	29.4 ± 12.4	15.9 ± 7.3	<0.05	13.5 ± 8.5	14.7 ± 8.7	0.7
Ellis angle (°)	34.5 ± 11.3	15.5 ± 5.1	<0.05	24.3 ± 7.5	12.1 ± 5.9	<0.05	16.1 ± 10.3	13.1 ± 4.7	0.3

AP, anterior–posterior; FU, follow up; TTW, titanium trapezoidal wedge.

the fact that autograft bone has osteoinductive and osteoconductive properties [1,22], recent literature describes complications with iliac crest autograft, including donor site pain, paresthesia, gait disturbance, hypertrophic scarring, friction and irritation from clothing, infection, local hematoma, and increased postoperative analgesic use because of pain [16,23]. In addition, the amount of bone that can be harvested is sometimes limited [17,18]. On the other hand, allografts eliminate donor site complications and reduce surgical time, but have disadvantages related to cost, availability, pathogen transmission, and rejection. No increased risk of nonunion has been reported with autografts and allografts, probably because of the rich vascularity that characterizes the calcaneus [1,22].

TTW is made of an inert material (titanium) that causes limited local inflammation, is not associated with autoimmune reactions, and has no biological risks. The use of TTW avoids donor site pain and potential complications, making it an attractive alternative to both autograft and allograft. The TTW implant is highly porous, which mimics trabecular bone and promotes osteointegration, allowing for secure and stable fixation. In addition, TTW has high wear resistance, similar mechanical behavior to native bone, eliminates the risk of graft nonintegration because of its good osteoconductive properties, and can reduce surgical time [16–18,24]. In our series, no additional fixation was required, reducing the risk of infection and avoiding a second surgical procedure. In comparison, non titanium fixation devices increase the likelihood of implant corrosion, which can lead to fracture [25–28]. TTW is available in a variety of sizes, allowing for accurate calculation of wedge dimensions, and has been reported to be associated with overall lower costs compared with patients treated with autografts and allografts [16–18].

Few articles have reported the use of a TTW as an inlay for CLO, but they either include only adults or mixed adult/pediatric samples.

Tucker [29] published the first reference on the use of a TTW as an alternative to autograft and allograft in adult flatfoot patients treated with CLO.

Gross *et al*. [16] reported the results of TTW in 28 adult flatfoot patients treated with CLO and found significant radiographic deformity correction with results comparable to autografts and allografts. Patients reported high clinical satisfaction with pain relief and osteointegration in 96% of cases at 14.6 months of follow-up. Only one patient experienced nonunion at the osteotomy site with fracture of the wedge requiring revision with iliac crest autograft.

Moore *et al*. [30] reported similar results in a retrospective series of 30 adults with flexible flat feet ($n = 34$) who underwent CLO with TTW. No cases of graft migration, nonunion, or removal were reported at a 4-year follow-up, although C-C joint pain and peroneal tendonitis were noted in less than 15% of patients.

Matthews *et al*. [18] reported that TTW grafts used in CLO were successfully integrated at 12-month follow-up, and none required removal. They reported minor complications in 12.6% of cases, including pain and nerve irritation, which resolved after treatment in all patients.

Tsai *et al*. [19] retrospectively reviewed 48 patients with severe flexible flatfoot treated with CLO and TTW at least 2 years after surgery. The authors reported two cases of nonunion, one asymptomatic, and the other requiring surgical revision with a larger wedge and stabilization using a locking plate. No loss of correction was noted in either patient. The authors also noted the ease of adjusting the correction during surgery due to the ability to use TTW studies of different sizes.

Stamatos *et al*. [17] compared autografts, allografts, and a TTW in 44 adult patients with flexible flatfoot. They found comparable results in terms of radiographic and clinical outcomes. There were no cases of nonunion or

loss of correction in the TTW group. In contrast, the study described the need for graft removal in cases where autografts or allografts were used. Gross *et al*. [16] and Tsai *et al*. [19] performed revision surgery for nonunion in patients with TTW, using either an allograft or a larger TTW. We have not had any cases of nonunion in our patients; however, it is possible to remove the TTW during revision surgery because the wedge is located in cancellous bone that can be easily approached.

Our data are consistent with the existing literature (Table 6). In our series, all radiographic measures improved with surgery and remained stable postoperatively. In particular, realignment of the talonavicular and C-C joints, improvement in Kite's angle (from 33 to 23.6°), anterior–posterior talus-first metatarsal angle, talonavicular uncoverage percentage (30.7 ± 9.8–17.3 ± 6.7%), Ellis angle (34.5 ± 11.3–15°), calcaneal pitch angle, and Maery's angle (from 20.6 to 8.2°) were noted in all patients. Importantly, the values obtained one month postoperatively were similar to those obtained at subsequent follow-ups, indicating that TTW provides a durable result in maintaining the correction achieved over time. The comparison of radiological parameters between the two groups, as summarized in Table 5, showed similar results.

In addition, the good osteointegration of the TTW allowed early weight bearing. Prolonged nonweight bearing with a cast or brace for 6–8 weeks, as required with autografts or allografts – the time needed for the graft to stabilize and integrate without risk of graft collapse – becomes unnecessary. It should be noted that there are no studies in the literature that allow protected weight bearing after CLO with a TTW; all reviewed cases still recommend nonweight bearing; however, in our case series, we felt sufficiently confident in the stability of the implant, and despite protected weight bearing, no cases of graft migration or nonunion occurred. Early weight bearing allows for a faster and less painful return to daily activities, including sports. In fact, two patients who had an allograft in one foot and a TTW in the other reported faster and better recovery with faster resolution of symptoms in the foot treated with the TTW. Patients in our study had a median return to full sports activity, including competitive sports, of 4.7 months (range: 2–9 months).

As described in the literature, CLO may cause minimal subluxation of the C-C joint, with an incidence ranging from 6 to 87%, and has been associated with an increased risk of C-C arthritis; however, evidence of subluxation in postoperative X-rays is not necessarily related to the development of pain. Recent studies report favorable clinical outcomes because of remodeling of the C-C joint over time and the absence of functional impairment [4]. Furthermore, studies have demonstrated that stabilizing the C-C joint with wires or Steinman pins to prevent subluxation does not reduce the incidence of C-C

Table 6 Comparison of current study with previously published data

	AP talo-first metatarsal angle			Talonavicular coverage angle			Lateral talo-first metatarsal angle			Calcaneal pitch			Talocalcaneal angle			Incongruency angle		
	Preop	Postop	Δ, *P* value	Preop	Postop	Δ, *P* value	Preop	Postop	Δ, *P* value	Preop	Postop	Δ, *P* value	Preop	Postop	Δ, *P* value	Preop	Postop	Δ, *P* value
Gross *et al.* [16]	21.6 ± 11.4	8.8 ± 7.4	15.2 ± 11.3	26.4 ± 9.6	14.0 ± 7.2	11.6 ± 9.5	15.2 ± 8.6	8.7 ± 7.7	7.1 ± 7.8	13.7 ± 4.7	18.9 ± 5.9	5.3 ± 3.5						
Moore *et al.* [30]				37.6 ± 14.8	11.0 ± 14.8	26.6 ± 16.1	10.9 ± 5.6	5.6 ± 4.9	5.4 ± 5.1									
Tsai *et al.* [19]	17.6	5.1	<0.001	31.6	12.5	<0.001	19.8	3.9	<0.001	13.1	18.2	<0.001	49.6	45.2	<0.001			
Matthews *et al.* [18]							5.2 ± 13.92	2.6 ± 6.2	0.0001	12.7 ± 6.27	19 ± 6.8	0.015	16.83 ± 7.56	12.58 ± 7.06	.0415			
Stamatos *et al.* [17]	23.1	7.3	<0.0001	32.3	10.5	<0.0001				14.8	23.2	<0.0001				63.3	8.1	<0.0001
Current study	24.6 ± 6.4	11.1 ± 7.7	<0.05	30.7 ± 9.8	17.3 ± 6.7	<0.05	20.6 ± 7.33	8.2 ± 7.7	<0.05	13.1 ± 5.8	18.2 ± 4	<0.05	33 ± 5.2	23.6 ± 3.4	<0.05	34.5 ± 11.3	15.5 ± 5.1	<0.05

AP, anterior–posterior.

joint arthritis [31]. In our series, we did not stabilize the C-C joint, and there were no cases of subluxation or C-C joint-related pain.

Our study has some limitations, including a small sample size and a relatively short follow-up period. These factors make it difficult to rule out the possibility of late-onset C-C joint osteoarthritis; however, this is the largest pediatric series of patients with severe flat foot treated with CLO and TTW. A longer follow-up is certainly needed in patients who have undergone CLO with TTW implantation to confirm that this procedure offers advantages over the use of autograft or allograft. The clinical and radiographic results obtained with the use of the TTW in children are comparable to those described with the original technique and do not differ from those reported in adults.

In conclusion, our study demonstrates that CLO using the TTW is an effective and safe procedure with clinical and radiographic results comparable to traditional autografts and allografts.

TTW allows the desired correction to be maintained over time and reduces operative time and radiation exposure. The TTW also allows a precocious return to an earlier weight bearing just 1 week after surgery, even if cast-protected. Despite the promising results, our findings should be considered as a preliminary report, and more data and a longer follow-up are needed to confirm our outcomes.

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Conflicts of interest

There are no conflicts of interest.

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