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Comparative effects of two calcaneal lengthening osteotomies (Hintermann vs. Evans) in stage II adult-acquired flatfoot

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Abstract

Background Stage II adult-acquired flatfoot (AAF) could be effectively treated by Hintermann (H) and Evans (E) lateral column lengthening (LCL) calcaneal osteotomies. This retrospective cohort study was aimed to compare the post-surgical outcome of this two osteotomies used in Chinese patients.

Methods Of 114 eligible patients (149 feet) with Stage II AAF admitted from October 2018 to October 2022, 92 feet treated by Hintermann osteotomy and 57 feet treated by Evans osteotomy were observed in 2-year follow-up. Pre-surgical and post-surgical radiographic parameters, clinic scores and degenerative changes of related joints were collected and analyzed.

Result Pitch angle, Meary's angle, Naviculocuboidal (NC) overlap (%), Medial arch sagittal (MAS) angle, Talocalcaneal (TC) angle, Talonavicular (TN) coverage angle, Talus–second metatarsal (T-2MT) angle were significantly corrected by both H-LCL and E-LCL osteotomies ($P<.05$). The clinic scores of AOFAS (American Orthopaedic Foot & Ankle Society) score, SF-36 (Short-Form 36-item Health Survey), Pain-NRS (Numerical Rating Scale), and UCLA (University of California at Los Angeles activity score) after surgery showed significant improvement for the patient in both groups. Comparing between the two groups, no significant differences were found regarding to radiographic parameters, clinic scores or degenerative changes. However, degenerative changes of calcaneocuboidal (CC) joint were found in 6 cases (6.5%) in H-LCL group and 17 cases (29.8%) in E-LCL group. Degenerative changes of subtalar joint were found in 6 cases (6.5%) in H-LCL group and 17 cases (24.6%) in E-LCL group. One case developed complication of osteotomy nonunion, and one case underwent secondary arthrodesis in E-LCL group.

Conclusion Both H-LCL and E-LCL osteotomies give rise to an outstanding radiographic correction and a significant enhancement of clinic scores in flatfoot deformity. Compared to E-LCL, H-LCL tends to protect the subtalar joint for Chinese patients.

Keywords Calcaneal osteotomy, Evans osteotomy, Flatfoot, Hintermann osteotomy, Lateral column lengthening

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Introduction

Arch collapse, forefoot abduction, and hind-foot eversion are typical signs of adult acquired flatfoot (AAF), and there is still a lack of agreement regarding the optimum surgical processing [1]. Patients with stage II AAF will present with an inability to raise single-leg heel, without fixed hind-foot deformity(stage III) yet [2], which often requires a combination of bone and soft tissue surgery [1, 3]. Lateral column lengthening(LCL) calcaneal osteotomy is often used as the surgical solution for AAF especially for feet with talonavicular (TN) coverage beneath 70% on weight-bearing dorsoventral X-ray photograph [1, 4]. A meta-analysis found that LCL is more effective in correcting the shortened lateral foot and improving clinical manifestations such as forefoot abduction deformity [5]. Among several surgical techniques for LCL, Evans lateral column lengthening(E-LCL) and Hintermann lateral column lengthening(H-LCL), are the two most widely applied osteotomies [1]. The difference between these two surgeries is the direction of calcaneal cutting, that is, the osteotomy line of E-LCL is located between the anterior and middle articular surfaces of the calcaneus, while that of H-LCL is located between the middle and posterior articular surfaces [6, 7].

There are currently few cohort studies comparing E-LCL and H-LCL in the literature. However, some European scholars have conducted a comparative analysis of both surgical techniques from autopsy and clinical operations [1, 6]. It was concluded that there is insignificant difference in risk between the two surgical procedures and both can achieve good clinical results. Nevertheless, H-LCL is less likely to damage the articular surface. The samples concluded in this studies were all Europeans, but there is a greater proportion of partial or complete fusion of the anterior and middle articular surfaces in Asian calcaneus [7, 8]. Therefore, the purpose of our study is to evaluate and compare the clinical and radiographic outcomes of E-LCL and H-LCL in Chinese patients with AAF.

Methods and materials

This look-back clinical research was permitted by the Ethics Committee of Wuhan Fourth Hospital, and all patients participating in the study signed written informed agreements. After inclusion and exclusion criteria, 114 patients (149 feet) underwent orthopedic surgery for flat feet from October 2018 to October 2022. Radiological and clinical data were collected and analyzed statistically. All procedures of 92 Hintermann osteotomies and 57 Evans osteotomies were performed by the same senior orthopedic specialist with experience in foot surgery.

Inclusion and exclusion criteria

Inclusion criteria: (1) patents with age from 18 to 65; (2) foot deformity met stage II AAF; (3) symptoms not relieved after six months of conservative treatment. Exclusion criteria: previous foot and ankle surgery, central nervous system defects, primary myasthenia, local inflammatory diseases such as gout, active local infection.

Surgical technique

After neuraxial anesthesia, the patient was placed in a supine position and sterile surgical drapes were spread. After blood was expelled, a tourniquet was tied to 1/3 of the thigh.

A same sinus tarsi incision was made in both H-LCL and E-LCL osteotomies. Hohmann retractor was employed to withdraw the peroneal tendon plantarly to expose the tarsal sinus and lateral wall of the calcaneus.

Approximately 1.3 cm from the proximal end of the CC joint is the common osteotomy starting point for both H-LCL and E-LCL osteotomies. The H-LCL osteotomy line passes between the middle and posterior articular surfaces of the TC joint, while the E-LCL osteotomy line passes between the anterior and middle articular surfaces. When performing H-LCL osteotomy, a temporary K-wire passing through the tarsal canal is used as a directional guide, while when performing E-LCL osteotomy, it is performed in a direction parallel to the CC articular surface. The medial wall of the calcaneus is kept as intact as possible. Schematic diagrams of the two osteotomies are shown in Fig. 1.

3-chisel technique was used to gradually open up the osteotomy line, and a spreader is used to maintain the opened-up state until continuity of the “Cyma line” was restored under the supervision of the C-arm machine. A trimmed allograft bone fragment of appropriate size was inserted, followed by internal fixation (1 reconstruction plate, 4 locking screws). If necessary, the Achilles tendon or gastrocnemius aponeurosis can be released on the basis of Achilles tendon contracture or gastrocnemius muscle contracture. Depending on the fundamental pathology, other osseous procedures may be combined, including MCO (medializing calcaneal osteotomy), Cotton osteotomy, subtalar joint immobilization and soft tissue procedures including Kidner procedure. Before the end of the operation, C-arm fluoroscopy showed that the arch of the foot was restored. The wound was sutured layer by layer and the foot fixed with a plaster in the neutral position.

Postoperative recovery

Postoperatively, the patient was placed in a cast external fixation for 4 weeks and allowed to engage in non-weight-bearing activities, including toe activities and lower limb strength training. After the review at 4 to 6 weeks, the

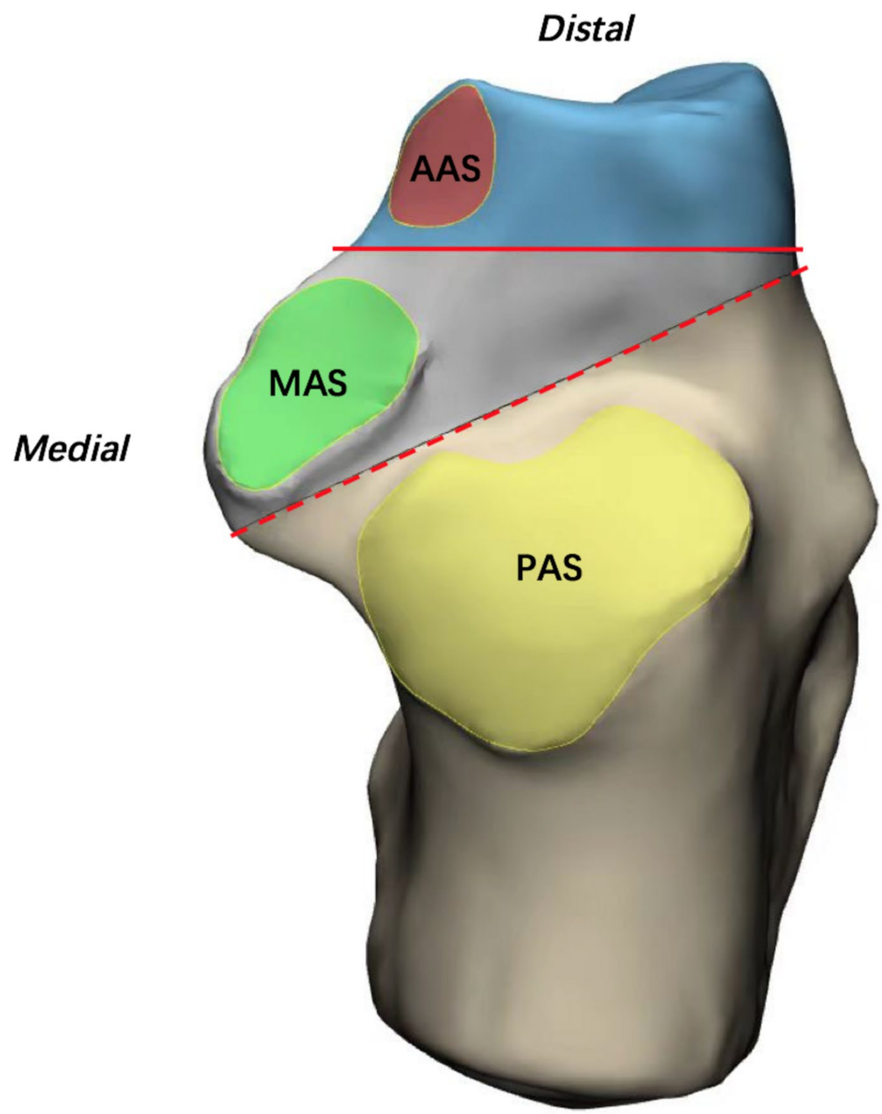

Fig. 1 Two osteotomy directions. The solid line is the direction of H-LCL osteotomy, between the middle and posterior articular surfaces of the subtalar joint. The dotted line is the direction of E-LCL osteotomy, between the anterior and posterior articular surfaces of the subtalar joint. AAS, anterior articular surface; MAS, middle articular surface; PAS, posterior articular surface

patient changed to a walking brace, used crutches to perform some weight-bearing activities, and actively moved the ankle joint. After 3 months, the patient can gradually increase weight-bearing and walk without crutches. Patients can participate in general sports activities 6 months after surgery.

Observation indicators and clinical efficacy evaluation

Basic data collected before surgery included age, gender, body mass index (BMI) and relevant surgery-related risk factors (Smoking, Rheumatoid Arthritis, Osteoporosis, Diabetes, PAOD). Added bony surgeries (including MCO, Cotton osteotomy, subtalar joint immobilization) and soft tissue surgeries (including Kidner procedure, Gastrocnemius recession, Achilles tendon lengthening) based on LCL osteotomy were recorded intraoperatively. After the operation, the patients were followed up to evaluate the clinical efficacy and record the occurrence and treatment of complications. Before and after surgery, weight-bearing lateral radiographs and weight-bearing dorsoplantar radiographs of the affected foot were taken. A single person uses the same method to accurately measure the weight-bearing lateral image indicators (Pitch angle, Meary's angle, NC overlap, MAS angle) and weight-bearing dorsoplantar image indicators (TC angle, TN coverage angle, T-2MT angle) (Fig. 2). Degeneration of joints (TN, CC, subtalar) was recorded according to Kellgren and Lawrence. Clinical efficacy data are collected based on AOFAS, SF-36, Pain-NRS, and UCLA.

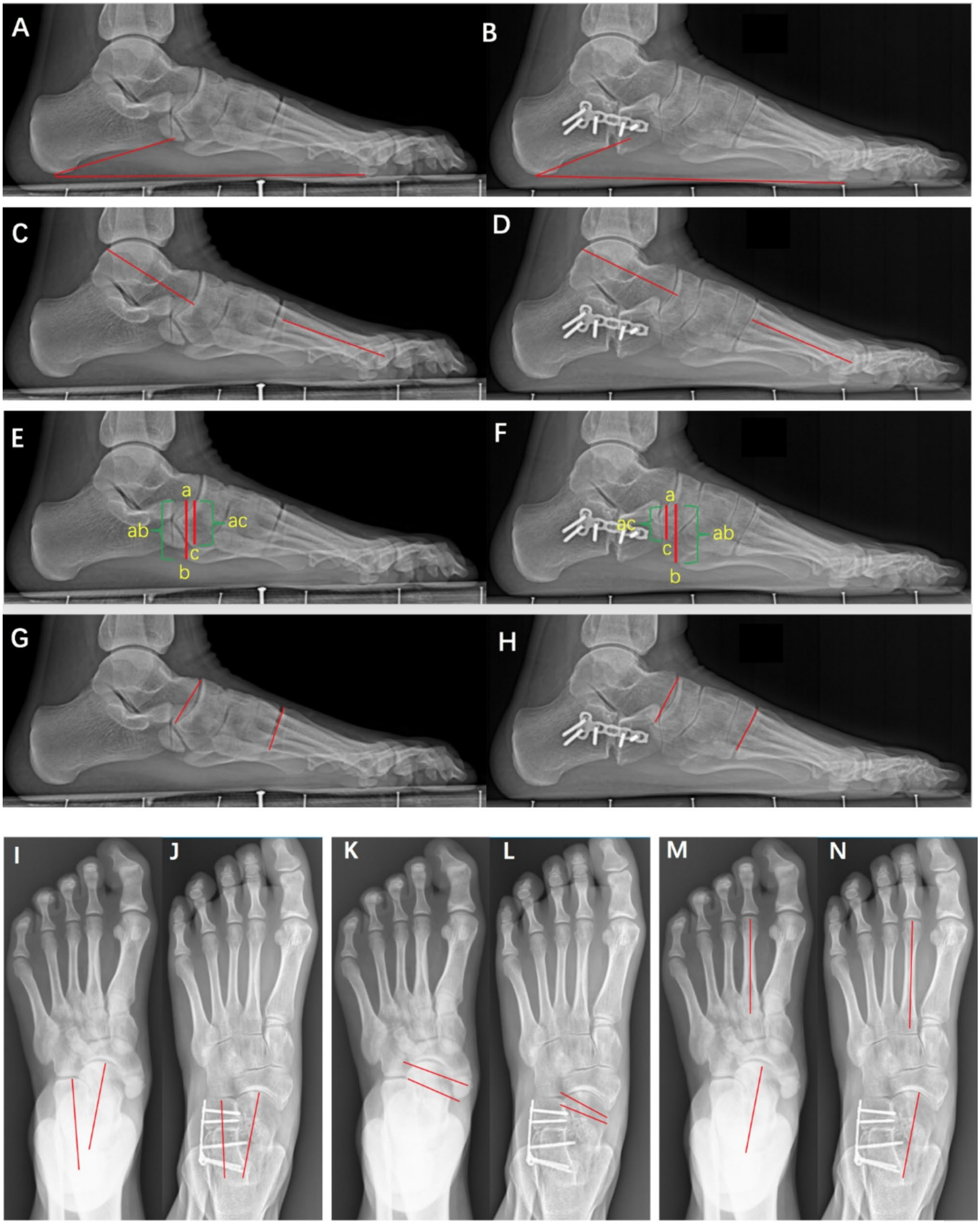

Fig. 2 (See legend on next page.)

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Fig. 2 Radiographic parameters of lateral and dorsoplantar weight-bearing images. Pitch angle was measured in pre-surgical (**A**) and post-surgical (**B**) weight-bearing lateral images. Meary's angle was measured in pre-surgical (**C**) and post-surgical (**D**) weight-bearing lateral images. Naviculocuboidal (NC) overlap (%) was measured in pre-surgical (**E**) and post-surgical (**F**) weight-bearing lateral images (calculated as ac/ab×100%). Medial arch sagittal (MAS) angle was measured in pre-surgical (**G**) and post-surgical (**H**) weight-bearing lateral images. Talocalcaneal (TC) angle was measured in pre-surgical (**I**) and post-surgical (**J**) weight-bearing dorsoplantar images. Talonavicular (TN) coverage angle was measured in pre-surgical (**K**) and post-surgical (**L**) weight-bearing dorsoplantar images. Talus–second metatarsal (T-2MT) angle was measured in pre-surgical (**M**) and post-surgical (**N**) weight-bearing dorsoplantar images

Statistical analysis

All statistical analyzes were carried out by an independent statistician using Prism software. Statistical differences between paired sample data were analyzed using t-test. Statistical differences between unpaired sample data were calculated by applying ANOVA (one-way analysis of variance). *P* values < 0.05 were considered statistically significant.

Result

After exclusion and inclusion criteria, 70 patients who underwent H-LCL surgery (92 feet) and 44 patients who underwent E-LCL surgery (57 feet) participated in this clinical study. In terms of age, gender, BMI, risk factors, and additional surgical procedures (*P* >.05), the basic characteristics of the two cohorts were roughly the same (Table 1). Among the patients in both groups, there were no rheumatism, osteoporosis and PAOD. The vast majority of the affected feet in both groups underwent an additional surgery: Kidner procedure.

No statistical differences were observed between the two groups in respect of postoperative complications and revision surgery (Table 2). In group of H-LCL, no osteotomy nonunion occurred, whereas in group of E-LCL, there was one case (1.8%) of osteotomy nonunion at the proximal CC articular surface (Fig. 3). Two cases (2.2%) in H-LCL group and also two cases (3.5%) in E-LCL group developed superficial wound infection, and all recovered well after treatment with antibiotics and simple dressing changes, without surgical debridement. No deep wound infection or deep vein thrombosis of the lower limbs occurred in the two groups of cases. There was one case (1.8%) in Group E-LCL who had an avulsion fracture of the anterior calcaneus on the radiograph during the last follow-up without any symptoms. Most patients in both groups required implant removal, not because of symptoms. One case (1.8%) in group E- LCL underwent arthrodesis of the subtalar joint, talonavicular joint, and calcaneocuboid joint during reoperation.

In the comparison of radiological parameters, although no significant statistical difference was observed concerning postoperative data between group H-LCL and group E-LCL(*P* >.05), all postoperative parameters in both group H-LCL and group E-LCL changed significantly (*P* <.05) compared to their own preoperative parameters, respectively, and it is worth noting that the *P* value of the change in group H-LCL is smaller (Table 3).

Similarly, from the perspective of various quantitative clinical effects after surgery, there was no statistical difference between the two groups of cases (*P* >.05) (Table 4). Compared with preoperatively, various clinic scores (AOFAS, SF-36, Pain-NRS, and UCLA) after surgery in both groups were significantly improved (*P* <.05), but the *P* value of H-LCL group was lower.

The preoperative and postoperative degenerative changes of TN, CC, and subtalar joints in the two groups of cases are summarized in Table 5. Before surgery, degenerative changes (I) were observed in three cases (two TN joints and one CC joint) in H-LCL group, while that was observed in one case (one TN joint) in group E. After surgery, degenerative changes (I, II and III) observed were significantly increased in the CC joint and subtalar joint in both groups, respectively (*P* <.05). However, the magnitude of these postoperative increases in degenerative changes was not statistically significant between the two groups. Nonetheless, 6 (6.5%) (I and II) versus 17 (29.8%) (I, II and III) cases in the H-LCL group and E-LCL group, respectively, developed CC joint degenerative changes. Meanwhile, 6 (6.5%) (I and II) versus 14 (24.6%) (I and II) cases in the H-LCL group and E-LCL group, respectively, developed subtalar joint degenerative changes.

Discussion

Shortening of the lateral column will cause abducted forefoot and talus lowering, which is an important pathogenesis of flatfoot deformity [9]. In order to effectively treat flat feet in children, Evans reported the LCL osteotomy in 1975 [10], which has since gradually developed into one of the important methods suitable for flat foot deformities of all ages [7], and has been shown to improve abnormal parameters of flatfoot deformity in three dimensions [11–13]. The extension of the lateral column not only adducts the abducted forefoot, but also improves the collapsed arch by lifting the sunken talus, ultimately restoring the normal anatomical structure of the foot [9, 11]. By using the tarsal tunnel as an osteotomy line, Hintermann reformed this surgery in 1999 to improve the orthopedic effect of the surgery [14], which was confirmed by his further clinical follow-up [15].

Our results indicate that both H-LCL and E-LCL osteotomies result in significant clinical enhancement and excellent radiographic modification of flatfoot deformity (Fig. 4). Although both osteotomies have the possibility

Table 1 Basic information of patients for H-LCL and E-LCL osteotomies

	H-LCL (*n*=)	E-LCL (*n*=)	*P* Value
Age, y, mean + SD	37.8 ± 16.8	39.7 ± 17.1	> 0.05
Male: female	48:44	30:27	> 0.05
BMI, kg/m^2, mean + SD	22.3 ± 3.1	22.7 ± 3.3	> 0.05
Risk factors			
Smoking	19 (20.7%)	9 (15.8)	> 0.05
RA	0	0	> 0.05
Osteoporosis	0	0	> 0.05
Diabetes	7 (7.6%)	3 (5.3%)	> 0.05
PAOD	0	0	> 0.05
Additional Procedures			
Modified Kidner procedure	90 (97.8%)	56 (98.2%)	> 0.05
MCO	9 (9.8%)	3 (5.3%)	> 0.05
Cotton osteotomy	16 (17.4%)	11 (19.3)	> 0.05
Gastrocnemius recession	21 (22.8%)	15 (26.3%)	> 0.05
Achilles tendon lengthening	24 (26.1%)	16 (28.1)	> 0.05
Subtalar joint immobilization	17 (18.5)	9 (15.8)	> 0.05

H-LCL, Hintermann lateral column lengthening; E-LCL, lateral column lengthening; RA, rheumatoid arthritis; PAOD, peripheral arterial occlusive disease; MCO, medializing calcaneal osteotomy. Unless otherwise stated, values are expressed as number (%) or mean ± standard deviation

Table 2 Complications of surgery and revision procedures

	H-LCL (*n*=)	E-LCL (*n*=)	*P* Value
Complications of Surgery			
Nonunion of Osteotomy	0	1 (1.8%)	> 0.05
Superficial wound infection	2 (2.2%)	2 (3.5%)	> 0.05
Deep wound infection	0	0	> 0.05
Deep vein thrombosis	0	0	> 0.05
CC subluxation/CC fracture	0	1 (1.8%)	> 0.05
Revision Procedures			
implant removal	89 (96.7%)	51 (89.5%)	> 0.05
wound debridement	0	0	> 0.05
Arthrodesis	0	1 (1.8%)	> 0.05

H-LCL, Hintermann lateral column lengthening; E-LCL, lateral column lengthening; CC, calcaneocuboid. Unless otherwise stated. Values are expressed as number (%)

of causing secondary degenerative changes in the three joints of the foot, the H-LCL osteotomy, to a certain extent, allows a higher proportion of protection of the CC joint and the subtalar joint in our study, which is consistent with the previous report [1]. The incidence of postoperative degeneration of the CC joint in our clinical study was 6.5% in the H-LCL group and 29.8% in the E-LCL group, respectively. This data supports the view in the literature that E-LCL causes greater pressure on the CC joint compared to H-LCL [16–19]. The H-LCL osteotomy line is located between the medial and posterior articular surfaces, with the osteotomy line centered on the talonavicular joint axis, which is considered the primary center of rotation of the hindfoot complex [20]. When the lateral column of the calcaneus is extended by the same distance, H-LCL has a greater ability to correct flatfoot deformity than E-LCL [20]. In other words, to achieve the same radiographic correction effect, a larger bone graft would be used in E-LCL procedure, thus exerting greater pressure on the CC joint. It is worth noting that compared with the study by Ettinger et al. [1], the incidence generative change in CC joint post-surgically in our clinical study was lower in both H-LCL and E-LCL groups, respectively. One of the important reasons is related to the choice of internal fixation. Compared with headed or headless screws used in Ettinger's study that passed through part of the articular surfaces, the reconstruction plates and screws which did not pass through the articular surfaces were applied in our study. However, there was a patient who had an osteotomy fracture that did not heal after E-LCL osteotomy in our study. This may be due to the fact that compared with the H-LCL osteotomy, the E-LCL osteotomy is located closer to the CC articular surface, leaving the distal bone fragment smaller, and the space for inserting plates and screws is limited, which weakens the fixation strength of the implant, resulting in nonunion of the osteotomy fracture.

Similarly, the postoperative degeneration rate of the subtalar joint decreased by H-LCL osteotomy in our study (6.5% versus 24.6% in H-LCL group versus E-LCL group, respectively), consistent with the literature [6]. Compared with previous studies [1], postoperative degeneration rate of the subtalar joint in H-LCL group in our research was lower, which may be related to the anatomical epidemiological differences of the subtalar joint between Asians and Europeans [8]. Moreover, the anatomy of the subtalar joint surface differs among people from different countries and ethnic groups [21]. The normal anatomy of the anterior and middle subtalar articular surfaces can be divided into 3 types: type A: the anterior and middle articular surfaces are completely separated; type B: the anterior and middle articular surfaces are partially merged; type C: the anterior and middle articular

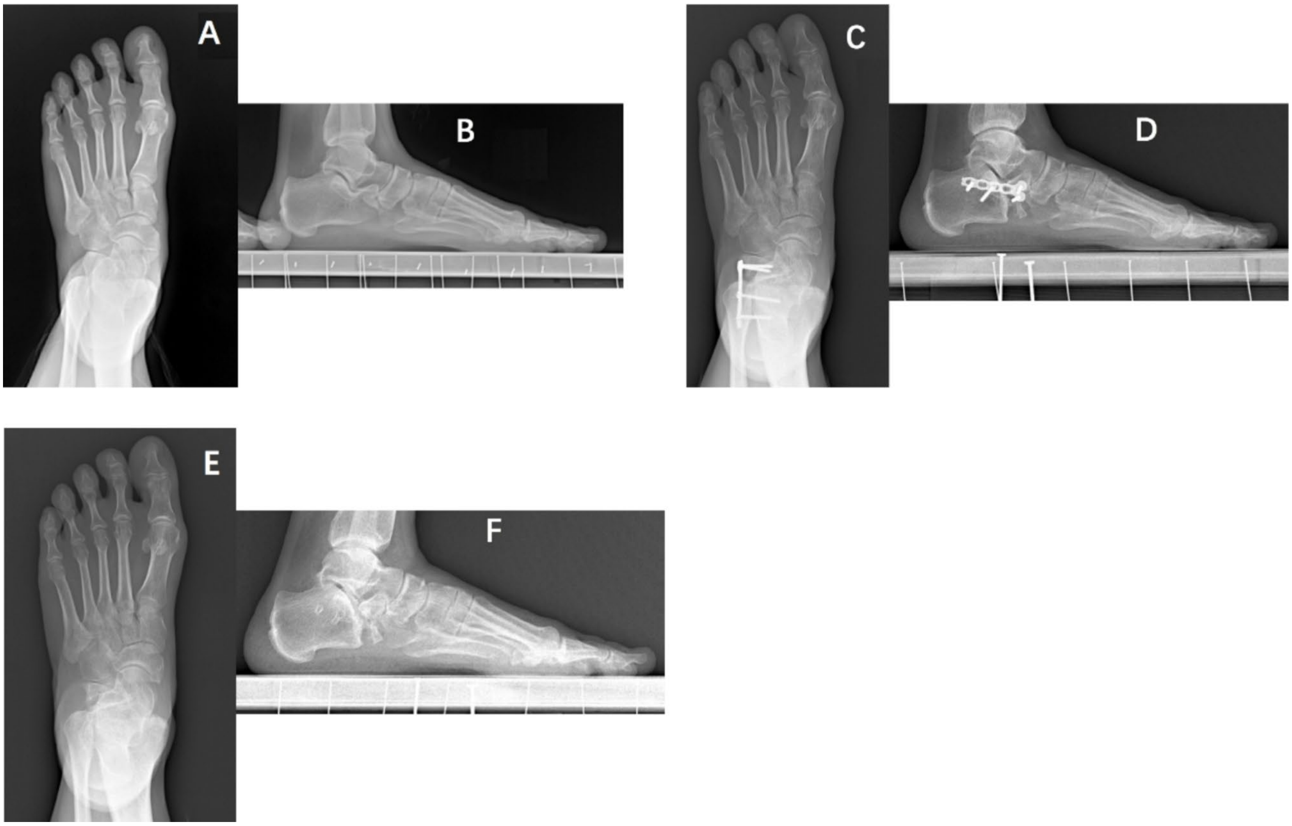

Fig. 3 One case of complication of osteotomy nonunion in E-LCL group. A 46-year-old female patient with flatfoot deformity (**A** and **B** represent presurgical X-ray images) developed osteotomy nonunion (**C** and **D**) after Evans lateral column lengthening calcaneal osteotomy. During the follow-up period, it does not affect daily life. She still decided to have the instrument removed 1 year later (**E** and **F**)

Table 3 Radiological assessments

	H-LCL (*n*=)			**E-LCL (*n*=)**			**H-LCL (*n*=) vs. E-LCL (*n*=)**
	Pre-op	**Post-op**	***P* Value**	**Pre-op**	**Post-op**	***P* Value**	***P* Value**
Lateral weightbearing image							
Pitch angle	15.9 ± 4.8	20.7 ± 5.1	0.0226	16.1 ± 5.0	20.4 ± 5.6	0.0349	> 0.05
Meary's angle	15.8 ± 7.8	3.9 ± 5.4	0.0128	15.4 ± 8.2	4.3 ± 6.1	0.0291	> 0.05
NC overlap (%)	77.1 ± 16.2	53.3 ± 15.4	0.0003	75.7 ± 17.1	55.2 ± 16.3	0.0023	> 0.05
MAS angle	-10.2 ± 7.8	0.4 ± 6.5	0.0001	-9.3 ± 8.1	-0.6 ± 7.5	0.0002	> 0.05
Dorsoplantar weightbearing image							
TC angle	26.8 ± 10.0	17.5 ± 7.6	0.0102	26.4 ± 10.7	18.6 ± 8.8	0.0401	> 0.05
TN coverage angle	25.1 ± 12.5	-2.5 ± 10.1	< 0.0001	24.6 ± 13.1	-1.3 ± 11.2	< 0.0001	> 0.05
T-2MT angle	25.4 ± 9.6	7.7 ± 9.6	0.0001	25.7 ± 10.8	3.9 ± 12.0	0.0002	> 0.05

H-LCL, Hintermann lateral column lengthening; E-LCL, lateral column lengthening; NC, Naviculocuboidal; MAS, medial arch sagittal; TC, talocalcaneal; TN, talonavicular; T-2MT, talus–second metatarsal. Unless otherwise stated, values are expressed as mean ± standard deviation

surfaces are completely merged [7]. Data from Wu et al. [7] show that type A subtalar joint surface accounts for 36.1% of the Chinese population, while types B and C together account for 63.8%. In other words, among Chinese patients with flatfoot deformity, only 1/3 (i.e., type A subtalar joint surface) are suitable for E-LCL osteotomy surgery. Therefore, H-LCL osteotomy which does not harm to the anterior and middle articular surfaces is more suitable for the Chinese population.

Accessory navicular syndrome is more common in stage II AAF, and more than 90% of cases present with medial foot pain [22–24]. Some scholars believe that combining osteotomy with soft tissue surgery may lead to better clinical and radiographic outcomes [25, 26]. Since most patients had painful accessory navicular and we believed that insufficient function of posterior tibial tendon (PTT) was an important reason for the development of flatfoot deformity [27], most patients in our study

Table 4 Clinical efficacy

	H-LCL (*n*=)			E-LCL (*n*=)			H-LCL (*n*=) vs. E-LCL (*n*=)
	Pre-op	**Post-op**	***P* Value**	**Pre-op**	**Post-op**	***P* Value**	***P* Value**
AOFAS	64.3 ± 16.2	81.3 ± 15.6	0.0091	67.1 ± 14.8	79.3 ± 16.2	0.0301	> 0.05
SF-36	60.9 ± 19.7	79.6 ± 18.6	0.0185	59.8 ± 20.1	77.3 ± 19.4	0.0357	> 0.05
Pain-NRS	4.7 ± 1.9	2.3 ± 2.6	0.0044	5.0 ± 2.8	3.1 ± 2.8	0.0176	> 0.05
UCLA	5.3 ± 2.2	2.5 ± 2.1	0.0091	5.1 ± 2.8	3.7 ± 2.7	0.0401	> 0.05

H-LCL, Hintermann lateral column lengthening; E-LCL, lateral column lengthening; AOFAS, American Orthopaedic Foot & Ankle Society; SF-36, Short-Form 36-item Health Survey; NRS, Pain Numerical Rating Scale; UCLA, University of California at Los Angeles activity score. Unless otherwise stated, values are expressed as mean ± standard deviation

Table 5 Degenerative changes according to Kellgren & Lawrence classification (A, B and C)

A. Degenerative changes for talonavicular joint

	Kellgren & Lawrence classification					*P* Value
	0	**I**	**II**	**III**	**IV**	
H-LCL						
Pre-op TN	90(97.8%)	2(2.2%)	0	0	0	0.0932
Post-op TN	84(91.3%)	7(7.6%)	1(1.1%)	0	0	
E-LCL						
Pre-op TN	56(98.2%)	1(17.5%)	0	0	0	0.0592
Post-op TN	48(84.2%)	6(10.5%)	3(5.3%)	0	0	
H-LCL vs. E-LCL						0.4950

B. Degenerative changes for Calcaneocuboid joint

	Kellgren & Lawrence classification					*P* Value
	0	**I**	**II**	**III**	**IV**	
H-LCL						
Pre-op CC	91(98.9%)	1(1.1%)	0	0	0	0.0425
Post-op CC	86(93.5%)	4(4.3%)	2(2.2%)	0	0	
E-LCL						
Pre-op CC	57(100%)	0	0	0	0	0.0124
Post-op CC	40(70.2%)	9(15.8%)	6(10.5%)	2(3.5%)	0	
H-LCL vs. E-LCL						0.1040

C. Degenerative changes for Subtalar joint

	Kellgren & Lawrence classification					*P* Value
	0	**I**	**II**	**III**	**IV**	
H-LCL						
Pre-op Subtalar	92(100%)	0	0	0	0	0.0111
Post-op Subtalar	86(93.5)	5(5.4%)	1(1.1%)	0	0	
E-LCL						
Pre-op Subtalar	57(100%)	0	0	0	0	0.0079
Post-op Subtalar	43(75.4%)	11(19.3%)	3(5.3%)	0	0	
H-LCL vs. E-LCL						0.1275

H-LCL, Hintermann lateral column lengthening; E-LCL, lateral column lengthening; TN, talonavicular; CC, calcaneocuboidal

underwent modified Kidner surgery in addition. Furthermore, it was reported that bony surgery combined with modified Kidner surgery can not only effectively ameliorate pain symptoms but also improve foot function and radiographic performance for flat feet with accessory navicular pain [28–30]. The postoperative TN coverage angle in both groups in our study that was improved better than that in previous research may be owning to the

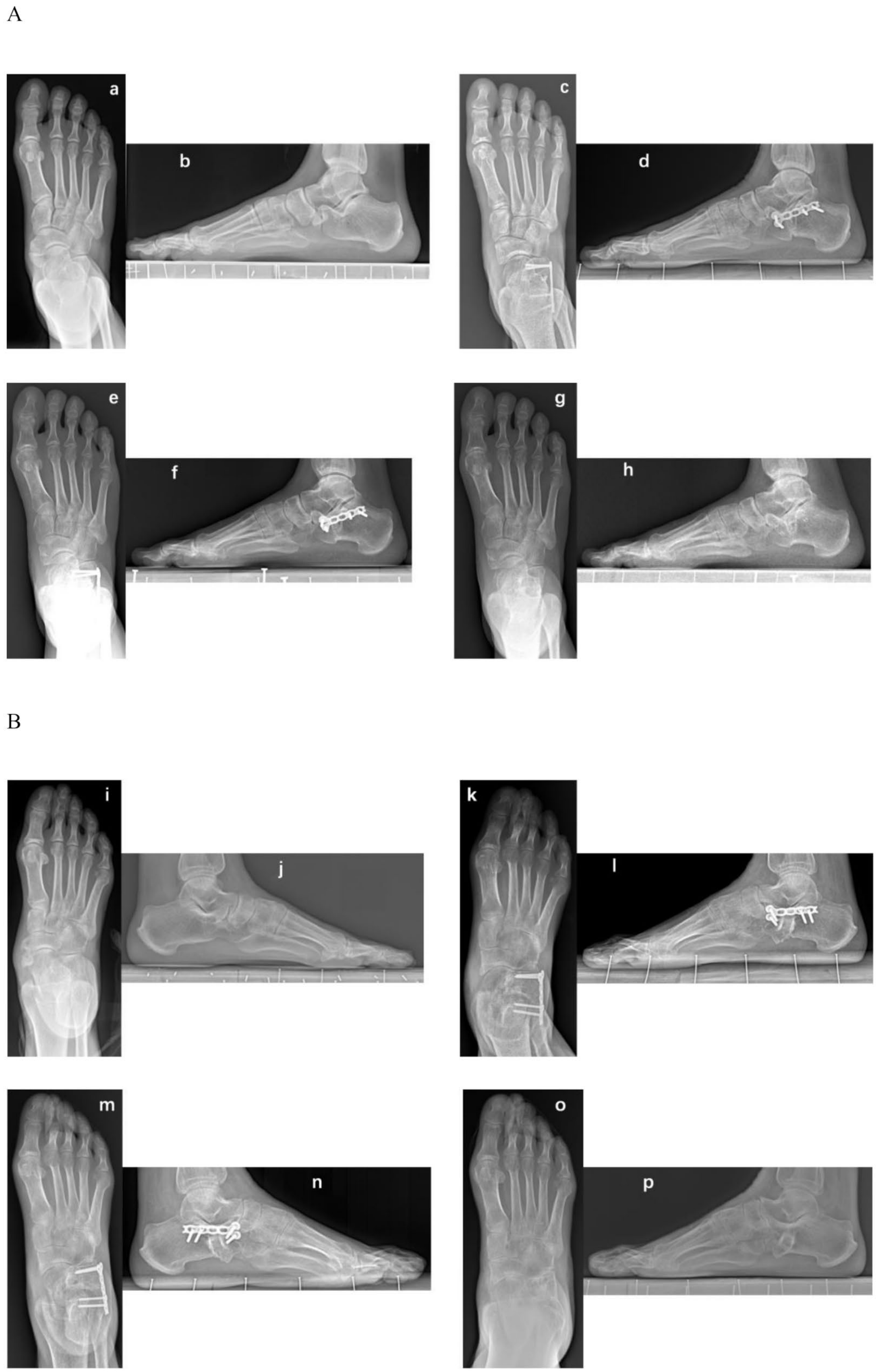

Fig. 4 Radiographic comparison between H-LCL (**A**) and E-LCL (**B**) osteotomies. Both a 36-year-old male patient who received H-LCL osteotomy and a 41-year-old male patient who received E-LCL osteotomy decided to remove the internal fixation one year later. (a) and (b), (c) and (d), (e) and (f), (g) and (h) represent pre-surgery, post-surgery, 6 months post-surgery, 1 year post-surgery, respectively. (i) and (j), (k) and (l), (m) and (n), (o) and (p) represent pre-surgery, post-surgery, 6 months post-surgery, 1 year post-surgery, respectively

contribution of the modified Kidner surgery used in our study, which is consistent with literature [31]. It may be that the total length of the PTT is shortened after the distal end of the PTT is resected and reconstructed, which in turn strengthens the adduction force on the navicular bone, thereby restoring the TN coverage angle [32–34].

It is worth mentioning that the proportion of implant removal surgeries was quite high in our study than that in previous study [1]. Most people choose to remove the internal fixation out of their own volition not because they have pain symptoms, but because of the Chinese culture: rejection of objects outside the body.

Because the institution that implemented this study is the Foot and Ankle Center of the province, the number of eligible cases collected in the past four years is much higher than that in previous similar studies, which thanks to China's large population of patients. Moreover, this is the first clinical case control research in China describing the comparison between H-LCL and E-LCL. Furthermore, in order to reduce the variability in results among surgeons, all surgeries were performed by the same experienced foot and ankle surgeon. However, there are several flaws in our study that need to be noted. Firstly, rather than being planned in as much detail as a prospective study, this study is a retrospective study. Secondly, degenerative changes of relevant joint recorded were all completed within 2 years, so how subsequent changes develop is unknown. Thirdly, since various soft tissue or bony procedures were additionally used, it is difficult to determine the separated effect of each osteotomy.

Conclusion

In summary, both H-LCL and E-LCL osteotomies demonstrated significant and excellent performance in terms of radiographic correction and improvement in clinical outcome scores in patients with flatfoot deformity. Although both osteotomies can cause secondary degenerative changes in the degeneration of the subtalar joint and CC joint, H-LCL shows a tendency to protect the above joints. Considering ethnic differences, Chinese people may be more suitable for H-LCL to correct flatfoot deformity.

Abbreviations

AAF	Adult-acquired flatfoot
AOFAS	American Orthopaedic Foot & Ankle Society
CC	Calcaneocuboidal
H-LCL	Hintermann lateral column lengthening
H-LCL	Evans lateral column lengthening
MAS	Medial arch sagittal
MCO	Medializing calcaneal osteotomy
NC	Naviculocuboidal
NRS	Numerical Rating Scale
PTT	Posterior tibial tendon
SF-36	Short-Form 36-item Health Survey
T-2MT	Talus–second metatarsal
TC	Talocalcaneal
TN	Talonavicular
UCLA	University of California at Los Angeles activity

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Author contributions

Cheng Hao and Zi Li participated in the design of the study; Cheng Hao collected all of the radiographic data and Chenyu Xu collected all the data of clinic score from the eligible cases; Jingjing Zhao and Wei Xie calculated the data; Zi Li and Yaping Ye drafted the manuscript. Zhenhua Fang supervised this study and refined the draft and gave several important suggestions. All authors read and approved the final manuscript.

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Data availability

The datasets generated and analyzed during this clinical study, which compared two surgical approaches involving 114 patients, are not publicly available due to the protection of patient privacy. This research was reviewed and approved by the Ethics Committee of Wuhan Fourth Hospital (Reference Number: KY2024-190-01), ensuring the integrity and confidentiality of clinical data. Non-private data supporting the findings are available from the corresponding author upon reasonable request, subject to compliance with institutional data sharing policies and a signed data access agreement.

Declarations

Ethics approval and consent to participate

This study was performed in accordance with the Declaration of Helsinki, and was approved by the Clinical Research Ethics Committee of Wuhan Puai Hospital. The reference number is KY2024-190-01. Each patient signed a written informed consent before the operation.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trial number

Not applicable.

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