의 학 석 사 학 위 논 문

유연성 평발 교정을 위한 종골 절골술의 임상적, 방사선학적 결과

Clinical and Radiological Outcomes of Flexible Flatfoot Correction with Calcaneal Osteotomy

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의학과

김성후

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이 논문을 의학 석사학위 논문으로 제출함

2024년 7월

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목 차

Abstract

Background: This study was performed to evaluate the radiographic and clinical effectiveness of double calcaneal osteotomy (medial displacement calcaneal osteotomy with lateral column lengthening) to correct flexible flatfoot deformities.

Methods: Thirty-one patients who had 44 symptomatic flexible flatfeet and underwent double calcaneal osteotomy were examined retrospectively with a mean follow-up of 50 months. Visual analog scale, foot and ankle activity measure, and other clinical data were obtained from medical records. Various radiographic variables for assessing flatfoot and osteoarthritic change in tarsal joints were analyzed from weightbearing radiographs.

Results: Clinical scores and radiographic variables were significantly improved postoperatively. The mean values of medial sliding and lateral lengthening were 7.6 and 8.7 mm, respectively. No osteoarthritic changes were observed.

Conclusion: Double calcaneal osteotomy could be used to correct flatfoot deformities effectively and sustainably and provide symptomatic relief and patient satisfaction.

Introduction

Flatfoot deformity is a progressive and devastating disease that contains three-dimensional deformities including hindfoot valgus, forefoot abduction, forefoot or midfoot varus, peritalar subluxation and ankle instability. It is important to correct the deformities to prevent progression of the disease by realigning normal foot alignment. Various surgical procedures are currently performed to treat flatfoot deformities. For flexible flatfoot, medial displacement calcaneal osteotomy (MDCO) and lateral column lengthening (LCL) are the prevailing bony procedures (1-3).

MDCO is conducted to slide the calcaneal body medially and correct the heel valgus. However, the medial longitudinal arch cannot be easily restored using MDCO alone. Some reports have shown insufficient correction compared with lateral calcaneal lengthening (2,4-7). LCL is performed to elongate the lateral column of the foot and restore forefoot abduction and medial longitudinal arch. Other studies have described various side effects, including lateral-sided foot pain, stiffness, and calcaneocuboid joint (CCJ) arthritis, because of an increased joint reaction force of the lateral column (2,4). Although LCL is an efficient method to correct midfoot deformities, its ability to correct hindfoot deformities is insufficient compared with that of MDCO (5).

A flatfoot is a complex three-dimensional deformity. When surgical interventions, including MDCO or LCL, are performed independently, these three-dimensional deformities may be incompletely corrected. Consequently, a double calcaneal osteotomy has been proposed to resolve this issue by simultaneously performing both surgeries; it is an efficient procedure for correcting flatfoot deformities (8-10). In addition, it not only reduces lateral column pressure but also possibly decreases the rates of CCJ arthritis (4,8,11). However, limited studies have extensively analyzed the degree of deformity correction in three dimensions following double calcaneal osteotomy. Therefore, this study was performed to evaluate the effectiveness of double calcaneal osteotomy for flexible flatfoot deformities radiographically and clinically.

Patients and Methods

Patients

This study was approved by our hospital's institutional review board, and informed consent was obtained from all individuals participating in this study. Consecutive patients who were unresponsive to conservative treatments for at least 6 months and who underwent double calcaneal osteotomy in our hospital from January 2011 to December 2020 were included. Patients with a follow-up period of <2 years, post-traumatic flatfoot, neurological disease, congenital abnormalities, and other medical conditions that affected foot alignment were excluded. Thus, 31 patients with 44 symptomatic flexible flatfeet were enrolled in this study.

Clinical evaluations

The patients' subjective satisfaction with the surgery, visual analog scale (VAS) score, and foot and ankle activity measure (FAAM), which is useful for addressing patients' functional outcomes, were obtained by reviewing medical records before and after the operation. The degrees of ankle joint dorsiflexion, plantarflexion, inversion, and eversion were also recorded.

Radiologic evaluations

Weightbearing radiographs, including anteroposterior and lateral views of the foot and hindfoot alignment views, were obtained. Several variables reflecting three-dimensional foot alignment were measured at three time points: preoperatively, 3 months postoperatively, and final follow-up. On the anteroposterior radiographs, the talonavicular coverage angle (TNCA) and anteroposterior talo-first metatarsal angle (AP-TMT) were measured. On the lateral radiographs, the calcaneal pitch angle (CPA), lateral talocalcaneal angle (L-TCA), and lateral talo-first metatarsal angle (L-TMT) were determined. On the hindfoot alignment views, the hindfoot alignment angle (HAA) and hindfoot moment arm (HMA) were measured (12). The radiographic variables were measured twice by two orthopedic surgeons at a 2-week interval, and the average of four measurements was used. The tarsal joints were analyzed at each time point and graded for osteoarthritis according to the Kellgren and Lawrence classification system.

In flatfoot deformity, the relative position between the talus and calcaneus tends to be changed and the posterior talo-calcaneal articulation appears to be obliterated on standing lateral radiograph of the foot. We defined these findings as "posterior facet obliteration sign" in flatfoot. When the deformity was sufficiently corrected, the obliterated posterior facet of the subtalar joint was clearly visible. Thus, we assessed the change of "posterior facet obliteration sign" between preoperative and postoperative standing lateral radiograph (Fig. 1).

When performing LCL, the CCJ tend to be subluxated and we assessed dorsal elevation of the calcaneus at the CCJ to evaluate CCJ subluxation during LCL. To evaluate this elevation of the calcaneus, the vertical length of the articular surface of the CCJ and the dorsal height of the articular surface of the calcaneus above the cuboid were measured on lateral radiographs of the foot. The dorsal height of the articular surface of the calcaneus above the cuboid was divided by the total length of the articular surface of the calcaneus at the CCJ and multiplied by 100 to obtain the percentage of CCJ subluxation (Fig. 2).

Surgical techniques

A double calcaneal osteotomy was performed, beginning with MDCO, followed by LCL. If necessary, the heel cord was lengthened.

First, an oblique incision was made along the lateral aspect of the calcaneal body for MDCO, and an oblique osteotomy was applied. The distal fragment was displaced medially and fixed with one screw (4.0 mm partially threaded cancellous screw). For two juvenile patients whose calcaneal epiphysis was not closed, the screw fixation was replaced with K-wires to fix the osteotomy (Fig. 3).

Second, a straight incision was made proximally from the CCJ along the upper border of the calcaneus. Then, the dorsal capsule of the CCJ was minimally opened to visualize the articulation; a K-wire was inserted percutaneously from the cuboid to the anterior calcaneal segment to stabilize the CCJ while lengthening the lateral column (Fig. 4A). The osteotomy was completed using a power sagittal saw at the interval between the anterior and middle facet of the calcaneus, parallel to the CCJ; this procedure was performed carefully to preserve the medial cortex of the calcaneus. After the osteotomy, two Steinmann pins were inserted divergently on both sides of the osteotomy (Fig. 4B), and distraction was conducted using a pin distractor (Fig. 4C). A tricortical iliac autograft was harvested from the patient and sculpted to form a wedge-shaped graft (Fig. 4D). The graft was impacted into the osteotomy, and two K-wire fixations were carried out from the dorsolateral side of the distal calcaneal fragment to the proximal calcaneal fragment. Subsequently, the two K-wire fixations were advanced to the caudal end of the calcaneus to further stabilize the MDCO (Fig. 4E). The peroneus brevis tendon was not lengthened. Through this fixation for both osteotomy with one screw and K-wires, sufficient stability could be obtained without additional screw and plate fixation; furthermore, incisions and implant irritation could be minimized (Fig. 5).

Third, if the dorsiflexion of the ankle joint was restricted because of tight calf muscles, the Achilles tendon was lengthened (for 19 feet), or the Strayer gastrocnemius recession (for 5 feet) was performed. The heel cord was lengthened to achieve 10 degrees of ankle dorsiflexion with knee joint extension intraoperatively. The foot was immobilized in a neutral position by using a short leg splint.

Postoperative management

After the surgery, the patients were recommended to be nonweightbearing for 2 weeks. Afterward, the sutures and external pin for CCJ fixation were removed. The short leg splint was changed to a short leg cast with a neutral ankle position, and partial weightbearing was allowed for 2 weeks. On the 4th week, the cast was replaced with an ankle foot orthosis brace with an arch support. The patients were permitted to be full weightbearing and instructed to perform a range of motion exercises. On the 8th week, the patients returned to their ordinary shoes with arch support insoles. They were required to perform a standing bike exercise and a more vigorous range of motion exercises, especially ankle inversion and dorsiflexion. The implants were removed at the 6-month follow-up. The superolateral small bony prominence of the calcaneus over the CCJ was resected when the pins were removed from 12 feet.

Statistical analysis

All analyses were performed using IBM SPSS Statistics for Windows, version 28.0.1.1 (14) (IBM Corp., NY, USA). Descriptive statistics, including means, standard deviations, ranges, and percentages, were calculated. Differences in clinical scores (VAS and FAAM score) and ranges of motion (ankle dorsiflexion, ankle plantarflexion, and inversion) between preoperative and postoperative assessments were analyzed by paired *t*-tests. For seven radiographic variables acquired over time (preoperatively, 3 months postoperatively, and final follow-up), differences in the averaged values at each time point were calculated via repeated-measures analysis of variance. Post-hoc tests were conducted using Bonferroni correction for pairwise comparisons. Results with $P \leq .05$ were considered significant. For Bonferroni's method, data with $P < .017$ were considered statistically significant.

Results

Of the 31 enrolled patients, 15 presented with bilateral flatfeet, and 13 of them underwent double calcaneal osteotomy on both feet. The average interval between operations was approximately 16 months. Their satisfaction with the surgery on one side influenced their decision to undergo the operation on the contralateral side. Of the 18 remaining patients, 6 and 12 had surgery on their right and left feet, respectively. The mean age of the patients was 21 (range, 12 to 45) years at the time of operation. Furthermore, 21 patients were male, and 10 patients were female. The mean follow-up period was 50 (range, 25 to 133) months. The mean medial sliding was 7.6 (range, 6 to 10) mm, and the mean lateral lengthening was 8.7 (range, 5 to 11) mm.

The mean preoperative VAS and FAAM scores were 5.3±1.5 and 47.8±5.4, respectively, and these scores respectively improved to 0.1±0.3 and 91.2±3.8 after surgery (Table 1). Preoperative symptoms, including pain on the medial arch, sinus tarsi, and plantar fascia, resolved postoperatively. Only two patients complained about postoperative pain on the Achilles tendon, but it alleviated spontaneously. The active ankle dorsiflexion degree improved from 12.8±7.4 to 15.3±6.9 (Table 1). The mean ankle dorsiflexion degree in the heel cord lengthening group (24 out of 44 feet) was about 5 degrees preoperatively and decreased under 0 degrees after the osteotomy. After the heel cord was lengthened, ankle dorsiflexion was corrected to approximately 15 degrees. All patients were satisfied with the surgery, and they returned to their daily living activities without limitations.

All radiographic variables, including TNCA, AP-TMT, L-TCA, L-TMT, CPA, HAA, and HMA, were improved significantly after the surgery. Although AP-TMT and CPA showed slight deterioration at the final follow-up, the variables remained significantly different when compared to preoperative measurements (Table 2, Fig. 6). For further long-term data, we conducted additional analysis on 13 feet with follow-up periods over 60 months. The average follow-up period was 91 months, and most radiographic variables, except for L-TCA, exhibited significant improvement and maintenance until the final follow-up ($P < .001$). Although L-TCA also improved significantly ($P = .039$), it did not reach statistical significance in the post-hoc test (Table 3).

The preoperative mean dorsal elevation of the calcaneus on the CCJ was 7.0±4.9%. The value increased significantly to 19.2±5.9% at 3 months postoperatively (Table 4).

The "posterior facet obliteration sign" on the lateral view was observed (positive) in 93% cases preoperatively. This sign became invisible (negative) in 85% cases postoperatively (Fig. 1).

No wound complication, delayed union, and nonunion were observed during the follow-up period; furthermore, the tarsal joints had no obvious osteoarthritic change. One patient who underwent operations on both sides developed fatigue fractures on the fifth metatarsal bones 15 months after the surgery. These fractures were detected in routine follow-up X-rays and recovered spontaneously. The medial sliding and lateral lengthening on both feet were 9 and 10 mm, respectively. These fatigue fractures could be attributed to the overloading of the lateral ray of the patient's feet possibly because of overcorrection.

Discussion

Various surgical procedures have been used to correct flexible flatfoot deformity; however, the most effective procedure for this deformity remains controversial. In this study, we evaluated the clinical and radiological outcomes of double calcaneal osteotomy, which we exclusively performed as a bony procedure to correct the deformity of all patients. Since our indication for double calcaneal osteotomy was restricted to flexible deformity, the procedure was sufficient to correct the deformity, and additional bony procedures, including medial column procedures such as Cotton osteotomy, were unnecessary. It also substantially improved the patients' symptoms and functional scores. Moreover, each radiological variable reflecting the three-dimensional changes in flatfoot deformity was significantly enhanced postoperatively, and most of the variables were maintained until the final follow-up. We found no significant complications and degenerative changes in the tarsal joints during the follow-up period.

MDCO is commonly performed to correct the hindfoot valgus (1). However, several reports have suggested that MDCO is not fully effective in restoring complex deformities (2,4-7). Niki and colleagues reported that the L-TMT and tibiocalcaneal angle are the only radiographic variables that remarkably improve after MDCO (6). Moreover, excessive medial displacement can overcorrect the hindfoot. Conti and colleagues also demonstrated that the moderate radiographic varus (>5 mm varus moment arm on the hindfoot alignment view) after MDCO is associated with clinical outcomes inferior to those of the mild (0–5 mm) varus or residual valgus (13).

LCL is frequently performed to correct the flat foot deformity (3). Several studies have demonstrated that its radiological outcomes and sustainability over time are superior to those of MDCO (2,4,5,7). However, LCL has less or no ability to correct the hindfoot valgus compared with MDCO (5,7,14). Moreover, the overlengthening of the lateral column results in lateral foot pain and CC joint arthritis (15,16). Oh and colleagues reported that as the lateral column increasingly lengthens, the plantar pressure in the lateral aspect of the forefoot consistently increases (17). One study has suggested that the size of the graft used in the LCL procedure should be limited to 6 mm because larger grafts do not provide additional correction without damaging the long plantar ligament, possibly compromising the intrinsic stability of the foot (18). Another study has proposed that the graft size (6–8 mm) should be appropriate to avoid overlengthening and graft failure (19).

Previous studies showed the effectiveness of double calcaneal osteotomy (4,8-10). Zanolli demonstrated that LCL combined with MDCO provides superior correction and maintenance over repeated weight loading compared with MDCO alone in a cadaver model (4). However, Smith reported that although the combination of MDCO with LCL can remarkably correct deformities, this procedure increases the joint contact force, especially at the CC joint, and the ground reaction force along the lateral column (7). The authors created patient-specific computational models and performed a simulated operation, including MDCO and LCL. In their simulation, they lengthened the lateral column by 10 mm, which can be considered an overcorrection and may have led to the increased joint contact and ground reaction forces (15,17-19).

In our study, the average medial sliding (7.6 mm) in MDCO and the wedge graft size (8.7 mm) in LCL were similar or lower than the values reported previously (13,17,19). Nevertheless, we obtained favorable radiologic and functional results. The combination of MDCO and LCL may have realigned the deformity with a less extensive correction required at each operation than that of MDCO or LCL performed alone. Reducing the degree of displacement and lengthening for adequate correction may have prevented the potential risks associated with overcorrection, which could affect adjacent joints. Moreover, MDCO, which mainly recovers the hindfoot valgus, and LCL, which primarily restores forefoot abduction, appear to have a complementary relationship; thus, severe deformities may be more easily corrected by applying the combination of the two osteotomies.

In this study, both osteotomies were fixed simply with two K-wires and one screw. In comparison with plating or multiple screw fixations, our method showed fair outcomes related to surgical site complications and union rates by minimizing incision for fixation. Because the fixation was sufficiently stable, postoperative rehabilitation could be initiated early, and patients could quickly return to their daily activities. The simple fixation and early postoperative rehabilitation might also positively influence patient satisfaction.

Dorsal elevation of the calcaneus at the CCJ was observed in this study despite its temporary pin fixation. This finding is consistent with those reported previously (20-22). During the operation, we confirmed reduction of the CCJ by direct visualization via a small opening in the dorsal capsule of the CCJ. However, CCJ subluxation was identified in the follow up radiograph. Further studies are needed to identify the usefulness of the CCJ stabilization pin and exact timing to remove the pin.

This study has several limitations. Its weaknesses are inherent to its retrospective design. Our report does not involve a comparative study on MDCO or LCL alone. It also has a relatively short follow-up period.

In conclusion, double calcaneal osteotomy could be an effective procedure for a flexible flatfoot. A single screw with multiple pin fixation was sufficient for maintaining the correction and union of the calcaneus. Therefore, this method could be applied to effectively correct all abnormal components of flatfoot deformity and provide symptomatic relief and patient satisfaction.

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Tables

Table 1 Comparison of preoperative and postoperative VAS, FAAM score, range of motions (N=44 feet in 31 patients)

		Preoperative	Postoperative	*P*-value
VAS score		5.25 ± 1.52	0.11 ± 0.32	< 0.001
FAAM score		47.84 ± 5.36	91.20 ± 3.75	< 0.001
Range of motion	Ankle dorsiflexion (°)	12.73 ± 7.43	15.34 ± 6.85	0.013
	Ankle plantar flexion (°)	38.75 ± 7.91	38.74 ± 11.26	> 0.999
	Inversion (°)	33.41 ± 10.51	34.09 ± 11.41	0.672

Abbreviations: VAS, visual analog scale; FAAM, foot and ankle ability measure

Table 2 Mean values of the seven radiographic variables over time (N=44 feet in 31 patients)

Radiographic variable		Preoperative	Postoperative 3 months	Final follow-up	*P*-value[a]	Pairwise comparison[b]	
						Within group difference	
AP radiograph	TNCA (°)	28.2 ± 10.1	6.6 ± 6.1	6.7 ± 5.0	< 0.001	D1	< 0.001
						D2	> 0.999
						D3	< 0.001
	AP-TMT (°)	21.0 ± 8.8	6.7 ± 6.3	8.3 ± 6.6	< 0.001	D1	< 0.001
						D2	0.036
						D3	< 0.001
Lateral radiograph	L-TCA (°)	54.2 ± 11.5	42.7 ± 6.8	42.3 ± 6.5	< 0.001	D1	< 0.001
						D2	> 0.999
						D3	< 0.001
	L-TMT (°)	24.7 ± 11.8	5.4 ± 5.0	6.4 ± 5.5	< 0.001	D1	< 0.001
						D2	0.302
						D3	< 0.001
	CPA (°)	12.4 ± 5.1	21.4 ± 5.3	19.8 ± 5.2	< 0.001	D1	< 0.001
						D2	0.002
						D3	< 0.001
Hindfoot axial view	HAA (°)	16.8 ± 7.2	2.4 ± 4.7	1.8 ± 4.4	< 0.001	D1	< 0.001
						D2	0.266
						D3	< 0.001
	HMA (mm)	22.1 ± 7.6	3.8 ± 5.4	4.4 ± 5.5	< 0.001	D1	< 0.001
						D2	0.728
						D3	< 0.001

[a] Within group analysis

[b] Differences in the group (Pairwise comparison): Post-hoc test with Bonferroni correction was used to estimate pairwise mean difference within group (D1: preoperative vs. postoperative 3 months, D2: postoperative 3 months vs. final follow-up and D3: preoperative vs. final follow-up).

Table 3 Mean values of the seven radiographic variables over time for long-term follow-up patients (N=13 feet in 11 patients)

Radiographic variable		Preoperative	Postoperative 3 months	Final follow-up	*P*-value[a]	Pairwise comparison[b] Within group difference	
AP radiograph	TNCA (°)	27.5 ± 10.7	11.4 ± 8.3	9.9 ± 6.6	< 0.001	D1	< 0.001
						D2	0.945
						D3	< 0.001
	AP-TMT (°)	22.6 ± 9.6	10.8 ± 6.3	12.6 ± 7.0	0.001	D1	< 0.001
						D2	0.513
						D3	0.002
Lateral radiograph	L-TCA (°)	50.4 ± 15.3	43.1 ± 5.4	42.5 ± 7.1	0.039	D1	0.158
						D2	> 0.999
						D3	0.096
	L-TMT (°)	22.5 ± 14.9	6.3 ± 6.8	7.4 ± 7.6	< 0.001	D1	< 0.001
						D2	> 0.999
						D3	0.002
	CPA (°)	10.3 ± 6.1	18.7 ± 4.7	18.5 ± 5.6	< 0.001	D1	< 0.001
						D2	> 0.999
						D3	0.004
Hindfoot axial view	HAA (°)	19.4 ± 5.6	4.1 ± 2.6	2.6 ± 4.5	< 0.001	D1	< 0.001
						D2	0.521
						D3	< 0.001
	HMA (mm)	22.9 ± 9.7	6.7 ± 6.1	7.0 ± 6.3	< 0.001	D1	< 0.001
						D2	> 0.999
						D3	< 0.001

[a] Within group analysis

[b] Differences in the group (Pairwise comparison): Post-hoc test with Bonferroni correction was used to estimate pairwise mean difference within group (D1: preoperative vs. postoperative 3 months, D2: postoperative 3 months vs. final follow-up and D3: preoperative vs. final follow-up).

Table 4 Comparison of preoperative and postoperative 3 months mean percentage of dorsal subluxation of calcaneocuboid joint.

	Preoperative	Postoperative 3 months	P-value
Subluxation (%)	7.0 ± 4.9	19.2 ± 5.9	<0.001

Figures

Figure 1 “posterior facet obliteration sign” on the lateral radiographs of a patient with flatfoot. (A) Preoperative plain radiograph of the weight-bearing lateral view of the foot showing obliterated posterior talo-calcaneal articulation (*). (B) Postoperative plain radiograph of the weight-bearing lateral view of the foot showing clearly visible posterior talo-calcaneal articulation (**).

Figure 2 Postoperative plain radiograph of the lateral view of the foot showing dorsal subluxation of the calcaneus at the calcaneocuboid joint. Line A describes the total length of the articular surface of the calcaneus at the calcaneocuboid joint. Line B represents the dorsal height of the articular surface of the calcaneus above the cuboid. The equation for the percentage of calcaneocuboid joint subluxation is B/A x 100(%).

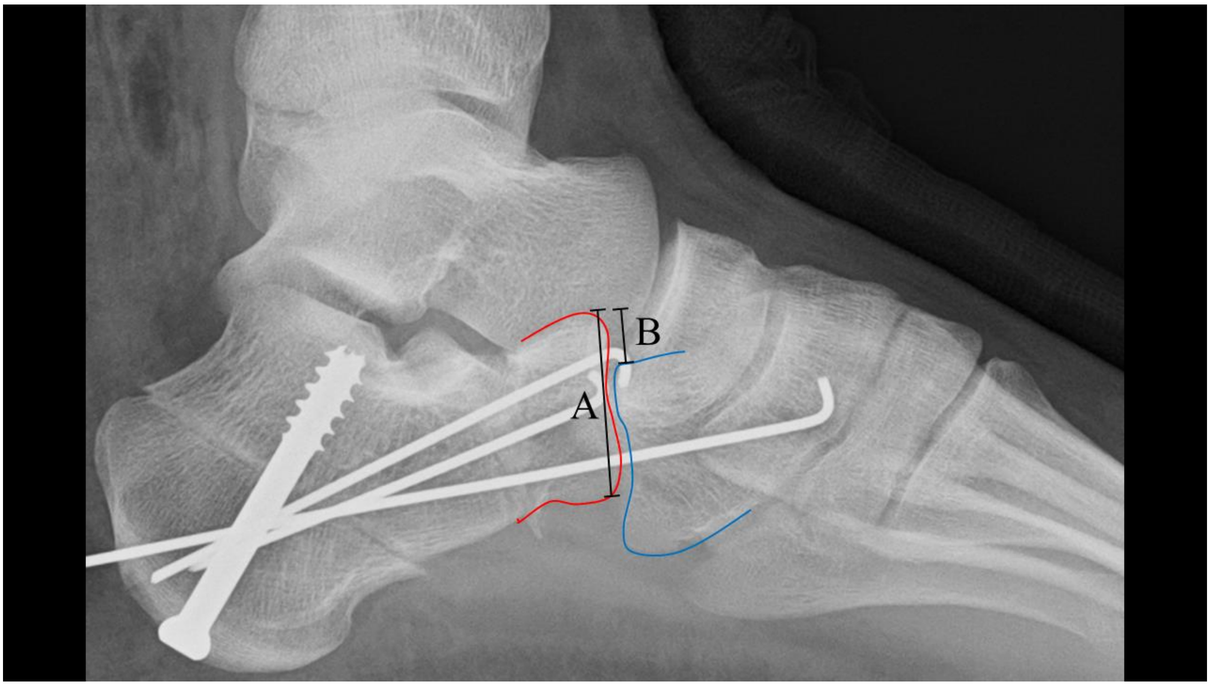


Figure 3 Preoperative photograph and immediate postoperative radiograph of a 12-year-old female patient who underwent double calcaneal osteotomy. Heel valgus (*) and flattened medial arch and painful callosity on the medial arch (**). Immediate postoperative plain lateral radiograph showing the calcaneus fixed with four K-wires without a screw because of the remaining calcaneal epiphysis.

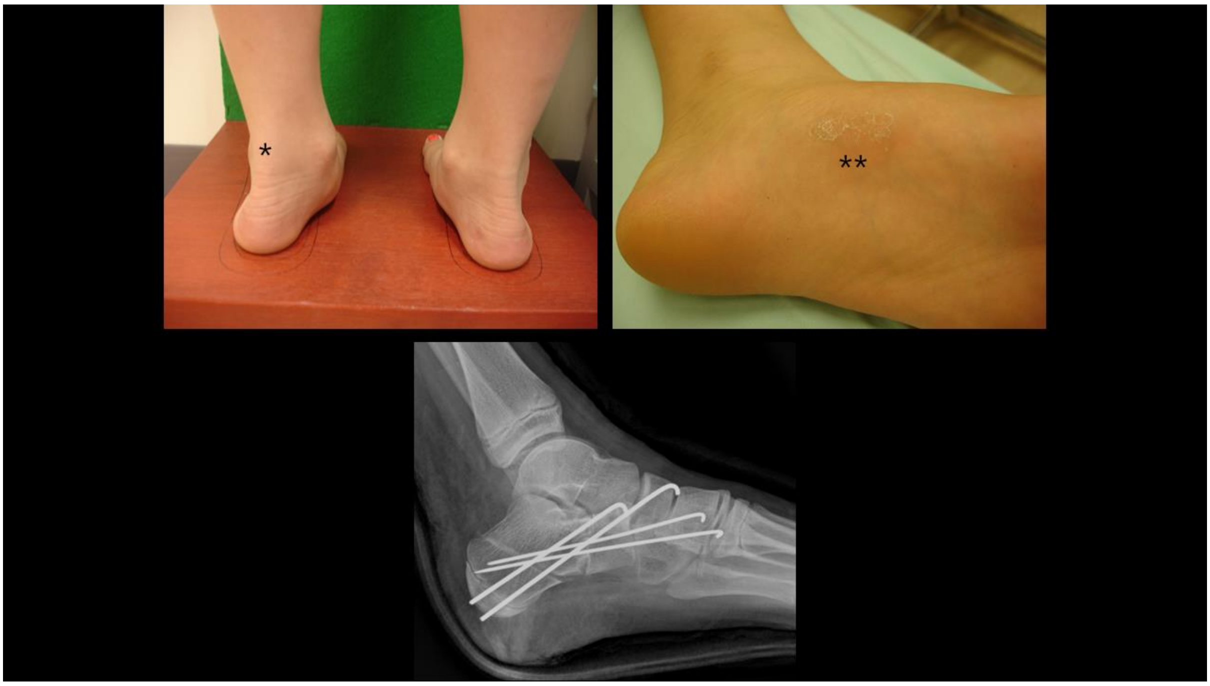


Figure 4 Intraoperative photos and illustration. (A) The temporary K-wire fixation of the calcaneocuboid joint (*) is shown. (B) Two Steinmann pins were divergently inserted on both sides of the osteotomy. (C) The osteotomy was distracted with a pin distractor, and a tricortical iliac autograft was inserted. (D) The tricortical iliac autograft was sculpted into a wedge-shaped graft. The size of the wedge was determined by the patient's condition (**). (E) K-wires were advanced to additionally stabilize the medial displacement calcaneal osteotomy (black arrow).

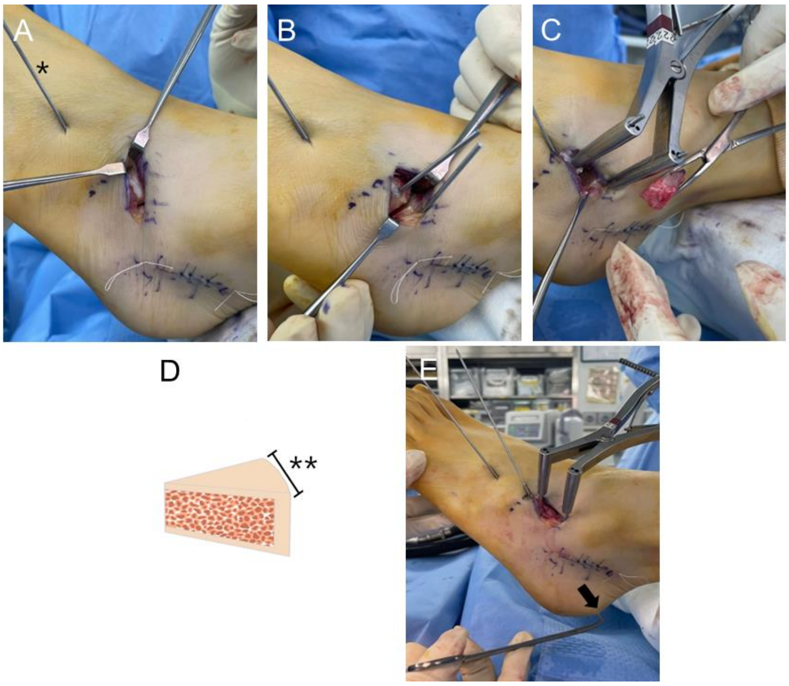


Figure 5 Preoperative and postoperative plain radiograph of the weight bearing anteroposterior, lateral, and hindfoot views of a 20-year-old female patient with a unilateral flatfoot deformity.

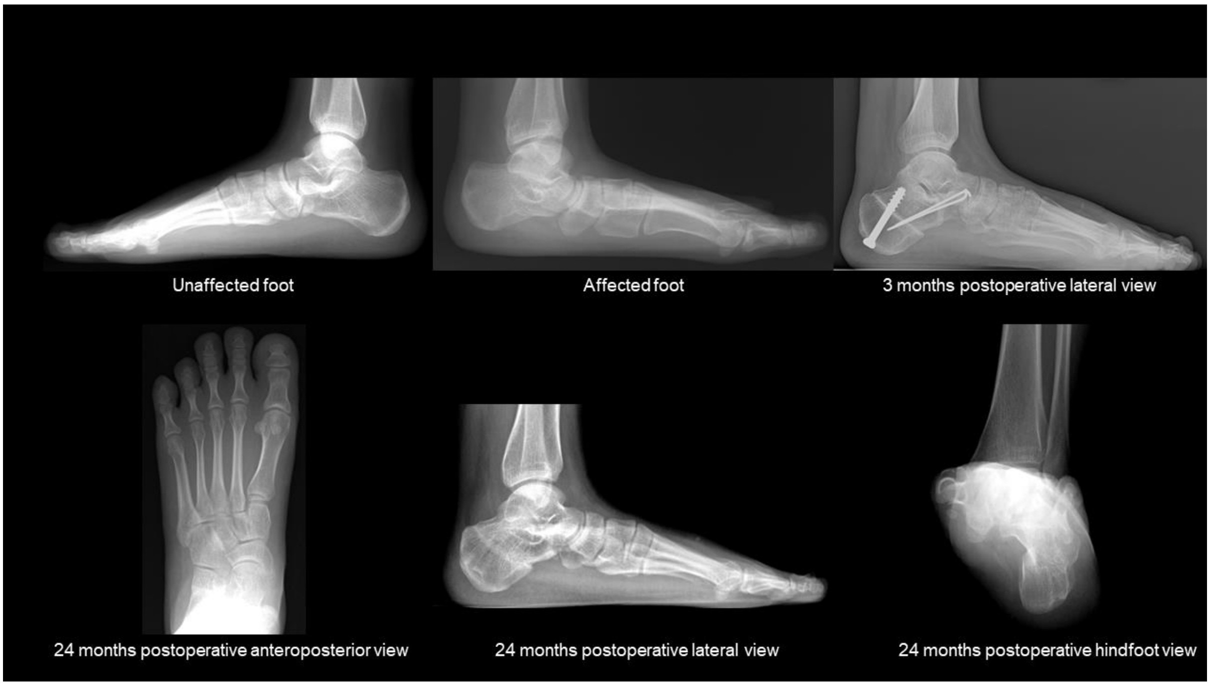
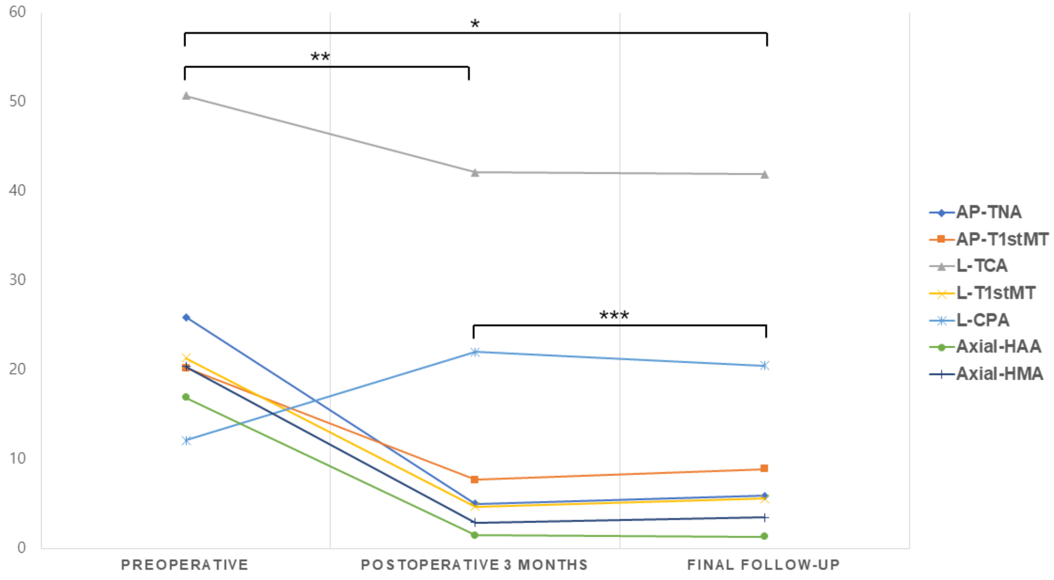


Figure 6 Mean radiologic parameters at each time point. All parameters improved significantly (p<0.05) between preoperative and 3 months postoperatively and the final follow-up (*, **). Only the lateral calcaneal pitch angle decreased significantly (p<0.05) between 3 months postoperatively and the final follow-up (***).



국문 초록

유연성 편평족을 치료하기 위해 지금까지 다양한 수술방법이 제시되어 왔으며, 그 중 종골의 내측 전위 절골술과 외측주 연장술은 가장 흔히 사용되는 수술법이다. 그러나 각각의 수술법은 한계점을 가지고 있기 때문에 이를 보완하기 위해 두 수술을 동시에 시행하는 이중 종골 절골술이 제시되었고, 본 연구는 유연성 편평족을 교정하기 위해 시행하는 이중 종골 절골술의 방사선학적 및 임상적 효과를 평가하고자 하였다.

이중 종골 절골술을 받은 31명의 환자(44례의 증상이 있는 유연성 편평족)를 평균 50개월 동안 추적 관찰하여 후향적으로 분석하였으며, 시각적 통증 평가 척도, Foot and Ankle Ability Measure(FAAM) 점수, 발목의 운동범위 및 기타 임상 정보를 의무 기록으로부터 얻을 수 있었고, 체중 부하 방사선 사진을 통해 편평족을 평가하는 여러 지표들을 측정하고, 발목 및 족근관절의 골관절염 발생을 확인하였다. 이후 각 수치들의 수술 전후 변화를 비교하였다.

임상 점수들과 편평족의 정도를 나타내는 모든 방사선적 지표들이 수술 후 유의미하게 개선되었고 최종 추시까지 악화되지 않고 유지되었음을 확인할 수 있었다. 또한 추시 기간 동안 골관절염의 발생은 확인되지 않았다.

이중 종골 절골술은 편평족 변형을 효과적이고 지속 가능하게 교정할 수 있으며, 증상 완화와 환자 만족도를 제공할 수 있는 유용한 수술법임을 확인할 수 있었다.