

Impact of Asymptomatic Flatfoot on Clinical and Radiographic Outcomes of the Modified Lapidus Procedure in Patients With Hallux Valgus

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Abstract

Background: Patients with hallux valgus commonly present with concomitant flatfoot deformity. First-ray hypermobility, among other biomechanical factors, has been suggested as a potential link between these deformities. However, not all hallux valgus patients exhibit symptoms associated with flatfoot deformity, and the necessity of correcting the asymptomatic flatfoot at the time of hallux valgus correction is unclear. We aimed to investigate the relationship between asymptomatic flatfoot and patient-reported and radiographic outcomes after the Lapidus procedure.

Methods: This study included 142 patients who underwent the Lapidus procedure for hallux valgus at a single institution. Sixty-one patients met radiographic criteria for flatfoot. No patients exhibited symptoms related to flatfoot deformity on review of clinical notes. Preoperative, minimum 1-year postoperative, and change in Patient-Reported Outcomes Measurement Information System (PROMIS) scores between asymptomatic flatfoot and control groups were compared. Radiographic outcomes including hallux valgus angle (HVA), intermetatarsal angle (IMA), Meary angle, talonavicular coverage angle (TNCA), and calcaneal pitch (CP) were compared.

Results: Preoperatively, the flatfoot group had higher BMI 22.6 vs 24.6 ($P < .01$) and IMA 15.32 vs 14.0 degrees ($P < .05$). Both groups demonstrated preoperative to postoperative improvement in PROMIS physical function ($P < .01$), pain interference ($P < .001$), pain intensity ($P < .001$), and global physical health ($P < .001$). There were no preoperative or postoperative differences in PROMIS scores between groups. Postoperatively, there were no differences in HVA or IMA between groups; however, the flatfoot group exhibited greater deformity in Meary angle, TNCA, and CP (all $P < .001$).

Conclusion: There were no significant postoperative differences in patient-reported outcomes of the Lapidus procedure between patients with and without asymptomatic flatfoot, and both groups achieved similar radiographic correction of their hallux valgus deformity. The Lapidus procedure appears to be a reasonable surgical option for hallux valgus correction in patients with asymptomatic flatfoot deformity.

Level of Evidence: Level III, retrospective cohort study.

Keywords: hallux valgus, bunionectomy, Lapidus, flatfoot, patient-reported outcomes, PROMIS

Introduction

Hallux valgus is a common progressive forefoot deformity with an estimated prevalence of 23% in the adult population.¹⁷ The etiology of hallux valgus has been attributed to various factors including hereditary predisposition, constricting footwear, and first tarsometatarsal (TMT) joint hypermobility, and patients often present with pain over the medial eminence,

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difficulty wearing shoes, or pain under the second metatarsal head.²⁴ This condition is frequently associated with flatfoot deformity, with significant radiographic relationships found between the 2 deformities in both adolescents and adults.^{2,3,12}

Not all hallux valgus patients with radiographic evidence of flatfoot deformity exhibit symptoms associated with flatfoot deformity, and there is debate on whether to correct the flatfoot deformity at the time of hallux valgus correction in these cases. In theory, the deforming forces associated with unmanaged flatfoot deformity, including increased pronation rotational force and increased medial column pressure, all act as deforming forces capable of eliciting symptoms and potentially resulting in hallux valgus recurrence.^{2,7,18} Prior studies have demonstrated that hallux valgus patients who also have an asymptomatic flatfoot have a higher recurrence rate but similar patient-reported outcomes when the hallux valgus is corrected with osteotomies.^{7,26}

Interestingly, the modified Lapidus procedure, which is the fusion of the first TMT joint, is a technique that is frequently used to correct both hallux valgus and flatfoot deformities.^{5,22} The Lapidus procedure has been found to correct not only the forefoot deformity but also the hindfoot deformity (or 3D correction) in flatfoot deformity.¹¹ Thus, it is reasonable to assume that hallux valgus patients with radiographic evidence of flatfoot deformity would benefit from the Lapidus procedure. However, few prior studies have investigated the clinical and radiographic outcomes of the Lapidus procedure in patients who meet radiographic flatfoot criteria and compared the findings to patients with a normal arch.

The aim of this study was to determine if postoperative patient-reported and radiographic outcomes of the Lapidus procedure are affected by the presence of asymptomatic flatfoot. We hypothesized that hallux valgus correction with the Lapidus procedure would be minimally affected by the presence of asymptomatic flatfoot.

Methods

Approval for this retrospective cohort study was obtained by an institutional review board (IRB)-approved foot and ankle registry steering committee at the authors' institution. Patient data including demographic information, operative reports, clinic notes, and patient-reported outcome scores were extracted from the registry database. Patients who underwent the modified Lapidus procedure between 2016 and 2020 for a diagnosis of hallux valgus by one of 10 fellowship-trained foot and ankle surgeons from a single institution were included. Patients with concomitant lesser toe, midfoot, hindfoot, or ankle procedures were excluded from the initial registry search to eliminate potential confounding variables that could affect patient-reported and radiographic outcomes. The initial registry search

yielded 232 patients. Patients were excluded if they did not have preoperative and minimum 1-year Patient Reported Outcome Measures Information System (PROMIS) scores (n=50), a minimum of 3-month radiographic follow-up (n=23), or if they had severe cavus foot deformity defined as a Meary angle less than -5 degrees and calcaneal pitch greater than 30 degrees (n=11).¹⁶ Additionally, patients with symptomatic flatfoot deformity who underwent hindfoot correction were excluded (n=6). A minimum 3-month radiographic follow-up was chosen because previous studies have demonstrated that patients undergoing the Lapidus procedure achieve full healing by 3 months, with minimal changes in radiographic parameters after this time point.^{14,22,23} The final cohort consisted of 142 patients who fulfilled the inclusion and exclusion criteria.

Patients were divided into 2 groups depending on whether they had radiographic evidence of flatfoot deformity. As described by Flores et al, patients with (1) Meary angle >4 degrees, (2) calcaneal pitch <18 degrees, and talonavicular coverage angle (TNCA) >7 degrees were allocated to the "flatfoot" group.⁴ Sixty-one patients met the criteria for this group, leaving 81 patients in the "control" group. The purpose of choosing these measurements was to include components of both longitudinal arch collapse and forefoot abduction to encompass the multiple facets of flatfoot deformity. Review of hospital records and clinic visits demonstrated that these patients did not complain of symptoms related to their flatfoot during the initial consult.

An a priori power analysis was conducted to determine adequate sample size for this study. The prevalence of flatfoot in the adult population has been estimated to be 26.6% to 37%, so the upper limit of 37% was used in the power analysis.^{19,20} The power analysis was based on achieving a minimum difference of 4.5 between groups in the PROMIS physical function score, based off of Hung et al's calculation of the minimal clinically important difference for PROMIS physical function in foot and ankle patients, with an SD of 9, an alpha of 0.05, and a power of 0.8.¹⁰ This yielded a recommended number of 51 patients in the flatfoot group and 87 patients in the normal arch, or control, group.

Surgical Techniques and Recovery

For the purposes of this study, the modified Lapidus procedure was defined as a first TMT arthrodesis. This was accomplished using an open technique and fixation with 2 cortical screws (n=116), or fixation using a cross screw and dorsomedial plate (n=20). The decision to include a modified McBride procedure, medial eminence excision, and/or Akin osteotomy was made at the surgeon's discretion. The modified McBride procedure was defined as a release of adductor hallucis and lateral capsule, and the Akin osteotomy was defined as a medial closing wedge osteotomy of

Table 1. Demographics.

	Control (n=81)	Flatfoot (n=61)	P Value ^a
Age, y, median (IQR)	52.56 (33.36, 59.69)	49.44 (34.79, 60.11)	.822
Gender, n (%)			
Female	72 (88.9)	53 (86.9)	.918
BMI, median (IQR)	22.60 (20.80, 24.60)	24.60 (22.10, 28.20)	.002
Follow-up time, mo, mean (SD)	19.37 (6.06)	18.14 (6.06)	.24

Abbreviations: BMI, body mass index; IQR, interquartile range.

^aBoldface indicates significance.

the proximal phalanx. Postoperatively, patients were non-weightbearing for 2-6 weeks depending on the fixation method. Patients progressively increased partial weight-bearing over the next 4 weeks. Patients were fully weight-bearing by 10-12 weeks.

Clinical Outcome Assessment

Clinical outcomes were assessed using the Patient Reported Outcome Measures Information System (PROMIS), a patient-reported outcome measure that uses computer adaptive testing and has been validated for use in foot and ankle patients, and validated against the Foot and Ankle Outcome Score (FAOS) in patients with hallux valgus and flatfoot deformity.^{1,8,13} Patients completed PROMIS surveys from 6 domains: physical function, pain interference, pain intensity, global physical health, global mental health, and depression. Questionnaires were completed preoperatively and at a minimum of 1 year postoperatively. Outcomes for each PROMIS scale were recorded as *t* scores, with a mean of 50 and SD of 10 representing the mean and SD of the US population. Patients with complications completed postoperative PROMIS questionnaires, and these were included in our analysis so as to not bias our results to more positive results.

Radiographic outcome assessment

Radiographic parameters including hallux valgus angle (HVA), intermetatarsal angle (IMA), Meary angle, calcaneal pitch (CP), and talonavicular coverage angle (TNCA) were measured using the Picture Archiving and Communications System by a medical student who was trained in these measurements, which have been shown to be reliable in the literature.^{15,28} The average radiographic follow-up for the study cohort was 6.6 months. Preoperative and postoperative measures were compared between the 2 groups.

Statistical Methods

Descriptive statistics were reported as median and interquartile range for continuous variables and count and percentage for categorical variables. The assumption of normality was

assessed using Shapiro Wilk test. Differences between groups were tested using Mann Whitney *U* tests for continuous variables and Pearson chi-square test for categorical variables. The paired *t* test was used to test for differences between preoperative and postoperative radiographs between groups, and confirmed with the Wilcoxon signed rank test for nonparametric data. For PROMIS *t* scores, differences between groups were evaluated using least squares means (LS-means) from linear models while adjusting for patient demographics and preoperative PROMIS *t* scores. Specifically, the LS-means for postoperative PROMIS scores were adjusted for age, sex, BMI, and preoperative *t* score, whereas LS-means for preoperative to postoperative changes in PROMIS scores were adjusted for age, sex, and BMI. LS-means were reported with CIs and with type II analysis of variance test *P* values from the linear models. Paired *t* test was used to test for differences between preoperative and postoperative radiographs and PROMIS *t* scores and confirmed with the Wilcoxon signed rank test for nonparametric data. Statistical significance was established at a *P* value of .05. All analyses were performed on R: A Language and Environment for Statistical Computing (R Core Team 2021, Vienna, Austria) with emmeans and car packages.

Results

Demographics

The flatfoot group had a significantly higher BMI when compared to the control group ($P < .01$). There were no significant differences in age, gender distribution, or follow-up time between the 2 groups (Table 1).

Clinical Outcomes

Both cohorts demonstrated significant preoperative to postoperative improvement in the PROMIS physical function (flatfoot $P < .01$, control $P < .001$), pain interference (both $P < .001$), pain intensity (both $P < .001$), and global physical health domains (both $P < .001$) (Table 2). There were no significant improvements in the global mental health and depression domains.

Table 2. Preoperative to Postoperative Improvement in PROMIS Scores.^a

	Control (n=81)	P Value ^b	Flatfoot (n=61)	P Value ^b
Physical function	5.65 (3.57, 7.73)	<.001	3.26 (0.80, 5.72)	.01
Pain interference	-8.09 (-10.12, -6.06)	<.001	-7.80 (-9.92, -5.67)	<.001
Pain intensity	-8.35 (-10.43, -6.26)	<.001	-8.26 (-10.48, -6.04)	<.001
Global physical health	5.32 (3.34, 7.30)	<.001	3.93 (1.84, 6.01)	<.001
Global mental health	0.26 (-1.88, 2.4)	.81	0.17 (-1.74, 2.07)	.86
Depression	-0.66 (-2.42, 1.10)	.46	-0.41 (-1.93, 1.12)	.60

Abbreviation: PROMIS, Patient-Reported Outcomes Measures Information System.

^aAll data are reported as mean (95% CI) of PROMIS *t* scores. Boldface indicates significance.

^b*P* value of preoperative to postoperative improvement within groups.

Table 3. Preoperative and Postoperative PROMIS Scores.^a

	Control (n=81)	Flatfoot (n=61)	P Value
Preoperative			
Physical function	49.4 (47.9, 50.9)	49.9 (48.0, 51.8)	.68
Pain interference	55.1 (53.6, 56.7)	54.5 (53.0, 56.1)	.58
Pain intensity	46.1 (44.5, 47.6)	46.4 (44.9, 47.9)	.75
Global physical health	49.9 (48.1, 51.7)	50.2 (48.6, 51.8)	.84
Global mental health	49.9 (48.1, 51.7)	54.4 (52.4, 56.3)	.90
Depression	46.8 (45.2, 48.5)	46.8 (45.2, 48.5)	.99
Postoperative^b			
Physical function	53.3 (50.9, 55.8)	51.7 (49.0, 54.5)	.27
Pain interference	48.1 (45.8, 50.4)	48.0 (45.4, 50.6)	.94
Pain intensity	38.2 (36.0, 40.4)	38.2 (35.7, 40.7)	.99
Global physical	53.6 (51.2, 56.0)	52.6 (50.0, 55.3)	.50
Global mental	54.7 (52.2, 57.2)	54.7 (51.9, 57.5)	.98
Depression	46.4 (44.5, 48.4)	47.0 (44.8, 49.2)	.65

Abbreviations: PROMIS, Patient-Reported Outcomes Measures Information System.

^aAll data reported as mean (SD) in degrees.

^bLeast squares means adjusting for age, gender, body mass index, and preoperative PROMIS score.

There were no significant differences in preoperative PROMIS scores or adjusted postoperative PROMIS scores between the flatfoot group and the control group (Table 3).

Radiographic Outcomes

Preoperative IMA, Meary angle, and TNCA were significantly larger in the flatfoot group (all $P < .05$), and CP was significantly smaller in the flatfoot group (all $P < .001$) (Table 4). Postoperatively, Meary angle and TNCA were significantly larger in the flatfoot group, and CP was significantly smaller in the flatfoot group ($P < .001$) (Table 4). Both groups demonstrated significant improvement in all radiographic parameters, except for CP in the control group (Table 5).

Complications

Three patients in the flatfoot group experienced symptomatic recurrence of their bunion during the time of follow-up.

Table 4. Preoperative and Postoperative Radiographic Measures.^a

	Control (n=81)	Flatfoot (n=61)	P Value
Preoperative			
HVA	28.6 (22.4, 32.4)	29.3 (24.1, 34.9)	.19
IMA	14.0 (12.4, 15.2)	15.2 (13.0, 16.8)	.016
Meary angle	1.4 (-1.8, 3.7)	10.6 (8.3, 14.1)	<.001
CP	19.3 (17.7, 21.3)	14.8 (12.7, 16.4)	<.001
TNCA	14.9 (9.8, 19.5)	20.9 (16.6, 24.7)	<.001
Postoperative			
HVA	8.1 (4.5, 12.6)	7.2 (4.8, 12.9)	.9
IMA	5.1 (3.8, 7.1)	6.2 (4.2, 7.6)	.079
Meary angle	-0.1 (-1.9, 4.3)	8.3 (6.0, 10.7)	<.001
CP	19.6 (17.4, 21.4)	15.1 (12.7, 16.6)	<.001
TNCA	14.3 (8.8, 19.2)	19.2 (13.8, 24.8)	<.001

Abbreviations: CP, calcaneal pitch; HVA, hallux valgus angle; IMA, intermetatarsal angle; TNCA, talonavicular coverage angle.

^aAll data reported as median (interquartile range) in degrees. Boldface indicates significance.

Table 5. Preoperative to Postoperative Change in Radiographic Measures.^a

	Mean Change	Lower 95% CI	Upper 95% CI	P Value
Flatfoot				
HVA	-22.07	-24.28	-19.86	<.001
IMA	-9.16	-9.95	-8.36	<.001
Meary angle	-2.78	-3.88	-1.69	<.001
CP	0.41	0.031	0.79	.034
TNCA	-2.19	-3.57	-0.80	.0024
Control				
HVA	-20.01	-21.71	-18.31	<.001
IMA	-8.72	-9.32	-8.12	<.001
Meary angle	-0.95	-1.84	-0.061	.036
CP	-0.014	-0.44	0.41	.95
TNCA	-0.96	-1.81	-0.10	.029

Abbreviations: HVA, hallux valgus angle; IMA, intermetatarsal angle; CP, calcaneal pitch; TNCA, talonavicular coverage angle.

^aAll data are reported in degrees. Boldface indicates significance.

However, these patients did not undergo a revision Lapidus procedure. One patient in the control group had nonunion of their first TMT fusion, and a revision Lapidus procedure was performed that led to union of fusion site. Three patients in the flatfoot group and 6 patients in the control group experienced painful hardware and underwent removal of hardware, which led to resolution of their symptoms.

Discussion

This was the first study to investigate the impact of asymptomatic flatfoot on outcomes of the modified Lapidus procedure in hallux valgus patients. Both groups experienced satisfactory correction of their hallux valgus demonstrated by their improvements in HVA and IMA. There were no significant differences in postoperative PROMIS scores or improvements in PROMIS scores between the flatfoot and control groups. All radiographic parameters assessing flatfoot deformity improved after Lapidus procedure, which may partially explain the equivalent clinical outcomes between groups found in this study.

Although flatfoot deformity is frequently observed in radiographic evaluation of hallux valgus patients, whether these cases should be corrected at the time of hallux valgus correction is controversial, especially in the absence of flatfoot symptoms. Prior studies have explored the relationship between asymptomatic flatfoot, patient-reported outcomes, and bunion recurrence following various osteotomies.^{3,7,26} Catani et al³ found that their case series of 14 patients with hallux valgus and asymptomatic flatfoot undergoing percutaneous distal metatarsal osteotomy and exostectomy experienced significant improvement in American Orthopaedic

Foot & Ankle Society (AOFAS) function and pain scores; however, these postoperative scores were lower than those reported in the literature for percutaneous bunionectomy. On the other hand, Tay et al²⁶ found that there were no associations between the degree of flatfoot deformity and pain VAS, AOFAS, or SF-36 scores in patients who underwent scarf osteotomy. They also found no significant differences in postoperative radiographic outcomes between patients with and without flatfoot.²⁶

When compared to the osteotomies for hallux valgus correction, the Lapidus procedure more directly addresses the flatfoot deformity along with hallux valgus by correcting the height of the metatarsal and stabilizing the medial arch. The Lapidus procedure is an important component of flatfoot reconstruction, and it has been shown to lead to adequate correction of hindfoot alignment, even when used in isolation for correction of flatfoot deformity.^{6,11,27} Therefore, we hypothesized that hallux correction through Lapidus procedure in asymptomatic flatfoot deformity patients would exhibit comparable postoperative clinical outcomes to control groups even without concomitant flatfoot correction, and this was the case in our cohort of patients. We believe our findings may be explained by the versatility of the Lapidus procedure and its documented use for flatfoot deformity in addition to hallux valgus, and its ability to radiographically correct arch parameters.

Radiographically, there was significant improvement and no postoperative differences between groups in postoperative HVA and IMA, showing that the presence of flatfoot did not affect the ability of the Lapidus procedure to achieve adequate and similar correction of the bunion deformity. In addition, the flatfoot group exhibited improvement in all radiographic parameters. These findings may be explained by the demonstrated capability of the Lapidus procedure to address the first ray mobility seen in hallux valgus and assist with stabilization of the medial column during flatfoot reconstruction for patients with symptomatic flatfoot.²⁷ The medial column stabilization effect of the Lapidus procedure may address parts of the asymptomatic flatfoot deformity in our flatfoot cohort, which can explain the significant correction of Meary angle, TNCA, and CP. However, despite the statistically significant improvement in these parameters, the magnitude of improvement was small (median 2.3 degrees in Meary angle, median 0.3 degrees in TNCA, and median 1.7 degrees in CP), indicating that these changes may not be clinically significant. Additionally, the flatfoot group did not reach the values of control group postoperatively, which suggests the limited ability of isolated Lapidus in correcting flatfoot deformity. Thus, even though we have observed comparable outcomes in this series, possible future symptomatic development of associated flatfoot deformity should be explained to patients at the time of consultation, because of its progressive nature.¹²

This study has several limitations. Because of the retrospective nature of this study, we were unable to physically examine all patients and ask about related symptoms to rule out symptomatic deformity with certainty, leaving room for potential bias in the results. Patients may have had more minor symptoms that they did not report at their visits. However, on review of clinical notes of these patients, there was no evidence of flatfoot-related symptoms in their documented history or physical examination. The exclusion of patients with lesser toe surgery may limit the severity of hallux valgus to more moderate cases; however, the presence of lesser toe procedures may negatively affect PROMIS scores and confound the results.²¹ Additionally, radiographic outcomes are limited by single-rater measurements and short-term follow-up of 3 months. However, previous studies have demonstrated that patients undergoing the Lapidus procedure demonstrate full healing by 3 months, with minimal changes in radiographic parameters after this time point.^{14,22,23} Because the study was slightly underpowered, we may have missed differences in PROMIS scores that would have been present if the sample size was larger. However, not enough patients that met the inclusion and exclusion criteria could be found through the registry database to meet this requirement of 51 patients in the flatfoot group, and 87 patients in the control group. There was also a significant difference in BMI between cohorts, and while associations between BMI and flatfoot have been found in the literature, the retrospective nature of this study prevents us from making any conclusions about this because of potential confounding factors leading to this result.^{9,25} The difference in BMI could also limit the conclusions made in this study. Finally, the inclusion of 10 surgeons in this study can limit our results due to differences in surgical technique and postoperative protocols between surgeons, which could affect outcomes. However, the inclusion of multiple surgeons may also make the findings more generalizable.

Although this study examined some aspects of the relationship between the Lapidus procedure, flatfoot deformity, and clinical and radiographic outcomes, there is much to be explored to fully understand how hallux valgus and flatfoot deformity are connected, and the role of specific procedures in addressing varying degrees of these deformities. A similar study with long-term follow-up can be done to understand the lasting effects of the Lapidus procedure in patients with flatfoot deformity. Other future extensions of this study can include comparisons between the Lapidus procedure and osteotomies such as the Scarf or the percutaneous distal chevron and Akin osteotomies in treating hallux valgus in patients with radiographic flatfoot deformity. Additionally, the use of pedographs and plantar pressures can aid in evaluating the gait mechanics of patients who underwent the Lapidus procedure, and examine if there are any postoperative differences in those with and without flatfoot deformity.

Conclusion

The use of the modified Lapidus procedure in patients with asymptomatic flatfoot resulted in comparable clinical outcomes to patients with normal foot alignment, as well as improvements in radiographic arch parameters and hallux valgus parameters in this short-term follow-up study. These results suggest that this procedure is a reasonable surgical option for hallux valgus correction in patients with asymptomatic, nonpainful flatfoot deformity and that an average of 1.5 years' follow-up was not associated with an increase in radiographic signs of flatfoot deformity.

Ethical approval

Ethical approval for this study was obtained from the Foot and Ankle Registry Steering Committee of the authors' institution (IRB 2013-038).





Declaration of Conflicting Interests

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