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Research Article

First Metatarsal Shortening and Sesamoid Position as Predictors of Postoperative Metatarsalgia After Hallux Valgus Surgery

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ABSTRACT

Background: To evaluate whether the presence of metatarsalgia at final postoperative follow-up after hallux valgus surgery is associated with preoperative clinical and radiographic parameters together with postoperative first metatarsal shortening and sesamoid position.

Methods: This retrospective cohort study included 144 patients treated with distal chevron osteotomy combined with the McBride procedure between 2018 and 2023. Preoperative clinical and radiographic parameters, postoperative first metatarsal shortening, and sesamoid position were analyzed. Univariate and multivariate logistic regression analyses were performed to identify independent predictors. Model performance was assessed using calibration and discrimination metrics, and receiver operating characteristic analysis was used to determine optimal cut-off values.

Results: Metatarsalgia was present at the final postoperative follow-up examination in 63 patients (43.8%). In the clinically adjusted multivariable analysis, first metatarsal shortening (odds ratio [OR]=1.92, 95% confidence interval [CI]: 1.21–3.04, p=0.005), postoperative sesamoid position score (OR=3.00, 95% CI: 1.13–7.98, p=0.028), diabetes mellitus (OR=11.20, 95% CI: 2.70–46.46, p<0.001), and smoking status (OR=9.98, 95% CI: 3.01–33.09, p<0.001) were independently associated with metatarsalgia at final postoperative follow-up.

The final model showed high apparent classification performance (Nagelkerke R^2=0.670; accuracy=89.4%; sensitivity=85.0%; specificity=92.6%), although the significant Hosmer–Lemeshow test indicated that model calibration should be interpreted cautiously. A first metatarsal shortening threshold of ≥4.2 mm showed high specificity (96.3%) but moderate sensitivity (57.1%) for the presence of metatarsalgia at final postoperative follow-up, whereas a postoperative sesamoid position threshold of ≥1 grade showed high sensitivity (90.5%) but limited specificity (51.9%).

Conclusion: First metatarsal shortening and postoperative sesamoid position were independently associated with the presence of metatarsalgia at final follow-up after hallux valgus surgery. Because most patients had preoperative metatarsalgia, these findings should not be interpreted as demonstrating newly developed transfer metatarsalgia in all symptomatic patients. Preservation of first ray length and adequate sesamoid reduction may help optimize clinical outcomes. Further prospective studies are needed.

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Introduction

Hallux valgus is one of the most common forefoot deformities in the adult population and is associated with pain, functional impairment, and reduced quality of life. Surgical treatment aims to correct the deformity, relieve pain, and improve function; however, postoperative complications, particularly metatarsalgia, may adversely affect clinical outcomes (Cho et al., 2025; Dias et al., 2024).

Postoperative metatarsalgia is a frequent complication following hallux valgus surgery and is generally associated with alterations in the biomechanics of the first ray. In particular, changes in first metatarsal length have been shown to affect plantar load distribution, leading to load transfer to the lateral metatarsal heads (Geng et al., 2019; Lopez et al., 2024; Wong et al., 2023). These mechanical alterations are considered a primary mechanism in the development of transfer metatarsalgia (Chong et al., 2022). The effect of first metatarsal shortening on metatarsalgia has been investigated in several studies, demonstrating that the risk of this complication increases beyond certain threshold values of shortening (Justiniano et al., 2022; Ma, 2024). However, not only metatarsal length changes but also sagittal plane displacement and alterations in load distribution may influence clinical outcomes (Lopez et al., 2024). The position of the sesamoid complex also plays a critical role in the pathomechanics of hallux valgus deformity. The degree of postoperative sesamoid reduction may affect first metatarsophalangeal joint biomechanics and load transmission (Hwang et al., 2023; Skweres et al., 2019). Inadequate sesamoid reduction has been associated with deformity recurrence and suboptimal functional outcomes (Lewis et al., 2024a; Lewis et al., 2024b). Furthermore, sesamoid alignment has been shown to correlate with intra-articular pathology and biomechanical imbalance (Skweres et al., 2019).

Comparative studies and systematic reviews evaluating different surgical techniques for hallux valgus have demonstrated that postoperative outcomes depend not only on the degree of deformity correction but also on the final biomechanical alignment achieved (Cho et al., 2025; Dias et al., 2024). However, the majority of existing studies focus either on preoperative deformity parameters or on isolated radiographic measurements.

In this context, studies evaluating the combined role of preoperative parameters and postoperative structural changes in predicting postoperative metatarsalgia remain limited. In particular, investigations assessing both first metatarsal length changes and sesamoid position, along with their comparative predictive value, are scarce (Karagoz et al., 2025; Rossi et al., 2025).

Therefore, the aim of this study was to evaluate whether the presence of metatarsalgia at final postoperative follow-up after hallux valgus surgery was associated with preoperative clinical and radiographic parameters together with postoperative first metatarsal shortening and sesamoid position. Additionally, we aimed to compare the relative contributions of these parameters in relation to metatarsalgia status at final postoperative follow-up

Materials and Methods

Study Design and Patient Selection

This retrospective cohort study was approved by the Aksaray University Health Sciences Scientific Research Ethics Committee on August 14, 2025 (Decision No: 2025/160; Protocol No: SAGETİK 2025-94).

Patients who underwent surgical treatment for hallux valgus deformity between January 2018 and December 2023 at a single center were retrospectively reviewed. All patients were treated with distal chevron osteotomy combined with the McBride procedure. The inclusion criteria were as follows: (1) symptomatic hallux valgus deformity, (2) surgical treatment using distal chevron osteotomy combined with the McBride procedure, (3) a minimum of 12 months of clinical and radiographic follow-up, and (4) availability of preoperative and postoperative weight-bearing radiographs sufficient for assessment of the primary radiographic parameters. The exclusion criteria were as follows: (1) prior forefoot surgery, (2) rheumatoid arthritis or neuromuscular disease, (3) trauma-related deformity, and (4) incomplete clinical or radiographic data. A total of 144 patients met the eligibility criteria and were included in the study.

Surgical Technique

All patients underwent a standard distal chevron metatarsal osteotomy combined with the McBride soft tissue procedure. The osteotomy was performed in a V-shaped configuration at the distal metatarsal region, and the distal fragment was laterally translated. Medial eminence resection was performed, and capsular plication was added when necessary. All procedures were carried out by the same surgical team following consistent technical principles.

Clinical and Radiographic Assessment

Clinical and radiographic evaluations were performed preoperatively and at the final follow-up. Clinical assessment included the American Orthopaedic Foot and Ankle Society (AOFAS) score and the Visual Analog Scale (VAS) for pain. Radiographic evaluation was performed using standardized weight-bearing anteroposterior foot radiographs. The following parameters were measured: hallux valgus angle (HVA), intermetatarsal angle (IMA), distal metatarsal articular angle (DMAA), first metatarsal length (mm), and sesamoid position. Sesamoid position was graded according to the Hardy–Clapham classification. First metatarsal shortening was calculated as the difference between preoperative and postoperative length (in millimeters). All radiographic measurements were independently assessed by two orthopedic surgeons. Interobserver reliability for the continuous radiographic measurements, including angular and linear measurements, was evaluated using the intraclass correlation coefficient (ICC).

Outcome Definition

The primary outcome was the presence of metatarsalgia at the final postoperative outpatient follow-up examination. Postoperative metatarsalgia was defined as pain localized to the plantar aspect of the lesser metatarsal head region, corresponding to the second through fifth metatarsal heads, during weight-bearing or walking. The diagnosis was based on both patient-reported symptoms and tenderness detected in the corresponding plantar region on physical examination. Metatarsalgia was recorded as present or absent at the final follow-up visit; symptom duration or persistence over a predefined time interval was not used as a diagnostic criterion.

Statistical Analysis

Statistical analyses were performed using R statistical software, version 4.6.0 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were summarized as mean ± standard deviation, and categorical variables as counts and percentages. Comparisons between patients with and without metatarsalgia at final postoperative follow-up were performed using the Wilcoxon rank-sum test for continuous variables and Pearson's chi-square test or Fisher's exact test for categorical variables, as appropriate.

Univariate logistic regression analysis was performed to identify variables associated with the presence of metatarsalgia at final postoperative follow-up. A clinically adjusted multivariable logistic regression model was constructed including the principal postoperative structural variables of interest, namely first metatarsal shortening and postoperative sesamoid position score, together with diabetes mellitus, smoking status, and preoperative metatarsalgia status because of their clinical relevance and potential confounding effects. Missing values were present for diabetes mellitus and preoperative distal metatarsal articular angle in three patients. No imputation was performed. Univariate analyses involving these variables were conducted using available-case data. Because diabetes mellitus was included in the clinically adjusted multivariable model, multivariable analysis was performed using complete-case data from 141 patients. An extended model additionally including age and body mass index (BMI) was evaluated; however, these variables were not retained in the final model because their inclusion did not improve model fit, as assessed by the Akaike Information Criterion and likelihood ratio test. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported.

Model performance was assessed using the Akaike Information Criterion, Nagelkerke R^2, Cox–Snell R^2, and the Hosmer–Lemeshow goodness-of-fit test. Classification performance was evaluated using accuracy, sensitivity, and specificity at a predicted probability threshold of 0.50.
Receiver operating characteristic (ROC) curve analysis was performed to evaluate the classification performance of individual radiographic variables in relation to metatarsalgia status at final postoperative follow-up. Optimal cut-off values were determined using the Youden index. Correlation between first metatarsal shortening and postoperative VAS score was evaluated using Spearman's rank correlation coefficient. A two-sided p-value <0.05 was considered statistically significant.

Results

A total of 144 patients who underwent chevron osteotomy combined with the McBride procedure for hallux valgus deformity were included. Baseline demographic and clinical characteristics are presented in Table 1. The cohort consisted of 123 women (85.4%) and 21 men (14.6%), with a mean age of 55.1 ± 17.2 years (range, 20–79). The mean BMI was 27.4 ± 5.4 kg/m^2. Surgery was performed on the left foot in 63 patients (43.8%) and on the right foot in 81 patients (56.3%). Smoking was present in 45 patients (31.3%), and diabetes mellitus in 33 patients (23.4%). Preoperative metatarsalgia was observed in 132 patients (91.7%). The mean follow-up duration was 41.2 ± 17.5 months. Preoperative and postoperative clinical and radiographic measurements are summarized in Table 2.

At the final postoperative follow-up examination, metatarsalgia was present in 63 patients (43.8%) and absent in 81 patients (56.3%). Patients with metatarsalgia demonstrated significantly greater first metatarsal shortening (4.2 ± 1.9 mm vs 2.6 ± 1.0 mm), higher postoperative sesamoid position values, greater changes in sesamoid position, and higher postoperative VAS scores (all p<0.001). Univariate comparisons also showed significant differences in age (p=0.001), smoking status (p<0.001), and diabetes mellitus (p<0.001). No significant differences were observed for BMI (p=0.073) or sex (p>0.999). Detailed comparisons are presented in Table 3.

In univariate analysis, first metatarsal shortening (OR=2.11, 95% CI: 1.61–2.89, p<0.001), postoperative sesamoid position (OR=7.00, 95% CI: 3.63–15.3, p<0.001), age (OR=1.03, 95% CI: 1.01–1.05, p=0.009), smoking (OR=6.33, 95% CI: 2.95–14.4, p<0.001), and diabetes mellitus (OR=26.0, 95% CI: 8.47–114, p<0.001) were significantly associated with postoperative metatarsalgia. BMI (p=0.068), preoperative metatarsalgia (p=0.184), and preoperative sesamoid position (p=0.585) were not significant (Table 4). Interobserver reliability for the continuous radiographic measurements was excellent, with a mean ICC of 0.89 (95% CI: 0.86–0.92).

Table 1. Baseline demographic and clinical characteristics of the study population.

Characteristic	Overall, N = 144
Age, years	55.1 ± 17.2 (20.0–79.0)
Sex, n (%)	
Female	123 (85.4)
Male	21 (14.6)
Body mass index, kg/m^2	27.4 ± 5.4 (19.0–45.0)
Operated side, n (%)	
Left	63 (43.8)
Right	81 (56.3)
Preoperative metatarsalgia, n (%)	
Absent	12 (8.3)
Present	132 (91.7)
Smoking status, n (%)	
Nonsmoker	99 (68.8)
Smoker	45 (31.3)
Diabetes mellitus, n (%)	
Absent	108 (76.6)
Present	33 (23.4)
Missing data	3
Follow-up duration, months	41.2 ± 17.5 (17.0–78.0)

Continuous variables are presented as mean ± standard deviation (range), and categorical variables as number (percentage). Percentages for diabetes mellitus were calculated using available data (n=141) because data were missing in three patients.

Table 2. Preoperative and final postoperative follow-up clinical and radiographic measurements.

Characteristic	Preoperative, N = 144	Final postoperative follow-up, N = 144
HVA, °	30.9 ± 5.6	19.4 ± 5.9
IMA, °	13.7 ± 2.0	10.3 ± 1.7
DMAA, °	22.7 ± 4.8	18.5 ± 5.5
First metatarsal length, mm	70.7 ± 3.6	67.5 ± 4.4
First metatarsal shortening, mm	—	3.3 ± 1.7
AOFAS score	49.8 ± 13.8	82.9 ± 14.2
Sesamoid position, n (%)		
Normal	0 (0.0)	48 (33.3)
Mild	12 (8.3)	72 (50.0)
Moderate	90 (62.5)	24 (16.7)
Severe	42 (29.2)	0 (0.0)
VAS score, n (%)		
0	0 (0.0)	66 (45.8)
1	0 (0.0)	30 (20.8)
2	3 (2.1)	27 (18.8)
3	9 (6.3)	3 (2.1)
4	9 (6.3)	9 (6.3)
5	27 (18.8)	6 (4.2)
6	36 (25.0)	3 (2.1)
7	27 (18.8)	0 (0.0)
8	21 (14.6)	0 (0.0)
9	12 (8.3)	0 (0.0)
Metatarsalgia status, n (%)		
Absent	12 (8.3)	81 (56.3)
Present	132 (91.7)	63 (43.8)

Continuous variables are presented as mean ± standard deviation, and categorical variables as number (percentage). HVA, hallux valgus angle; IMA, intermetatarsal angle; DMAA, distal metatarsal articular angle; AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analog scale. "—" indicates that the parameter is not applicable at the preoperative assessment. Missing data were present for preoperative DMAA in three patients.

Table 3. Comparison of patients according to metatarsalgia status at final postoperative follow-up.

Characteristic	Overall, N = 144	Metatarsalgia absent, N = 81	Metatarsalgia present, N = 63	p-value
Age, years	55.1 ± 17.2	51.8 ± 16.6	59.5 ± 17.1	0.001
Sex, n (%)				>0.999
Female	123 (85.4)	69 (85.2)	54 (85.7)	
Male	21 (14.6)	12 (14.8)	9 (14.3)	
Body mass index, kg/m^2	27.4 ± 5.4	26.6 ± 4.4	28.3 ± 6.3	0.073
Smoking status, n (%)				<0.001
Nonsmoker	99 (68.8)	69 (85.2)	30 (47.6)	
Smoker	45 (31.3)	12 (14.8)	33 (52.4)	
Diabetes mellitus, n (%)				<0.001
Absent	108 (76.6)	78 (96.3)	30 (50.0)	
Present	33 (23.4)	3 (3.7)	30 (50.0)	
Missing data	3	0	3	
Follow-up duration, months	41.2 ± 17.5	37.2 ± 16.8	46.3 ± 17.3	<0.001

Characteristic	Overall, N = 144	Metatarsalgia absent, N = 81	Metatarsalgia present, N = 63	p-value
Preoperative hallux valgus angle, °	30.9 ± 5.6	29.4 ± 4.9	32.8 ± 5.9	<0.001
Preoperative intermetatarsal angle, °	13.7 ± 2.0	13.5 ± 1.9	14.0 ± 2.2	0.037
Preoperative distal metatarsal articular angle, °	22.7 ± 4.8	22.6 ± 4.1	22.7 ± 5.6	0.823
Missing data	3	0	3	
Preoperative sesamoid position, n (%)				0.003
Mild	12 (8.3)	3 (3.7)	9 (14.3)	
Moderate	90 (62.5)	60 (74.1)	30 (47.6)	
Severe	42 (29.2)	18 (22.2)	24 (38.1)	
Preoperative first metatarsal length, mm	70.7 ± 3.6	70.5 ± 3.4	71.0 ± 3.9	0.198
Preoperative AOFAS score	49.8 ± 13.8	55.6 ± 9.1	42.3 ± 15.2	<0.001
Preoperative VAS score, n (%)				<0.001
2	3 (2.1)	0 (0.0)	3 (4.8)	
3	9 (6.3)	6 (7.4)	3 (4.8)	
4	9 (6.3)	6 (7.4)	3 (4.8)	
5	27 (18.8)	21 (25.9)	6 (9.5)	
6	36 (25.0)	33 (40.7)	3 (4.8)	
7	27 (18.8)	12 (14.8)	15 (23.8)	
8	21 (14.6)	3 (3.7)	18 (28.6)	
9	12 (8.3)	0 (0.0)	12 (19.0)	
Final postoperative hallux valgus angle, °	19.4 ± 5.9	18.2 ± 5.1	21.1 ± 6.5	<0.001
Final postoperative intermetatarsal angle, °	10.3 ± 1.7	10.3 ± 1.4	10.4 ± 2.0	0.829
Final postoperative distal metatarsal articular angle, °	18.5 ± 5.5	18.6 ± 3.9	18.4 ± 7.0	0.901
Final postoperative sesamoid position, n (%)				<0.001
Normal	48 (33.3)	42 (51.9)	6 (9.5)	
Mild	72 (50.0)	36 (44.4)	36 (57.1)	
Moderate	24 (16.7)	3 (3.7)	21 (33.3)	
Final postoperative first metatarsal length, mm	67.5 ± 4.4	67.8 ± 3.6	67.1 ± 5.2	0.705
First metatarsal shortening, mm	3.3 ± 1.7	2.6 ± 1.0	4.2 ± 1.9	<0.001
Final postoperative AOFAS score	82.9 ± 14.2	91.0 ± 8.4	72.5 ± 13.3	<0.001
Final postoperative VAS score, n (%)				<0.001
0	66 (45.8)	66 (81.5)	0 (0.0)	
1	30 (20.8)	15 (18.5)	15 (23.8)	
2	27 (18.8)	0 (0.0)	27 (42.9)	
3	3 (2.1)	0 (0.0)	3 (4.8)	
4	9 (6.3)	0 (0.0)	9 (14.3)	
5	6 (4.2)	0 (0.0)	6 (9.5)	
6	3 (2.1)	0 (0.0)	3 (4.8)	
Change in sesamoid position, n (%)				<0.001
−3	6 (4.2)	3 (3.7)	3 (4.8)	
−2	60 (41.7)	48 (59.3)	12 (19.0)	
−1	63 (43.8)	30 (37.0)	33 (52.4)	
0	12 (8.3)	0 (0.0)	12 (19.0)	
1	3 (2.1)	0 (0.0)	3 (4.8)	

Continuous variables are presented as mean ± standard deviation and were compared using the Wilcoxon rank-sum test. Categorical variables are presented as number (percentage) and were compared using Pearson's chi-square test or Fisher's exact test, as appropriate. AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analog scale. Diabetes mellitus and preoperative distal metatarsal articular angle data were missing in three patients. Percentages for diabetes mellitus were calculated using available data.

Table 4. Univariate logistic regression analysis of factors associated with metatarsalgia at final postoperative follow-up.

Variable	N	OR	95% CI	p-value
Age, years	144	1.03	1.01–1.05	0.009
Body mass index, kg/m²	144	1.06	1.00–1.13	0.068
Sex	144			
Female		Reference		
Male		0.96	0.37–2.43	0.929
Smoking status	144			
Nonsmoker		Reference		
Smoker		6.33	2.95–14.4	<0.001
Diabetes mellitus	141			
Absent		Reference		
Present		26.00	8.47–114	<0.001
Preoperative metatarsalgia	144	2.50	0.71–11.6	0.184
Preoperative hallux valgus angle, °	144	1.13	1.06–1.21	<0.001
Preoperative intermetatarsal angle, °	144	1.14	0.97–1.35	0.117
Preoperative distal metatarsal articular angle, °	141	1.01	0.94–1.08	0.876
Preoperative sesamoid position score	144	1.17	0.66–2.10	0.585
Preoperative first metatarsal length, mm	144	1.04	0.95–1.15	0.349
Preoperative AOFAS score	144	0.92	0.89–0.95	<0.001
Preoperative VAS score	144	1.68	1.33–2.18	<0.001
First metatarsal shortening, mm	144	2.11	1.61–2.89	<0.001
Postoperative sesamoid position score	144	7.00	3.63–15.3	<0.001
Change in sesamoid position score	144	3.86	2.25–7.12	<0.001

OR, odds ratio; CI, confidence interval; AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analog scale. For binary variables, the reference categories were female sex, nonsmoking status, absence of diabetes mellitus, and absence of preoperative metatarsalgia. For continuous and ordinal variables, ORs represent the change in odds per one-unit increase. Diabetes mellitus and preoperative distal metatarsal articular angle data were missing in three patients.

In the revised multivariable analysis, diabetes mellitus and smoking status were included in the clinically adjusted primary model together with first metatarsal shortening, postoperative sesamoid position, and preoperative metatarsalgia status. Because diabetes mellitus data were missing in three patients, this analysis included 141 patients.

First metatarsal shortening (OR=1.92, 95% CI: 1.21–3.04, p=0.005), postoperative sesamoid position (OR=3.00, 95% CI: 1.13–7.98, p=0.028), diabetes mellitus (OR=11.20, 95% CI: 2.70–46.46, p<0.001), and smoking status (OR=9.98, 95% CI: 3.01–33.09, p<0.001) were independently associated with the presence of metatarsalgia at final postoperative follow-up. Preoperative metatarsalgia showed a borderline association but did not reach statistical significance (OR=7.80, 95% CI: 0.96–63.49, p=0.055). An extended model additionally including age and BMI did not provide improved model fit compared with the clinically adjusted model (AIC: 107.26 vs 107.00; likelihood ratio test, p=0.154); therefore, the clinically adjusted model was retained as the final model (Table 5, Figure 3).

Table 5. Clinically adjusted multivariable logistic regression analysis of factors associated with metatarsalgia at final postoperative follow-up.

Variable	Multivariable OR	95% CI	p-value
First metatarsal shortening, mm	1.92	1.21–3.04	0.005
Postoperative sesamoid position score	3.00	1.13–7.98	0.028
Diabetes mellitus	11.20	2.70–46.46	<0.001
Smoking status	9.98	3.01–33.09	<0.001
Preoperative metatarsalgia	7.80	0.96–63.49	0.055

The multivariable analysis included first metatarsal shortening, postoperative sesamoid position, diabetes mellitus, smoking status, and preoperative metatarsalgia status. Because diabetes mellitus data were missing in three patients, complete-case analysis was performed in 141 patients. OR, odds ratio; CI, confidence interval

For binary variables, the reference categories were absence of diabetes mellitus, nonsmoking status, and absence of preoperative metatarsalgia. For first metatarsal shortening and postoperative sesamoid position score, ORs represent the change in odds per one-unit increase.

The final multivariable model, based on 141 patients with complete data, yielded an AIC value of 107.002. The model demonstrated a Nagelkerke R^2 of 0.670 and a Cox–Snell R^2 of 0.499. At a probability threshold of 0.50, classification accuracy was 89.4%, with a sensitivity of 85.0% and a specificity of 92.6%. However, the Hosmer–Lemeshow goodness-of-fit test was statistically significant (χ^2=17.175, df=8, p=0.028), indicating that model calibration should be interpreted with caution (Table 6).

Table 6. Performance metrics of the final clinically adjusted multivariable model.

Metric	Value
Number of patients included in the model	141
Akaike Information Criterion (AIC)	107.002
Nagelkerke R^2	0.670
Cox–Snell R^2	0.499
Hosmer–Lemeshow χ^2	17.175
Hosmer–Lemeshow degrees of freedom	8
Hosmer–Lemeshow p-value	0.028
Accuracy, %	89.4
Sensitivity, %	85.0
Specificity, %	92.6

The final model included first metatarsal shortening, postoperative sesamoid position, diabetes mellitus, smoking status, and preoperative metatarsalgia status. Because diabetes mellitus data were missing in three patients, complete-case analysis was performed in 141 patients. Classification metrics were calculated using a predicted probability threshold of 0.50. The statistically significant Hosmer–Lemeshow test indicates that model calibration should be interpreted with caution.

Receiver operating characteristic (ROC) analysis showed that first metatarsal shortening (area under the curve [AUC]=0.766, 95% CI: 0.679–0.853), postoperative sesamoid position score (AUC=0.775, 95% CI: 0.708–0.842), and change in sesamoid position score (AUC=0.729, 95% CI: 0.651–0.808) demonstrated classification ability for metatarsalgia status at final postoperative follow-up, whereas preoperative sesamoid position score was not informative (AUC=0.535). The optimal cut-off for first metatarsal shortening was ≥4.2 mm (sensitivity 57.1%, specificity 96.3%). For postoperative sesamoid position, the optimal cut-off value was ≥1 grade (sensitivity 90.5%, specificity 51.9%), whereas for change in sesamoid position the cut-off value was ≥−1 grade (sensitivity 76.2%, specificity 63.0%). Results are presented in Table 7 and Figures 1,2,4.

A moderate positive correlation was observed between first metatarsal shortening and postoperative VAS score (Spearman r=0.59, p<0.001).

Table 7. ROC-derived cut-off values and classification performance of individual radiographic variables for metatarsalgia at final postoperative follow-up.

Variable	AUC	95% CI	Cut-off value	Sensitivity, %	Specificity, %	PPV, %	NPV, %	Youden index
First metatarsal shortening, mm	0.766	0.679–0.853	≥4.2 mm	57.1	96.3	92.3	74.3	0.534
Postoperative sesamoid position score	0.775	0.708–0.842	≥1 grade	90.5	51.9	59.4	87.5	0.423
Change in sesamoid position score	0.729	0.651–0.808	≥−1 grade	76.2	63.0	61.5	77.3	0.392
Preoperative sesamoid position score	0.535	0.448–0.622	Not applicable	—	—	—	—	—

AUC, area under the receiver operating characteristic curve; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value. Cut-off values were determined using the Youden index and should be interpreted as exploratory clinical thresholds rather than stand-alone diagnostic criteria. A first metatarsal shortening threshold of ≥4.2 mm demonstrated high specificity but moderate sensitivity; therefore, values below this threshold do not exclude metatarsalgia at final postoperative follow-up.

A postoperative sesamoid position score threshold of ≥1 grade demonstrated high sensitivity but limited specificity; therefore, this threshold should be interpreted in conjunction with patient-reported symptoms and physical examination findings because of the potential for false-positive classification.

Figure 1. Receiver operating characteristic (ROC) curves for classifying metatarsalgia status at final postoperative follow-up.

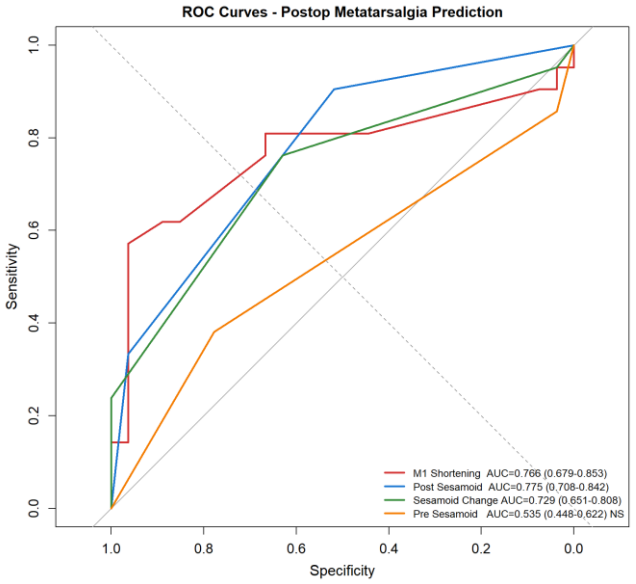


Figure 2. Distribution of first metatarsal shortening according to metatarsalgia status at final postoperative follow-up and the ROC-derived cut-off value

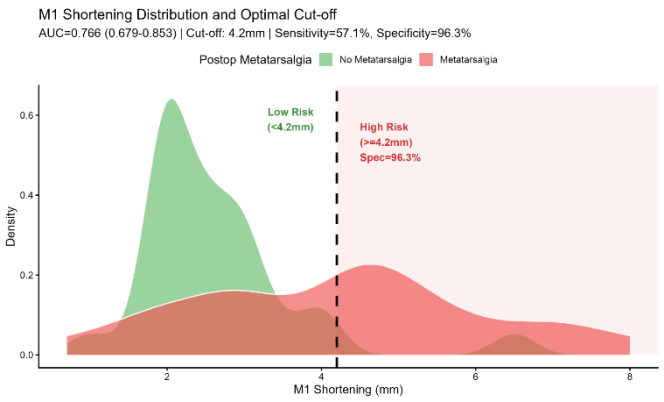
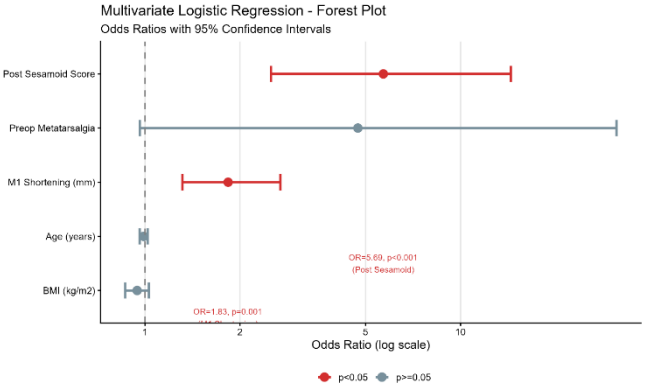


Figure 3. Clinically adjusted multivariable logistic regression analysis of factors associated with metatarsalgia at final postoperative follow-up



Discussion

The present study demonstrated that the presence of metatarsalgia at final postoperative follow-up after hallux valgus surgery was independently associated with postoperative structural changes, particularly first metatarsal shortening and postoperative sesamoid position score, as well as with diabetes mellitus and smoking status. Because the majority of patients had metatarsalgia preoperatively, the primary outcome of this study should be interpreted as the presence of metatarsalgia at final postoperative follow-up rather than exclusively as newly developed transfer metatarsalgia.

First metatarsal shortening is a recognized contributor to altered forefoot loading after hallux valgus correction. Biomechanical and finite element studies have shown that shortening of the first ray may redistribute plantar load toward the lesser metatarsal heads, thereby increasing local pressure and pain (Geng et al., 2019; Lopez et al., 2024). Clinical studies have also reported an association between relative first metatarsal shortening and postoperative metatarsalgia (Justiniano et al., 2022). Consistent with these findings, first metatarsal shortening remained independently associated with the presence of metatarsalgia at final postoperative follow-up in the clinically adjusted multivariable model (OR = 1.92, 95% CI: 1.21–3.04, p = 0.005). The ROC-derived threshold of ≥4.2 mm demonstrated high specificity (96.3%) but moderate sensitivity (57.1%). Thus, substantial shortening may help identify patients with a higher likelihood of metatarsalgia, whereas shortening below this threshold does not exclude symptoms.

These findings support preservation of first metatarsal length as an important technical objective during hallux valgus correction, while emphasizing that the threshold should be interpreted together with other structural and patient-related factors (Ma, 2024).

Postoperative sesamoid position score was also independently associated with the presence of metatarsalgia at final postoperative follow-up (OR = 3.00, 95% CI: 1.13–7.98, p = 0.028). The sesamoid complex contributes to load transmission and stabilization of the first metatarsophalangeal joint, and inadequate postoperative reduction may impair first-ray function and alter forefoot loading. Previous studies have associated improved sesamoid reduction with better functional outcomes and lower recurrence rates (Hwang et al., 2023; Lewis et al., 2024a; Lewis et al., 2024b), whereas persistent malalignment has been linked to intra-articular pathology and biomechanical imbalance (Skweres et al., 2019). The ROC-derived threshold of ≥1 grade for postoperative sesamoid position score demonstrated high sensitivity (90.5%) but limited specificity (51.9%). Thus, this threshold may identify patients who require closer clinical assessment, but it should not be used in isolation to establish clinically relevant metatarsalgia because of the possibility of false-positive classification. In this context, first metatarsal shortening and postoperative sesamoid position score provide complementary clinical information and should be interpreted alongside patient-reported symptoms and physical examination findings.

The present findings also suggest that metatarsalgia status at final postoperative follow-up cannot be explained by preoperative deformity measurements alone. Although previous studies have evaluated the relationship between preoperative morphology and postoperative metatarsalgia (Karagoz et al., 2025), our results emphasize the clinical relevance of postoperative structural parameters, particularly first metatarsal shortening and sesamoid position score, together with patient-related factors such as diabetes mellitus and smoking status. This interpretation is consistent with current concepts indicating that outcomes after hallux valgus correction depend not only on angular deformity correction but also on the postoperative biomechanical state and patient characteristics (Cho et al., 2025).

The combined assessment of first metatarsal shortening and postoperative sesamoid position score may provide a more complete structural interpretation of metatarsalgia status after hallux valgus correction. First metatarsal shortening may reduce first-ray load-bearing capacity, whereas residual sesamoid malalignment may further alter load transmission across the forefoot. Although plantar pressure distribution was not directly measured in the present study, previous evidence supports the relevance of postoperative forefoot loading patterns to clinical outcomes after hallux valgus surgery (Dias et al., 2024; Wong et al., 2023).

In addition to postoperative structural variables, diabetes mellitus and smoking status remained independently associated with the presence of metatarsalgia at final postoperative follow-up in the clinically adjusted model. This finding indicates that postoperative symptoms may be associated not only with changes in first-ray and sesamoid alignment but also with patient-related clinical factors. Although diabetes mellitus and smoking may plausibly influence soft-tissue recovery and tolerance to altered forefoot loading, the retrospective design of the present study does not allow causal or mechanistic conclusions. These associations should therefore be confirmed in larger prospective studies.

The moderate positive correlation between first metatarsal shortening and postoperative VAS score ($r=0.59$, $p<0.001$) further suggests that greater shortening may be associated with higher patient-reported pain levels at final follow-up.

From a clinical perspective, these findings suggest that evaluation of hallux valgus correction should extend beyond angular correction alone. Preservation of first metatarsal length and adequate sesamoid reduction remain important technical objectives, while diabetes mellitus and smoking status should also be considered when interpreting metatarsalgia symptoms at final postoperative follow-up.

Given the high prevalence of preoperative metatarsalgia, the final postoperative outcome may represent residual or persistent symptoms as well as newly developed metatarsalgia. Therefore, the observed associations with first metatarsal shortening and postoperative sesamoid position score should be interpreted in relation to metatarsalgia status at final follow-up rather than as evidence of de novo transfer metatarsalgia caused by these structural changes in all symptomatic patients.

This study has several limitations. First, its retrospective, single-center design and relatively limited sample size may restrict the generalizability of the findings. Second, although postoperative metatarsalgia was clinically defined using both patient-reported symptoms and physical examination findings, it was recorded as a binary outcome at final follow-up without a predefined symptom-duration criterion. Moreover, because preoperative metatarsalgia was present in the majority of patients, the postoperative outcome may include persistent or residual symptoms as well as newly developed metatarsalgia; therefore, the study cannot specifically determine de novo transfer metatarsalgia in all symptomatic patients. Third, dynamic plantar pressure analysis was not performed, limiting direct assessment of the proposed biomechanical load-transfer mechanism. Fourth, although excellent interobserver reliability was demonstrated for continuous radiographic measurements, a separate agreement analysis for the ordinal sesamoid position score and an intraobserver reliability assessment were not available. Fifth, although diabetes mellitus and smoking status were incorporated into the clinically adjusted multivariable model, residual confounding related to patient-level clinical factors cannot be excluded in a retrospective analysis. In addition, because of the retrospective design, blinding of the radiographic assessors to metatarsalgia status at final postoperative follow-up could not be reliably confirmed. Finally, the model was not subjected to internal resampling-based or external validation, and the statistically significant Hosmer–Lemeshow goodness-of-fit test indicates that its calibration should be interpreted with caution. Therefore, the identified associations and ROC-derived thresholds should be confirmed in larger, prospectively designed and externally validated studies.

Conclusion

Postoperative biomechanical factors, particularly first metatarsal shortening and postoperative sesamoid position, were independently associated with the presence of metatarsalgia at final follow-up after hallux valgus surgery. Because most patients had preoperative metatarsalgia, these findings should not be interpreted as demonstrating newly developed transfer metatarsalgia in all symptomatic patients. These findings emphasize the clinical importance of preserving first ray length and achieving adequate sesamoid reduction during surgical correction. However, given the retrospective design and relatively limited sample size, the results should be interpreted with caution and confirmed in prospective studies.

Ethics approval and consent to participate

This retrospective cohort study was approved by the Ethics Committee of Aksaray University Scientific Research Ethics Committee (Approval No: 2025/133; Protocol No: SAGETİK 2025-94; Date: 17 July 2025). The requirement for informed consent was waived due to the retrospective nature of the study.

Declaration of conflicting interests

The authors declare that they have no conflict of interest.

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Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

A.B.: Conceptualization, data curation, formal analysis, writing – original draft, writing – review & editing. S.A.: Conceptualization, supervision, writing – review & editing. All authors have read and approved the final manuscript.

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List of Abbreviations

Abbreviation	Definition
AIC	Akaike Information Criterion
AOFAS	American Orthopaedic Foot and Ankle Society
AUC	Area Under the Curve
BMI	Body Mass Index
CI	Confidence Interval
DMAA	Distal Metatarsal Articular Angle
HVA	Hallux Valgus Angle
ICC	Intraclass Correlation Coefficient
IMA	Intermetatarsal Angle
M1	First Metatarsal
NPV	Negative Predictive Value
OR	Odds Ratio
PPV	Positive Predictive Value
ROC	Receiver Operating Characteristic
VAS	Visual Analog Scale