Joint Diseases and Related Surgery

Jt Dis Relat Surg
2025;36(1):119-128

ORIGINAL ARTICLE

Is there a relationship between recurrence and obesity in the three-year mid-term follow-up of patients who underwent high tibial osteotomy due to medial gonarthrosis?

Ibrahim Bozkurt, MD[1], Mustafa Bulut, MD[2], Umut Öktem, MD[1], Sinan Yılmaz, MD[3], Özgür Selim Uysal, MD[4], Izzet Bingöl, MD[5], Durmuş Ali Öçgüder, MD[5]

[1]Department of Orthopedics and Traumatology, Ankara City Hospital, Ankara, Türkiye
[2]Department of Orthopedics and Traumatology, Polatlı Duatepe State Hospital, Ankara, Türkiye
[3]Department of Orthopedics and Traumatology, Memorial Ankara Hospital, Ankara, Türkiye
[4]Department of Orthopedics and Traumatology, Özel 100. Yıl Hospital, Ankara, Türkiye
[5]Department of Orthopedics and Traumatology, Ankara Yıldırım Beyazıt University, Ankara, Türkiye

ABSTRACT

Objectives: This study aimed to radiologically evaluate the possible relationship between the body mass index (BMI) and recurrence of varus deformity during the mid-term follow-up of patients treated for medial gonarthrosis.

Patients and methods: Fifty-six patients (11 males, 45 females; mean age: 53.8±7.2 years; range, 29 to 64 years) who underwent medial opening wedge osteotomy for the treatment of isolated medial varus gonarthrosis between January 1, 2020, and June 1, 2021, were retrospectively reviewed. Patients were categorized according to BMI values as having a healthy weight (18.5-24.9 kg/m^2), being overweight (25.0-29.9 kg/m^2), or being obese (≥30 kg/m^2). Mechanical medial proximal tibial angle, hip-knee-ankle angle, joint line convergence angle, and knee adduction moment calculations were performed based on radiographs.

Results: Among the 56 patients, the mean age of those with healthy weight was 42.5±13.2 years, that of the overweight group was 53.3±6.4 years, and that of the obese group was 54.0±5.8 years. Radiological evaluations were statistically improved postoperatively compared to preoperative scores across BMI groups ($p<0.05$). There were no correlations between age and radiological scores or BMI ($p>0.05$). Similarly, no correlation was found between BMI and radiological scores ($p>0.05$).

Conclusion: Body mass index is not of significance in medial opening wedge osteotomy radiological scores in short- and mid-term follow-up.

Keywords: Body mass index, high tibial osteotomy, recurrence, varus gonarthrosis.

Knee osteoarthritis (OA) is a prevalent condition often accompanied by medial compartment arthrosis and varus deformity. Varus deformity is a major cause of medial arthrosis. Several procedures are used to address medial compartment arthrosis, including osteotomy, which aims to correct deformity, redistribute joint load, and improve alignment and joint survival.[1]

The lateral closing wedge high tibial osteotomy (HTO), popularized by Coventry,[2] was historically used for varus knees. In 1987, Hernigou et al.[3] introduced the medial opening wedge technique. Medial opening wedge HTO (MOWHTO) is now widely used to preserve the knee joint and correct varus alignment.[4,5] High tibial osteotomy reduces pain, facilitates physical activity, and is

Received: September 19, 2024
Accepted: November 12, 2024
Published online: December 14, 2024

Correspondence: Ibrahim Bozkurt, MD. Ankara Şehir Hastanesi, Ortopedi ve Travmatoloji Kliniği, 06800 Çankaya, Ankara, Türkiye.

E-mail: dr.bozkurtibrahim@gmail.com

Doi: 10.52312/jdrs.2025.1985

Citation: Bozkurt I, Bulut M, Öktem U, Yılmaz S, Uysal ÖS, Bingöl I, et al. Is there a relationship between recurrence and obesity in the three-year mid-term follow-up of patients who underwent high tibial osteotomy due to medial gonarthrosis? Jt Dis Relat Surg 2025;36(1):119-128. doi: 10.52312/jdrs.2025.1985.

cost-effective.[6] Although primarily used for young, active patients, its application in cases of knee medial compartment arthrosis is growing, aided by advances in plate-screw technology.[7] Despite significant functional and clinical improvements, mid- to long-term recurrences are reported.[8-11] Factors such as obesity, surgical technique, sex, and plate-screw type may influence clinical outcomes and varus deformity recurrence.[12] There are also studies indicating that obesity is a risk factor for revision surgery in HTO.[13,14] We believe that obesity does not increase the risk of varus deformity recurrence after HTO. Therefore, this study aimed to evaluate the relationship between body mass index (BMI) and recurrence of varus deformity in mid-term follow-up.

PATIENTS AND METHODS

Records of patients who underwent MOWHTO for isolated medial varus gonarthrosis at the Orthopedics and Traumatology Department of Ankara Bilkent City Hospital by a single surgeon between January 1, 2020, and June 1, 2021, were retrospectively reviewed. A total of 103 patients were operated during this period, and 47 patients who did not comply with the follow-up period were excluded. Consequently, 56 patients (11 males, 45 females; mean age: 53.8±7.2 years; range, 29 to 64 years) were included in the analyses. Patients were categorized according to BMI as healthy weight (HW; 18.5-24.9 kg/m^2), overweight (OW; 25.0-29.9 kg/m^2), or obese (OB; ≥30 kg/m^2). The inclusion criteria were a diagnosis of isolated medial gonarthrosis without joint instability, varus alignment disorder, age ≤65 years, flexion contracture <15°, knee range of motion ≥120°, and three years of follow-up. Patients with other diagnoses (e.g., inflammatory arthritis or traumatic OA), graft applications, incomplete data, or follow-up of less than three years were excluded. No patients required total knee arthroplasty (TKA) during the three-year follow-up. The study protocol was approved by the Ankara Bilkent City Hospital Ethics Committee (date: 28.08.2024, no: TABED 1-24-209). Written informed consent was obtained all participants. The study was conducted in accordance with the principles of the Declaration of Helsinki.

All surgeries were performed by a single surgeon using biplanar MOWHTO. The opening wedge angle of the tibia was determined intraoperatively by fluoroscopy at the Fujisawa point.[15] The osteotomy was stabilized with a 4.5-mm locking compression plate (TomoFix™, TriS; Olympus Terumo Biomaterials, Tokyo, Japan).

Active and passive range of motion exercises and muscle-strengthening exercises began the day after surgery. Joint range of motion exercises continued until at least 130° of flexion was achieved within three weeks. Partial weight-bearing walking started on the first postoperative day, with full weight-bearing allowed in the second week. Return to sports was permitted once full bone union was observed.

Standing long-axis radiographs were taken preoperatively and one month, three months, six months, one year, two years, and three years after MOWHTO. Measurements of the mechanical medial proximal tibial angle (mMPTA), joint line convergence angle (JLCA), hip-knee-ankle angle (HKA), and knee adduction moment (KAM) were performed by two researchers. The researchers made a single measurement by jointly deciding on the same radiograph at the same time (Figure 1).

Statistical analysis

Statistical analyses were conducted using IBM SPSS version 24.0 software (IBM Corp., Armonk, NY, USA). Descriptive statistics included frequency, mean ± standard deviation (SD) and min-max. The Shapiro-Wilk and Kolmogorov-Smirnov tests were used to check normality. One-way analysis of variance was used to compare group means, and Student's t-test was used for repeated measures. The Mann-Whitney U test was used for pairwise comparisons when normality assumptions were not met. Pearson's correlation was used to test age and BMI correlations. A p-value <0.05 was considered statistically significant.

RESULTS

The mean age was 42.5±13.2 years in the HW group, 53.3±6.4 years in the OW group, and 54.0±5.8 years in the OB group. Mean ages differed significantly between the groups (p=0.010). There were more female patients in the OW and OB groups (p=0.008). The HW group had four (7%) patients (2 males, 2 females). In the OW group, 22 of 32 patients were female, and all 21 patients in the OB group were female. The mean BMI values were 24.35±0.37 kg/m^2 for the HW group, 28.00±1.32 kg/m^2 for the OW group, and 33.06±1.71 kg/m^2 for the OB group (p=0.000). The mean correction values were 9.25°±2.22 for the HW group, 9.58°±1.49 for the OW group, and 9.24°±1.14 for the OB group (p=0.674). Thirty-four patients were operated on the left

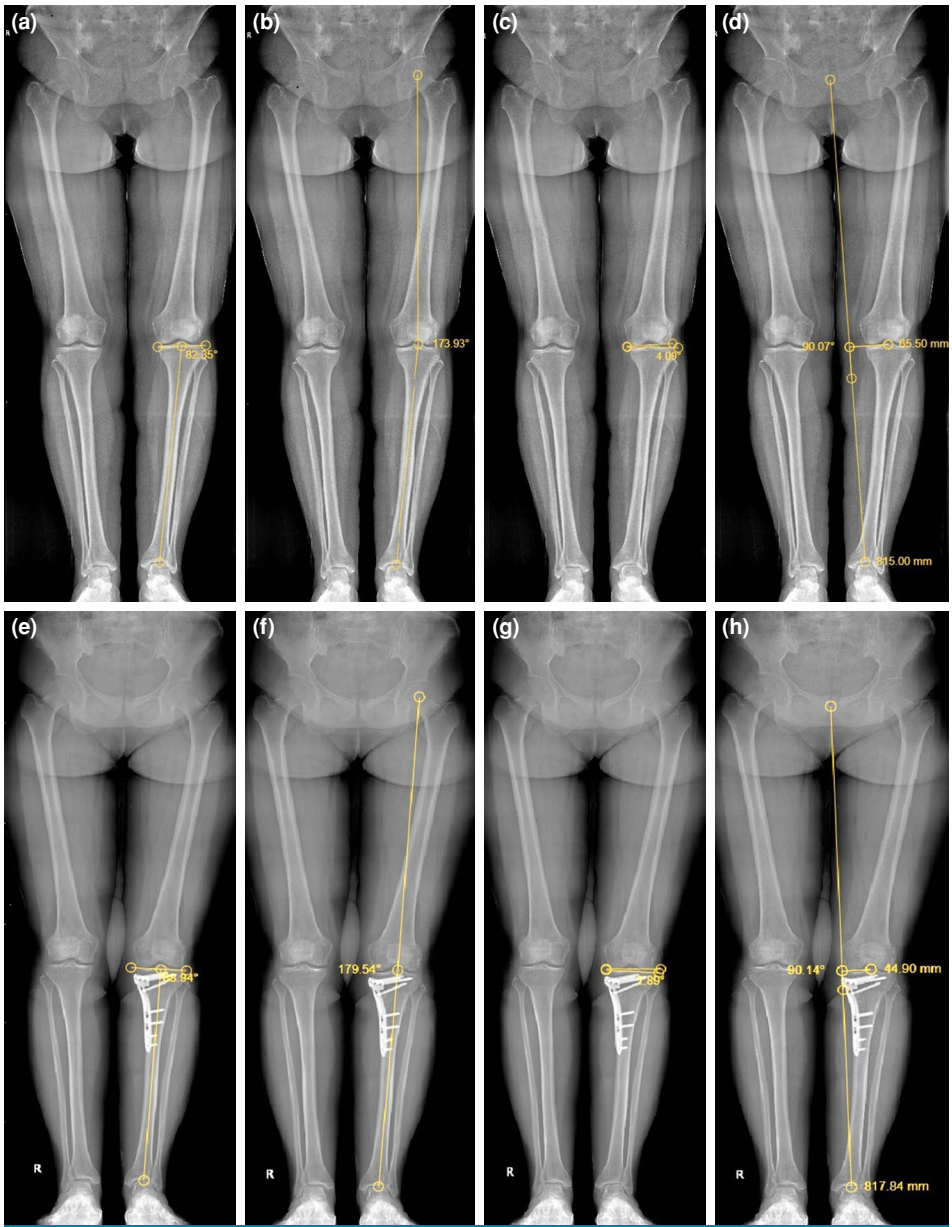

FIGURE 1. Preoperative and three-year postoperative standing long axis radiographs. **(a)** preoperative mMPTA, **(b)** preoperative HKA, **(c)** preoperative JLCA, **(d)** preoperative KAM, **(e)** three-year postoperative mMPTA, **(f)** three-year postoperative HKA, **(g)** three-year postoperative, **(h)** three-year postoperative KAM.

mMPTA: Mechanical medial proximal tibial angle; HKA: Hip-knee-ankle angle; JLCA: Joint line convergence angle; KAM: Knee adduction moment.

side, with no significant difference by BMI groups (p=0.674; Table I).

Table II presents radiological measurement values preoperatively and at one month and three years postoperatively. Postoperative scores showed significant improvement compared to preoperative scores for radiological evaluations across BMI groups. There was a partial regression in three-year results compared to one-month results, but it was not statistically significant (p=0.747 for JLCA, p=0.754 for KAM, p=0.912 for HKA, and p=0.808 for mMPTA; Figures 2-5).

Table III indicates no statistically significant difference between the groups in mMPTA values

TABLE I
Comparison of demographic data according to BMI

	BMI (kg/m²)									
	Normal			Overweight			Obese			
	18.5-24.9			25.0-29.9			≥30			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Number of patients	4	7.0		32	56.1		21	36.8		
Age (year)			42.5±13.2			53.3±6.4			54.0±5.8	0.010
Sex										
Female	2	4.4		22	48.9		21	46.7		0.008
Side-left	3	8.8		21	61.8		10	29.4		0.345
Correction			9.25±2.22			9.58±1.49			9.24±1.14	0.674
Body mass index (kg/m²)			24.35±0.37			28.00±1.32			33.06±1.71	0.000

SD: Standard deviation.

TABLE II
Radiological measurements

	Mean±SD	Min-Max
mMPTA		
Preoperative	82.47±2.68	76.2-87.0
1 month	88.14±2.28	82.4-93.0
3 years	87.62±2.43	81.6-92.0
HKA		
Preoperative	171.47±2.94	163.0-176.64
1 month	177.69±1.97	173.14-183.0
3 years	177.56±1.84	173.1-182.0
KAM		
Preoperative	69.76±12.27	51.1-99.0
1 month	48.79±10.21	28.31-71.20
3 years	49.29±11.46	32.43-92.28
JLCA		
Preoperative	3.19±1.28	0.27-8.0
1 month	2.56±5.36	0.11-4.2
3 years	2.61±5.22	0.20-4.1

SD: Standard deviation; mMPTA: Mechanical medial proximal tibial angle; HKA: Hip-knee-ankle angle; KAM: Knee adduction moment; JLCA: Joint line convergence angle.

preoperatively and at one month and three years postoperatively. Patient sex did not significantly affect mMPTA scores (p=0.570, p=0.590, and p=0.342 for the respective time points). Similarly, HKA values showed no significant difference by BMI groups or sex preoperatively and at one month or three years (p>0.05 for all). Additionally, KAM values showed no significant difference by BMI groups (p=0.795, p=0.767, and p=0.656, respectively) or sex (p=0.053, p=0.891, and p=0.544, respectively) preoperatively and at one month or three years. Finally, JLCA values showed no significant

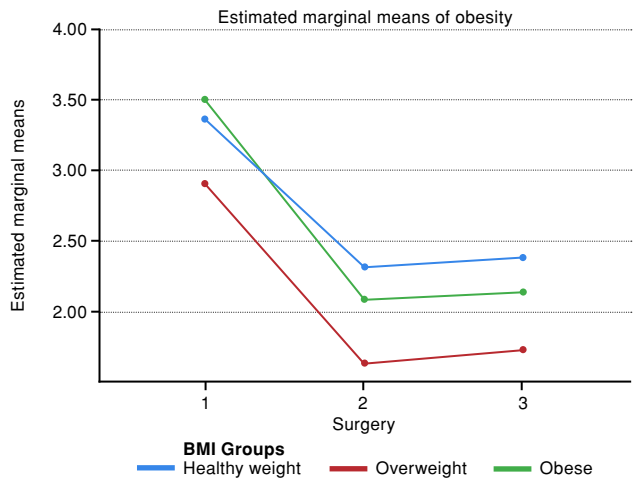

FIGURE 2. Relationship between JLCA and OB preoperatively (1), in the first postoperative month (2), and in the third postoperative year (3).
JLCA: Joint line convergence angle; OB: Obese; BMI: Body mass index.

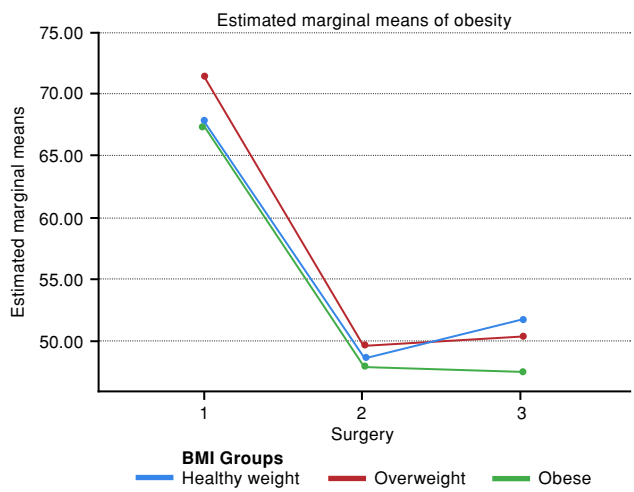

FIGURE 3. Relationship between KAM and OB preoperatively (1), in the first postoperative month (2), and in the third postoperative year (3).
KAM: Knee adduction moment; OB: Obese; BMI: Body mass index.

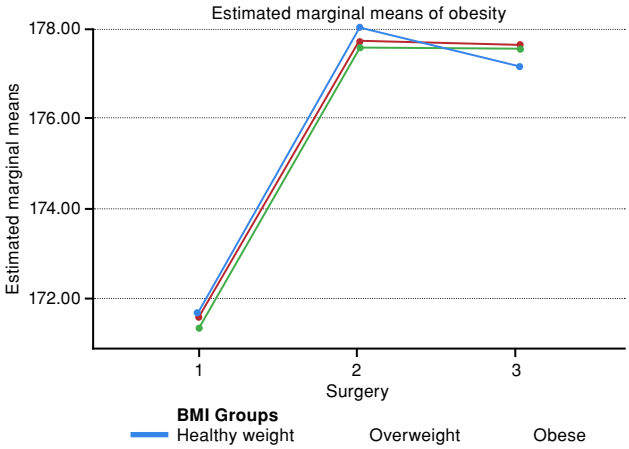

FIGURE 4. Relationship between HKA and OB preoperatively (1), in the first postoperative month (2), and in the third postoperative year (3).
HKA: Hip-knee-ankle angle; OB: Obese; BMI: Body mass index.

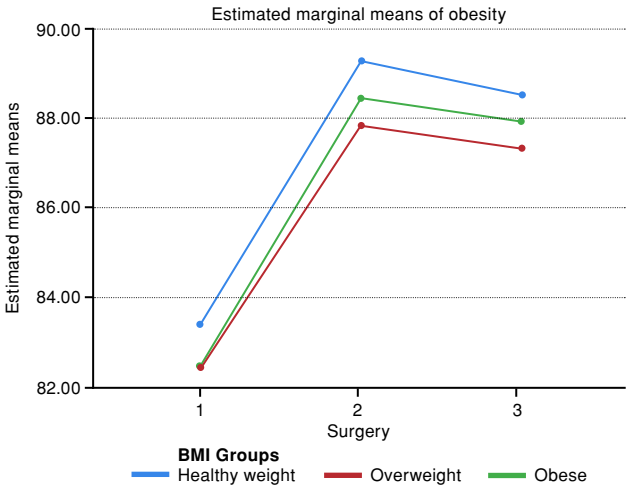

FIGURE 5. Relationship between mMPTA and OB preoperatively (1), in the first postoperative month (2), and in the third postoperative year (3).
mMPTA: Mechanical medial proximal tibial angle; OB: Obese; BMI: Body mass index.

difference by BMI groups or sex preoperatively and at one month or three years (p=0.186, p=0.332, p=0.352, respectively). Table 4 shows no significant correlations between age, radiological scores, and BMI (p>0.05; Table IV).

DISCUSSION

The findings revealed that BMI did not affect changes in radiological values over a three-year follow-up period after MOWHTO. Obesity is a controversial topic in the literature for HTO candidate patients. Although a BMI <30 kg/m² is generally recommended, MOWHTO can be safely performed for patients with BMI >30 kg/m² due to increased mechanical stability at the osteotomy site with the development of implant technology.[12] Although some studies have reported that patients with BMI >30 kg/m² are more frequently converted to TKA in mid- to long-term follow-up compared to those with normal BMI values, there are also studies supporting our finding that BMI has no effect on mid-term results. Guarino et al.[16] reported more frequent TKA revision in patients with BMI >30 kg/m² in their 17-year follow-up cohort study. Herbst et al.[17] reported greater loss of correction in patients with BMI >30 kg/m² in their six-year follow-up cohort study. Mabrouk et al.[18] reported no effect of BMI on mid-term outcomes in their retrospective cohort study. Tuhanioğlu et al.[19] reported good results after MOWHTO applied for OB patients in mid-term follow-up.

The HKA, mMPTA, and JLCA are frequently used for frontal plane evaluations in radiological assessments.[20] Although there is no consensus on the optimal amount of correction according to the HKA after HTO in the literature, Coventry et al.[21] stated that failure to correct the valgus angle by at least 8° in OW patients is one of the reasons for the failure of proximal tibial osteotomy. They reported better outcomes in cases where the valgus angle was corrected by 5° to 13° compared to cases with less than 5° correction. Hernigou[22] reported OA in the lateral compartment in a 10-year follow-up study of knees corrected to 6° of valgus postoperatively. Kerimoğlu et al.[23] found no significant difference in clinical and functional test results between patients divided into three groups according to HKA with overcorrection and those corrected within normal reference ranges. Akamatsu et al.[24] compared patients with excessively corrected MPTA (>95°) with those having normal MPTA after HTO. They found no significant difference between the groups in terms of medial cartilage preservation and lateral cartilage degeneration but reported lower clinical and functional scores in patients with higher postoperative MPTA values. The JLCA is defined as the angle between the tangents of the femoral condyle and tibial plateau, and it is important in evaluating soft tissue correction. The amount of frontal plane correction after MOWHTO depends on both bone and soft tissue.[25] Joint line convergence angle values calculated from preoperative radiographs under varus stress are associated

TABLE III
Comparison of radiological outcomes according to BMI and sex

	BMI			Sex	
	Normal	Overweight	Obese	Female	Male
	18.5-24.9	25.0-29.9	≥30		
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
mMPTA					
Preoperative	83.37±3.64	82.37±2.49	82.44±2.88	82.53±2.75	82.24±2.48
p	Ref.	0.579	0.415	Ref.	0.570
1 month	89.26±2.04	87.81±2.48	88.43±1.96	88.20±2.04	87.92±3.10
p	Ref.	0.247	0.552	Ref.	0.590
3 years	88.51±1.71	87.31±2.52	87.92±2.43	87.75±2.33	87.15±2.83
p	Ref.	0.406	0.941	Ref.	0.342
HKA					
Preoperative	171.65±4.30	171.55±3.10	171.31±2.56	171.70±2.62	170.61±3.95
p		0.880	0.824	Ref.	0.645
1 month	178.03±3.10	177.72±1.97	177.58±1.84	177.49±1.91	178.43±2.12
p	Ref.	0.632	0.528	Ref.	0.394
3 years	51.75±14.66	177.62±1.80	177.55±1.77	177.44±1.73	178.02±2.22
p	Ref.	1.00	0.911	Ref.	0.347
KAM					
Preoperative	67.80±16.85	71.53±13.23	67.44±9.81	67.80±10.84	77.11±14.89
p	Ref.	0.687	0.795	Ref.	0.053
1 month	48.55±10.97	49.35±9.78	47.99±11.16	48.82±11.01	48.68±6.76
p	Ref.	0.706	0.767	Ref.	0.891
3 years	51.75±14.66	50.11±11.86	47.57±10.58	49.09±12.30	50.05±7.93
p	Ref.	0.920	0.656	Ref.	0.544
JLCA					
Preoperative	3.36±2.37	71.54±13.23	3.50±1.00	3.27±1.03	2.91±2.01
p		0.450	0.882	Ref.	0.186
1 month	2.32±0.43	2.89±7.17	2.09±0.70	2.78±6.02	1.72±0.82
p	Ref.	0.059	0.374	Ref.	0.332
3 years	2.38±0.48	2.96±6.97	2.14±0.69	2.81±5.86	1.87±0.81
p	Ref.	0.097	0.415	Ref.	0.352

BMI: Body mass index; SD: Standard deviation; mMPTA: Mechanical medial proximal tibial angle; HKA: Hip-knee-ankle angle; KAM: Knee adduction moment; JLCA: Joint line convergence angle.

with overcorrection.[26-28] Patients with JLCA ≥4° are more likely to experience overcorrection.[28] We observed that the mean preoperative and postoperative one-month and three-year JLCA measurements in our patients were 3.19°±1.28°, 2.56°±5.36°, and 2.61°±5.22°, respectively, indicating sufficient correction in the frontal plane and maintenance of correction during follow-up.

Knee adduction moment is an indicator of dynamic mechanical load on the knee, and it increases with varus. Although the reduction in KAM after MOWHTO and its impact on the reduction of OA is not universally agreed upon, an increase in HKA with a decrease in KAM is clinically desirable.[29] There is a positive correlation between KAM and mechanical axis.[30] We found no significant change in KAM and HKA according to one-month and three-year follow-up data. This could indicate an even distribution of the load on the medial compartment since increased compressive

TABLE IV
Correlations among radiological measurements, BMI, and age

Correlations	Age	mMPTA (preoperative)	mMPTA (1 month)	mMPTA (3 years)	HKA (preoperative)	HKA (1 month)	HKA (3 years)	KAM (preoperative)	KAM (1 month)	KAM (3 years)	JLCA (preoperative)	JLCA (1 month)	JLCA (3 years)	BMI
Age														
Pearson correlation	1	0.065	0.048	0.054	−0.126	−0.236	−0.178	0.054	0.120	0.090	0.179	0.009	0.003	0.200
Sig. (2-tailed)		0.632	0.723	0.691	0.351	0.077	0.186	0.690	0.375	0.507	0.184	0.945	0.980	0.136
mMPTA (preoperative)														
Pearson correlation	0.065	1	0.508**	0.468**	0.363**	0.233	0.138	−0.301*	−0.237	−0.174	−0.230	−0.231	−0.238	−0.044
Sig. (2-tailed)	0.632		0.000	0.000	0.006	0.081	0.305	0.023	0.076	0.195	0.085	0.084	0.075	0.746
mMPTA (1 month)														
Pearson correlation	0.048	0.508**	1	0.903**	0.186	0.401**	0.389**	−0.174	−0.368**	−0.369**	−0.115	−0.300*	−0.305*	0.032
Sig. (2-tailed)	0.723	0.000		0.000	0.165	0.002	0.003	0.194	0.005	0.005	0.396	0.023	0.021	0.814
mMPTA (3 years)														
Pearson correlation	0.054	0.468**	0.903**	1	0.150	0.425**	0.415**	−0.126	−0.327*	−0.385**	−0.146	−0.145	−0.155	0.054
Sig. (2-tailed)	0.691	0.000	0.000		0.266	0.001	0.001	0.350	0.013	0.003	0.278	0.283	0.251	0.692
HKA (preoperative)														
Pearson correlation	−0.126	0.363**	0.186	0.150	1	0.479**	0.469**	−0.830**	−0.472**	−0.446**	−0.582**	−0.164	−0.170	−0.035
Sig. (2-tailed)	0.351	0.006	0.165	0.266		0.000	0.000	0.000	0.000	0.001	0.000	0.223	0.206	0.794
HKA (1 month)														
Pearson correlation	−0.236	0.233	0.401**	0.425**	0.479**	1	0.807**	−0.351**	−0.570**	−0.584**	−0.379**	−0.016	−0.019	−0.089
Sig. (2-tailed)	0.077	0.081	0.002	0.001	0.000		0.000	0.007	0.000	0.000	0.004	0.908	0.888	0.508
HKA (3 years)														
Pearson correlation	−0.178	0.138	0.389**	0.415**	0.469**	0.807**	1	−0.324*	−0.483**	−0.661**	−0.434**	−0.076	−0.088	−0.010
Sig. (2-tailed)	0.186	0.305	0.003	0.001	0.000	0.000		0.014	0.000	0.000	0.001	0.573	0.516	0.944
KAM (preoperative)														
Pearson correlation	0.054	−0.301*	−0.174	−0.126	−0.830**	−0.351**	−0.324*	1	0.596**	0.538**	0.379**	0.041	0.045	−0.195
Sig. (2-tailed)	0.690	0.023	0.194	0.350	0.000	0.007	0.014		0.000	0.000	0.004	0.761	0.738	0.146
KAM (1 month)														
Pearson correlation	0.120	−0.237	−0.368**	−0.327*	−0.472**	−0.570**	−0.483**	0.596**	1	0.837**	0.296*	−0.024	−0.018	−0.066
Sig. (2-tailed)	0.375	0.076	0.005	0.013	0.000	0.000	0.000	0.000		0.000	0.025	0.861	0.895	0.625
KAM (3 years)														
Pearson correlation	0.090	−0.174	−0.369**	−0.385**	−0.446**	−0.584**	−0.661**	0.538**	0.837**	1	0.241	0.063	0.075	−0.124
Sig. (2-tailed)	0.507	0.195	0.005	0.003	0.001	0.000	0.000	0.000	0.000		0.071	0.643	0.579	0.358
JLCA (preoperative)														
Pearson correlation	0.179	−0.230	−0.115	−0.146	−0.582**	−0.379**	−0.434**	0.379**	0.296*	0.241	1	0.254	0.258	0.174
Sig. (2-tailed)	0.184	0.085	0.396	0.278	0.000	0.004	0.001	0.004	0.025	0.071		0.057	0.053	0.196
JLCA (1 month)														
Pearson correlation	0.009	−0.231	−0.300*	−0.145	−0.164	−0.016	−0.076	0.041	−0.024	0.063	0.254	1	0.999**	−0.034
Sig. (2-tailed)	0.945	0.084	0.023	0.283	0.223	0.908	0.573	0.761	0.861	0.643	0.057		0.000	0.801

TABLE IV
Continued

Correlations	Age	mMPTA (preoperative)	mMPTA (1 month)	mMPTA (3 years)	HKA (preoperative)	HKA (1 month)	HKA (3 years)	KAM (preoperative)	KAM (1 month)	KAM (3 years)	JLCA (preoperative)	JLCA (1 month)	JLCA (3 years)	BMI
JLCA (3 years)														
Pearson correlation	0.003	−0.238	−0.305*	−0.155	−0.170	−0.019	−0.088	0.045	−0.018	0.075	0.258	0.999**	1	−0.038
Sig. (2-tailed)	0.980	0.075	0.021	0.251	0.206	0.888	0.516	0.738	0.895	0.579	0.053	0.000		0.781
BMI														
Pearson correlation	0.200	−0.044	0.032	0.054	−0.035	−0.089	−0.010	−0.195	−0.066	−0.124	0.174	−0.034	−0.038	1
Sig. (2-tailed)	0.136	0.746	0.814	0.692	0.794	0.508	0.944	0.146	0.625	0.358	0.196	0.801	0.781	

BMI: Body mass index; mMPTA: Mechanical medial proximal tibial angle; HKA: Hip-knee-ankle angle; KAM: Knee adduction moment; JLCA: Joint line convergence angle; * Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed).

loads on the medial compartment are one mechanism of varus development in the knee. High KAM indicates higher load and associated medial stress on the medial compartment. The decrease in KAM is crucial for the survival of MOWHTO, particularly in short-statured patients.[30,31]

The HKA, mMPTA, and JLCA values are important for preoperative planning and postoperative prognosis follow-up. In our study, we found no significant changes in radiological measurements in early postoperative or three-year follow-up data. Looking at the correlations of values, we found no correlation between obesity and radiological changes, and we observed similar correction amounts in the HW, OW, and OB patient groups without loss of correction.[32] This suggests that the surgical techniques and implants used have greater impact on outcomes than obesity. We also observed a significant decrease in postoperative KAM values compared to preoperative evaluations used for dynamic assessment.

While evaluating the frontal plane measurements according to obesity groups (HW, OW, and OB), we found partial regression in three-year results compared to one-month results, but this was not statistically significant. We observed that the scores of the OB group were better than those of the healthy group at the end of the third year. This finding could be attributed to the sample sizes of the respective groups (Figures 2-5).

Guarino et al.,[16] in their long-term study with 247 patients who underwent HTO, found that obesity was a risk factor for conversion to TKA. Floerkemeier et al.,[33] in their study involving 533 patients investigating the mid-term effects of obesity and smoking on healing and complications, reported that obesity had no negative impact on complications or nonunion in the mid-term. A recent publication concluded that BMI had no significant impact on radiological corrections, clinical outcomes, complications, or survival of MOWHTO in short- to mid-term follow-up.[18] Our results also showed that obesity did not contribute to the recurrence of varus deformity in the mid-term. However, the need for larger patient series to demonstrate long-term results remains.

The main limitations of this study included the lack of postoperative three-year BMI data for patients, the fact that all surgeries were performed by a single surgeon, and the absence of a subclassification for morbidly OB patients (BMI ≥40 kg/m^2) due to the retrospective nature of

the research. The evaluation of only radiological scores without clinical scores was another limitation of the study.

In conclusion, BMI did not have an effect on radiological values during the three-year follow-up period after MOWHTO. High tibial osteotomy is a good treatment option for isolated medial gonarthrosis, and we recommend its use even in OB patients. However, our study should be supported by larger case series with long-term results.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, design, control/supervision, data collection and processing, analysis and interpretation, literature review, writing the article, critical review: İ.B., M.B., U.Ö., İ.B.; Idea/concept, data collection and processing, analysis and interpretation, literature review, critical review: S.Y., Ö.S.U., D.A.Ö.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Kholeif AM, Mohamed ABZ, Bashandy AS, Khedr AM. Gradual on top-of-acute correction of neglected adolescent tibia vara by percutaneous tibial osteotomy and two-ring Ilizarov frame. Jt Dis Relat Surg 2023;34:265-70. doi: 10.52312/jdrs.2023.1072.
2. Coventry MB. Upper tibial osteotomy for osteoarthritis. J Bone Joint Surg [Am] 1985;67:1136-40.
3. Hernigou P, Medevielle D, Debeyre J, Goutallier D. Proximal tibial osteotomy for osteoarthritis with varus deformity. A ten to thirteen-year follow-up study. J Bone Joint Surg [Am] 1987;69:332-54.
4. Kubota M, Ohno R, Sato T, Yamaguchi J, Kaneko H, Kaneko K, et al. The medial proximal tibial angle accurately corrects the limb alignment in open-wedge high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc 2019;27:2410-6. doi: 10.1007/s00167-018-5216-8.
5. Kim MS, Koh IJ, Choi KY, Kim BS, In Y. Changes in joint space width over time and risk factors for deterioration of joint space width after medial opening-wedge high tibial osteotomy. Arch Orthop Trauma Surg 2022;142:2513-24. doi: 10.1007/s00402-021-03876-2.
6. Araya N, Koga H, Nakagawa Y, Shioda M, Ozeki N, Kohno Y, et al. Risk factors for delayed bone union in opening wedge high tibial osteotomy. Jt Dis Relat Surg 2024;35:546-53. doi: 10.52312/jdrs.2024.1636.
7. Staubli AE, De Simoni C, Babst R, Lobenhoffer P. TomoFix: A new LCP-concept for open wedge osteotomy of the medial proximal tibia--early results in 92 cases. Injury 2003;34 Suppl 2:B55-62. doi: 10.1016/j.injury.2003.09.025.
8. Hui C, Salmon LJ, Kok A, Williams HA, Hockers N, van der Tempel WM, et al. Long-term survival of high tibial osteotomy for medial compartment osteoarthritis of the knee. Am J Sports Med 2011;39:64-70. doi: 10.1177/0363546510377445.
9. Koshino T, Yoshida T, Ara Y, Saito I, Saito T. Fifteen to twenty-eight years' follow-up results of high tibial valgus osteotomy for osteoarthritic knee. Knee 2004;11:439-44. doi: 10.1016/j.knee.2004.03.005.
10. Akizuki S, Shibakawa A, Takizawa T, Yamazaki I, Horiuchi H. The long-term outcome of high tibial osteotomy: A ten- to 20-year follow-up. J Bone Joint Surg [Br] 2008;90:592-6. doi: 10.1302/0301-620X.90B5.20386.
11. Polat G, Balcı Hİ, Çakmak MF, Demirel M, Şen C, Aşık M. Long-term results and comparison of the three different high tibial osteotomy and fixation techniques in medial compartment arthrosis. J Orthop Surg Res 2017;12:44. doi: 10.1186/s13018-017-0547-6.
12. Lobenhoffer P, Van Heerwaarden R. Osteotomies Around the Knee: Indications - Planning - Surgical Techniques Using Plate Fixators. New York: Thieme; 2009. p. 57-84.
13. Constantin H, Salmon LJ, Russell V, Sundaraj K, Roe JP, Pinczewski LA. 20-Year outcomes of high tibial osteotomy: Determinants of survival and functional outcome. Am J Sports Med 2024;52:344-51. doi: 10.1177/03635465231217742.
14. Fitoussi A, Dartus J, Erivan R, Pasquier G, Migaud H, Putman S, et al. Management of medial femorotibial osteoarthritis: Epidemiology, and survival of unicompartmental knee arthroplasty versus valgus high tibial osteotomy in France. Study of 108,007 cases from the French National Hospitals Database. Orthop Traumatol Surg Res 2023;109:103692. doi: 10.1016/j.otsr.2023.103692.
15. Fujisawa Y, Masuhara K, Shiomi S. The effect of high tibial osteotomy on osteoarthritis of the knee. An arthroscopic study of 54 knee joints. Orthop Clin North Am 1979;10:585-608.
16. Guarino A, Farinelli L, Iacono V, Cozzolino A, Natali S, Zorzi C, et al. Long-term survival and predictors of failure of opening wedge high tibial osteotomy. Orthop Surg 2023;15:1002-7. doi: 10.1111/os.13674.
17. Herbst M, Ahrend MD, Grünwald L, Fischer C, Schröter S, Ihle C. Overweight patients benefit from high tibial osteotomy to the same extent as patients with normal weights but show inferior mid-term results. Knee Surg Sports Traumatol Arthrosc 2022;30:907-17. doi: 10.1007/s00167-021-06457-3.
18. Mabrouk A, Risebury M, Yasen S. Medial opening wedge high tibial osteotomy performs similarly irrespective of body mass index. Knee Surg Sports Traumatol Arthrosc 2024;32:2328-41. doi: 10.1002/ksa.12317.
19. Tuhanioğlu Ü, Oğur HU, Seyfettinoğlu F, Çiçek H, Gültekin A. High tibial osteotomy in obese patients: Is successful surgery enough for a good outcome? J Clin Orthop Trauma 2019;10(Suppl 1):S168-73. doi: 10.1016/j.jcot.2018.09.004.
20. Pratobevera A, Seil R, Menetrey J. Joint line and knee osteotomy. EFORT Open Rev 2024;9:375-86. doi: 10.1530/EOR-24-0037.
21. Coventry MB, Ilstrup DM, Wallrichs SL. Proximal tibial osteotomy. A critical long-term study of eighty-seven cases. J Bone Joint Surg [Am] 1993;75:196-201. doi: 10.2106/00004623-199302000-00006.
22. Hernigou P. Open wedge tibial osteotomy: Combined coronal and sagittal correction. Knee 2002;9:15-20. doi: 10.1016/s0968-0160(01)00111-9.

23. Kerimoğlu S, Cavuşoğlu S, Turhan AU. The effect of tibiofemoral angle changes on the results of dome osteotomy. Acta Orthop Traumatol Turc 2008;42:75-9.
24. Akamatsu Y, Kumagai K, Kobayashi H, Tsuji M, Saito T. Effect of increased coronal inclination of the tibial plateau after opening-wedge high tibial osteotomy. Arthroscopy 2018;34:2158-69.e2. doi: 10.1016/j.arthro.2018.01.055.
25. Chao EY, Neluheni EV, Hsu RW, Paley D. Biomechanics of malalignment. Orthop Clin North Am 1994;25:379-86.
26. Ogawa H, Matsumoto K, Ogawa T, Takeuchi K, Akiyama H. Preoperative varus laxity correlates with overcorrection in medial opening wedge high tibial osteotomy. Arch Orthop Trauma Surg 2016;136:1337-42. doi: 10.1007/s00402-016-2521-x.
27. Heijens E, Kornherr P, Meister C. The coronal hypomochlion: A tipping point of clinical relevance when planning valgus producing high tibial osteotomies. Bone Joint J 2016;98-B:628-33. doi: 10.1302/0301-620X.98B5.33394.
28. Park JG, Kim JM, Lee BS, Lee SM, Kwon OJ, Bin SI. Increased preoperative medial and lateral laxity is a predictor of overcorrection in open wedge high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc 2020;28:3164-72. doi: 10.1007/s00167-019-05805-8.
29. Bennell KL, Bowles KA, Wang Y, Cicuttini F, Davies-Tuck M, Hinman RS. Higher dynamic medial knee load predicts greater cartilage loss over 12 months in medial knee osteoarthritis. Ann Rheum Dis 2011;70:1770-4. doi: 10.1136/ard.2010.147082.
30. Mündermann A, Dyrby CO, Hurwitz DE, Sharma L, Andriacchi TP. Potential strategies to reduce medial compartment loading in patients with knee osteoarthritis of varying severity: Reduced walking speed. Arthritis Rheum 2004;50:1172-8. doi: 10.1002/art.20132.
31. Birmingham TB, Giffin JR, Chesworth BM, Bryant DM, Litchfield RB, Willits K, et al. Medial opening wedge high tibial osteotomy: A prospective cohort study of gait, radiographic, and patient-reported outcomes. Arthritis Rheum 2009;61:648-57. doi: 10.1002/art.24466.
32. Atik OŞ. Writing for Joint Diseases and Related Surgery (JDRS): There is something new and interesting in this article! Jt Dis Relat Surg 2023;34:533. doi: 10.52312/jdrs.2023.57916.
33. Floerkemeier S, Staubli AE, Schroeter S, Goldhahn S, Lobenhoffer P. Does obesity and nicotine abuse influence the outcome and complication rate after open-wedge high tibial osteotomy? A retrospective evaluation of five hundred and thirty three patients. Int Orthop 2014;38:55-60. doi: 10.1007/s00264-013-2082-3.