



Original Research

What Determines the Success of Closed-Wedge High Tibial Osteotomy: Severity of Malalignment, Obesity, Follow-up Period, or Age?

Ata Can,¹ Fahri Erdoğan,² Ayse Ovul Erdoğan,¹ İlker Abdullah Sarıkaya,³ Necip Selçuk Yontar¹

¹Nisantasi Orthopedic Center, İstanbul, Turkey

²Department of Orthopaedics and Traumatology, İstanbul University Cerrahpaşa Faculty of Medicine, İstanbul, Turkey

³Ortopediatri Child Orthopedic Academy, İstanbul, Turkey

Abstract

Objectives: High tibial osteotomy (HTO) is a well-established procedure for the treatment of medial knee osteoarthritis originating from malalignment of the lower extremity. The current study was designed to evaluate the clinical and radiographic results of closed-wedge HTO for the treatment of medial knee osteoarthritis and to reveal factors affecting the outcome.

Methods: A retrospective study was conducted with 138 patients who were operated on for medial knee osteoarthritis between 2000 and 2007 using closed-wedge HTO. Preoperative and follow-up physical examination findings, body mass index (BMI) values, and Hospital for Special Surgery (HSS) and Lysholm knee scores were reviewed. Radiographic evaluation included measurement of the mechanical axis preoperatively and the most recent follow-up orthoroentgenograms. The follow-up knee scores were evaluated according to preoperative mechanical axis, obesity, age, follow-up period, and gender of the patient. The mechanical axis measurement was assessed based on obesity, age, and follow-up period.

Results: The mean preoperative and latest follow-up mechanical axis was $4.92^{\circ} \pm 4.24^{\circ}$ varus and $3.43^{\circ} \pm 3.74^{\circ}$ valgus, respectively ($p=0.0001$). Improvement in the Lysholm ($p=0.0001$) and HSS ($p=0.0001$) knee scores was significant. The preoperative mechanical axis, obesity, follow-up period, and gender had no negative effect on the follow-up knee scores, whereas a preoperative age over 50 years had a negative effect on the follow-up knee score.

Obesity and the length of the postoperative follow-up period did not have a negative effect on the postoperative mechanical axis, whereas a preoperative age over 50 had a negative effect on the postoperative mechanical axis.

Conclusion: The results of this study suggest that medial knee osteoarthritis may be treated successfully with closed-wedge HTO. The analysis indicated that factors such as obesity, the degree of preoperative deformity, and gender do not adversely affect the success of treatment. However, a preoperative age over 50 adversely affected the outcome.

Keywords: Age; closed wedge; high tibial osteotomy; malalignment.

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Medial knee osteoarthritis may occur as a result of abnormal loading caused by mechanical knee malalignment.^[1] The aim of high tibial osteotomy (HTO), a well-established procedure, is correction of this malalignment, transferring the load from the affected compartment to the unaffected compartment, and obtaining the recovery of articular cartilage.^[2-4]

HTO has been performed since 1961; however, since most patients are currently treated with either unicondylar (UKA) or total knee arthroplasty (TKA), the use of HTO has declined significantly.^[5-7, 8] Therefore, indications of HTO and factors affecting clinical outcomes, such as age, obesity, preoperative deformity, and patellofemoral joint involvement, should be

Address for correspondence: Ata Can, MD. Nisantasi Orthopedic Center, İstanbul, Turkey

Phone: +90 542 411 83 33 **E-mail:** atababay@yahoo.com

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reevaluated.^[9-13] The objective of this study was to evaluate the clinical and radiographic results of closed-wedge HTO and to reveal the factors affecting the outcome.

Methods

The records of 138 patients (119 women, 86.2%; 19 men, 13.8%) who underwent HTO between 2000 and 2007 for medial knee osteoarthritis were evaluated retrospectively. Those included were patients with primary medial knee osteoarthritis with a corresponding varus deformity on weight bearing radiographs who were younger than 75 years of age and with a loss of extension of less than 10° and a flexion range of minimum 110°. The exclusion criteria were instability, a narrowing of the lateral compartment cartilage space, lateral tibial subluxation of more than 1 cm, severe synovitis, more than 20° of varus correction needed, and rheumatoid arthritis.

The mean age at surgery was 53 years (range: 37-74 years). The mean length of follow-up was 8 years (range: 6-16 years). The patients' preoperative and most recent follow-up physical examination findings, body mass index (BMI), and Hospital for Special Surgery (HSS) and Lysholm knee scores were reviewed. The mechanical axis of the lower extremities was measured preoperatively and at the latest follow-up with standing orthoroentgenograms.

Surgical Technique

A Modified Weber technique^[14] was used. Lateral closed-wedge HTO was performed with tourniquet hemostasis. A mid-diaphysis oblique fibular osteotomy was performed first. Then an incision was made 1 cm distal to the tibiofemoral joint line from the fibular head to the tibial tubercle.



Figure 1. Schematic drawing of the modified Weber high tibial osteotomy technique.

The tibialis anterior muscle was elevated from the tibia subperiostally and the proximal tibiofibular joint was released. A 6- or 7-hole semitubular plate was inserted into the tibial epiphysis 1 cm distal and parallel to the joint line from lateral to medial. First, the proximal osteotomy was made 1 cm distal to the plate parallel to the joint line from the lateral cortex of the tibia to the medial cortex using an oscillating saw. A second osteotomy was made distal to the first osteotomy from the lateral cortex to the medial cortex to form a lateral-based triangle to achieve the correction previously calculated. The medial cortex of the tibia was left intact. A wedge of bone was removed and fixation of the osteotomy was performed by bending the lateral end of the semitubular plate until it was parallel to the tibia and inserting an oblique 4.5-mm cortical screw (Figs. 1, 2a and

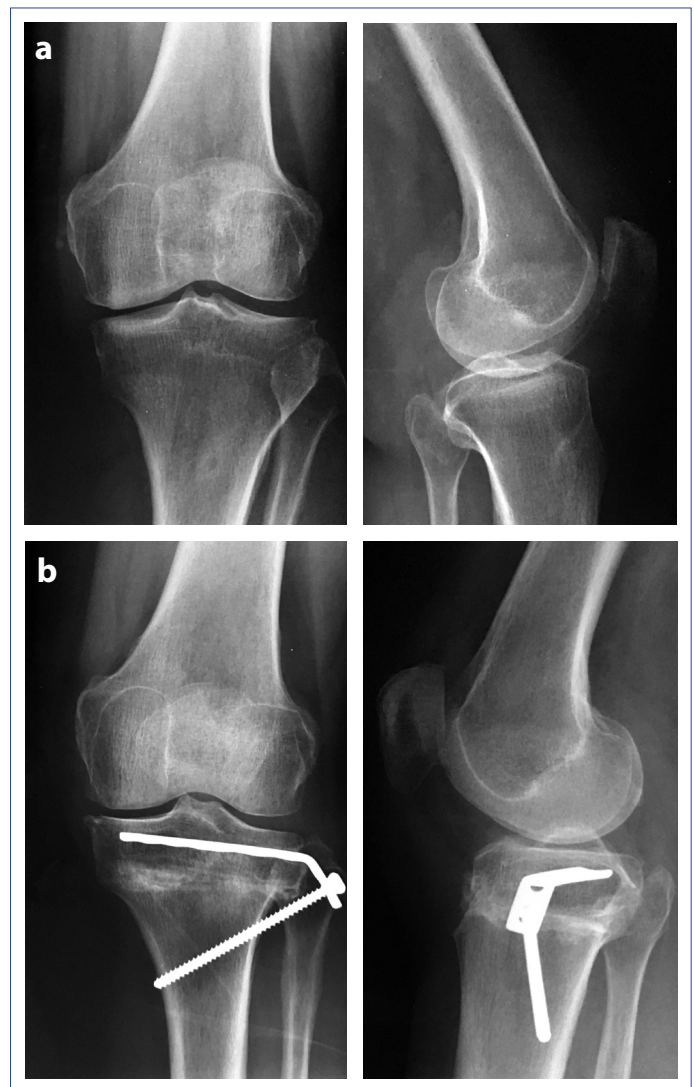


Figure 2 (a, b). X-ray of the left knee of a female patient who was 47 years old at surgery, preoperative (a) and 6 years postoperatively (b). The patient is very satisfied with the surgery with a Lysholm knee score of 94 and a Hospital for Special Surgery knee score of 86. Note the postoperative valgus alignment.

2b). Range of motion and isometric quadriceps exercises were initiated on the postoperative first day and the patients were ambulated with partial weight-bearing with crutches for 6 weeks.

The data were examined using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). The results were analyzed using descriptive statistical methods and the Student's t-test and the Mann-Whitney U test were used to gain mean values in the comparison of 2 groups. For differences between preoperative and postoperative values, a paired t-test and the Wilcoxon rank test were used. The Pearson correlation test was applied to determine the relationship between knee score and mean mechanical axis. The results were evaluated at a 95% confidence interval and a level of significance of $p < 0.05$.

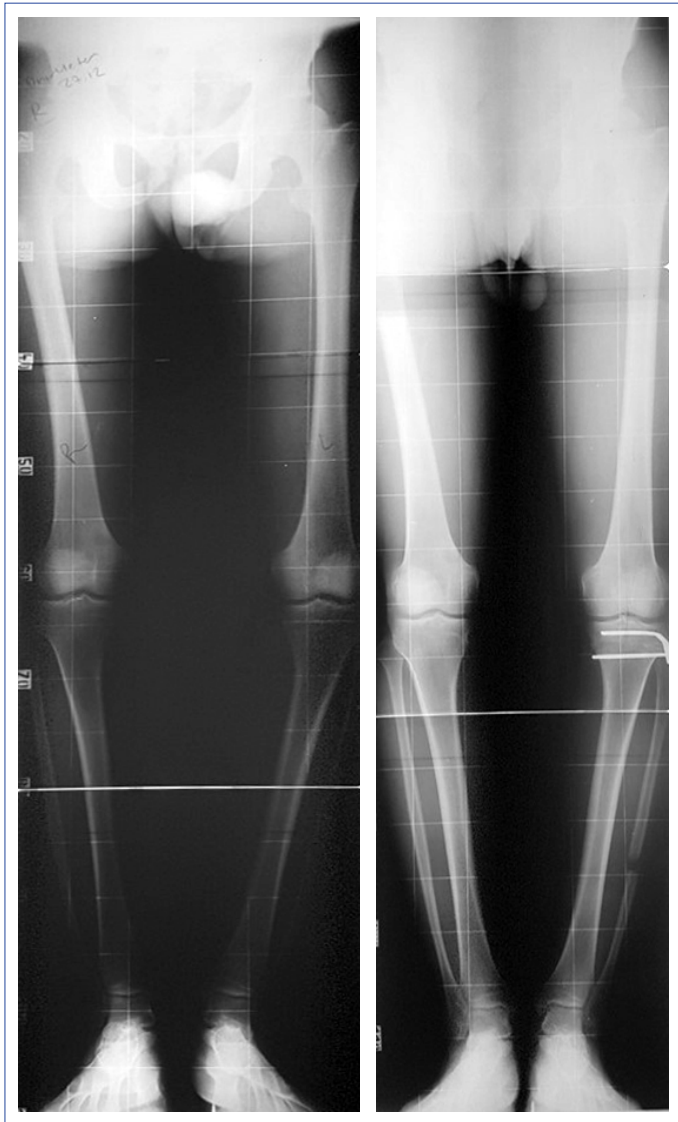


Figure 3. Preoperative and postoperative 18th-month follow-up orthoroentgenograms.

Results

The mean preoperative and last follow-up mechanical axis was $4.92 \pm 4.24^\circ$ varus and $3.43 \pm 3.74^\circ$ valgus, respectively. Improvement of the mechanical axis was significant ($p = 0.0001$). (Fig. 3) Preoperatively, the mean flexion was $110.66 \pm 10.98^\circ$ (range $90-130^\circ$) and the mean extension was $-0.76 \pm 1.92^\circ$ (range: $-5-2^\circ$) and these values did not change postoperatively. The pre- and postoperative Lysholm knee score was 80.99 ± 9.78 and 85.84 ± 10.66 , respectively ($p = 0.0001$). The pre- and postoperative HSS knee score was 69.07 ± 7.33 and 76.05 ± 10.62 , respectively ($p = 0.0001$). The improvement in the Lysholm and HSS knee scores was significant. No correlation was found between follow-up knee score and preoperative mechanical axis (Lysholm knee score: $r = -0.081$; HSS knee score: $r = -0.136$).



Figure 4. Preoperative and postoperative follow-up orthoroentgenograms of a 57-year-old female patient.

The mean preoperative and last follow-up BMI was 28.53 ± 3.67 kg/m² and 27.91 ± 4.24 kg/m², respectively. The number of patients with a BMI below 30 kg/m² was 65 and 73 patients had a BMI over 30 kg/m². The difference in the pre- and postoperative BMI was not significant ($p > 0.05$). The difference in the follow-up knee score between obese and non-obese patients was not significant (HSS: $p = 0.405$; Lysholm: $p = 0.137$) (Table 1, Fig. 4). The difference in the follow-up mechanical axis between obese and non-obese patients was not significant either ($p > 0.05$) (Table 2).

At the time of surgery, 48 patients were 50 years old or younger and 90 patients were older than 50 years of age. The difference in the follow-up knee score based on age

was significant (HSS: 81.96 ± 11.15 vs 72.90 ± 8.97 , $p = 0.0001$; Lysholm: 93.65 ± 7.27 vs 81.68 ± 9.84 , $p = 0.0001$) (Table 3). The difference in the follow-up mechanical axis between the age groups was also significant (≤ 50 years: 5.67 ± 4.82 vs > 50 years: 4.52 ± 4.24) ($p = 0.003$).

The number of patients followed up for fewer than 8 years was 72, while 66 patients were followed up for more than 8 years. The difference in the follow-up knee score between the groups according to the length of the postoperative follow-up period was not significant (HSS: $p = 0.084$; Lysholm: $p = 0.458$). The difference in the mechanical axis between the postoperative follow-up period groups was not significant either ($p = 0.080$) (Table 2). Nor was the differ-

Table 1. Obesity (Body mass index > 30 kg/m²) and follow-up knee scores

	Obese (n=65)		Non-obese (n=73)		p
	Average	Standard deviation	Average	Standard deviation	
Preoperative HSS knee score	69.48	7.26	68.70	7.43	0.535
Follow-up HSS knee score	76.85	10.56	75.34	10.77	0.405
Preoperative Lysholm knee score	81.92	8.94	80.15	10.46	0.285
Follow-up Lysholm knee score	87.26	9.81	84.58	11.29	0.137

HSS: Hospital for Special Surgery scoring system.

Table 2. Correlation between mechanical axes and age, follow-up period, and obesity

	Preoperative mechanical axes			Follow-up mechanical axes		
	Mean	Standard deviation	Median	Mean	Standard deviation	Median
Age ≤ 50 years	5.67	4.82	6.50	-4.83	4.26	-5.00
Age > 50 years	4.52	4.24	4.50	-2.69	3.21	-3.00
p	0.160			0.003		
Follow-up < 8 years	5.24	4.13	5.00	-3.97	3.36	-4.50
Follow-up ≥ 8 years	4.58	4.37	4.50	-2.85	4.05	-3.00
p	0.365			0.080		
Obesity	4.52	4.63	4.00	-3.55	3.87	-3.50
No obesity	5.27	3.87	6.00	-3.33	3.64	-4.00
p	0.307			0.726		

Table 3. Correlation between age and knee scores

	Age ≤ 50 years (48 patients)		Age > 50 years (90 patients)		p
	Mean	Standard deviation	Mean	Standard deviation	
Preoperative HSS knee score	69.19	7.87	69.00	7.08	0.891
Follow-up HSS knee score	81.96	11.15	72.90	8.97	0.0001
Preoperative Lysholm knee score	81.19	9.17	80.88	10.13	0.856
Follow-up Lysholm knee score	93.65	7.27	81.68	9.84	0.0001

HSS: Hospital for Special Surgery scoring system.

ence in the follow-up knee score between male and female patients significant. (HSS: $p=0.128$; Lysholm: $p=0.734$).

There were a total of 11 complications. There was a superficial wound infection in 5 patients, delayed union in 4, and transient peroneal nerve palsy in 2. None of the complications affected the final outcome.

Discussion

Medial knee osteoarthritis is one of the most common joint disorders and the consequences of malalignment of the lower extremity are apparent. HTO is an important option for the correction of the malalignment causing osteoarthritis.^[7, 8, 15-17] However, because of the rapidly increasing numbers of UKA and TKA performed, HTO has become questionable when considering factors such as gender, age, or obesity. This study showed that satisfactory outcomes may be achieved with closed-wedge HTO and that preoperative severity of the deformity, obesity, and gender did not adversely affect the outcome.

We used the modified Weber technique,^[14] which provides several advantages, including high stability of the osteotomy through the tension band principle with large bone contact areas and the possibility of bone impaction, intraoperative correction of the osteotomy, no increase in pressure in the medial compartment through tensioning of the medial collateral ligament, no increase of pressure in the patellofemoral joint, and no bone graft.

Numerous published studies have reported the outcomes of HTO.^[11, 18-21] Akizuki^[22] reported a survival rate of 90.4% after a 15-year follow-up period, and Hui^[17] achieved a mean 40-point Oxford Knee Score with HTO. Sprenger^[10] reported that the mean HSS knee score remained above 70 after a 7.4-year follow-up period. We also found that an 8.5° improvement of the mechanical axis was achieved after an 8-year follow-up period and that HSS and Lysholm knee scores were significantly improved.

Many authors believe that the new knee alignment obtained by HTO is a determinant of the clinical outcome, but a consensus has not been achieved on the ideal alignment.^[10, 21, 23-25] Overcorrection has been recommended by many authors.^[6, 9, 10, 12, 18, 26] Sprenger^[10] suggested that 8°-16° of valgus alignment at the postoperative first year should be decisive for a successful outcome. Naudie^[26] also reported that failure to obtain postoperative valgus alignment or deterioration of the valgus alignment at the first postoperative year can adversely affect clinical outcomes. However, many authors have claimed that overcorrection is not a determining factor on the clinical results and have argued that overcorrection is not necessary for HTO.^[22, 27] In this series of patients, a mean improvement from varus to

valgus alignment of 8.5° was achieved, which we believe had a positive impact on the clinical outcome. The severity of preoperative varus deformity was seen to be among the factors that reduced the success of HTO by many authors.^[21, 25, 28] Huang^[25] concluded that 9° of varus was a critical threshold and suggested that more severe varus deformities affect clinical outcomes adversely. However, we found that the severity of the preoperative varus deformity did not have a significant unfavorable effect on the success of HTO, as some other authors have noted.^[3, 6, 29]

Obesity has an important role in the pathogenesis of osteoarthritis.^[30-32] Many studies have shown that a greater BMI may reduce the success of HTO, as in TKA.^[6, 9, 11, 16, 17, 29, 30-35] Giagonoudis^[11] reported that patients with a BMI of less than 10% of normal have a longer painless postoperative period compared with patients with a BMI of more than 10% of normal. Miller^[36] found that a greater BMI led to a loss of the improvement achieved by HTO. However, some authors argue that obesity is not an obstacle for HTO.^[10, 25, 26] Jakop et al.^[37] reported that successful results can be obtained with obese patients, especially in the pain parameter, because they are less mobile in the postoperative period, so the degenerative process is slower. We also concluded that an increased BMI was not an obstacle for HTO.

Many studies have claimed that older age may lead to failure in the clinical results of HTO, and authors have pointed out that HTO should be performed before age 50.^[3, 9, 12, 25, 26, 29] Several other studies argue against this finding.^[6, 10, 21, 27, 38] In this study, the patients were divided into 2 groups according to age: those who underwent surgery at or before age 50, and those aged 50 years or more. The outcome was poorer in the operations performed after the age of 50. Given that the share of TKA in the overall health budget has increased rapidly in elderly patients in recent years, it should be kept in mind that HTO may be an appropriate treatment option for selected elderly patients.^[39]

Many studies have demonstrated that gender is a factor affecting the success of HTO.^[21, 38] Flecher et al.^[29] argued that after reviewing 18-year follow-up data of 313 patients treated with the closing wedge HTO, they found that gender did not affect the clinical results. The clinical and radiographic results of our study demonstrated, as many other studies have, that gender had no significant effect on the results of HTO.

As some studies have reported that successful outcomes obtained with HTO may deteriorate over time, other treatment methods have become popular for osteoarthritis.^[3, 6, 9, 12, 18, 21, 25, 29] Hui^[17] found a survival rate of closed-wedge HTO at 5, 10, and 15 years of 95%, 79%, and 56%, respectively, and reported that after a 15-year period, significant dete-

rioration occurred in the clinical results. However, Choi et al.^[40] demonstrated continuation of successful results after a mean 15.3 years of follow-up. Like many authors, they claimed that the follow-up period had no negative effect on the clinical results.^[41] In the current study, although the clinical and radiographic results deteriorated after 8 years of follow-up, this was not statistically significant.

The limitation of this study is that the number of patients included was relatively small. However, the size of this group of heterogeneous patients was sufficient to show the effects of age, BMI, severity of preoperative deformity, and gender.

Conclusion

In conclusion, the results of this study with a mean 8-year follow-up suggest that medial compartment osteoarthritis can be treated successfully with lateral closing wedge HTO. Factors such as obesity and the degree of preoperative deformity did not adversely affect the success of treatment, but age did have a significant effect.

Disclosures

Ethics Committee Approval: The study was approved by the Local Ethics Committee.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship contributions: Concept – A.C., F.E.; Design – A.O.E.; Supervision – F.E.; Materials – İ.A.S., A.C.; Data collection &/or processing – A.O.E., N.S.Y.; Analysis and/or interpretation – İ.A.S., A.O.E.; Literature search – İ.A.S., N.S.Y.; Writing – İ.A.S., N.S.Y.; Critical review – A.C., F.E.

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