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The effects of monoplanar and biplanar medial open wedge high tibial osteotomy on pain and functional capacity

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Abstract. – OBJECTIVE: This prospective cross-sectional study aimed to compare the effects of operation types on pain and functional capacity in patients who underwent monoplanar and biplanar medial open wedge high tibial osteotomy.

PATIENTS AND METHODS: The study included a total of 117 patients who presented at our clinic between January 2012 - January 2016 and underwent monoplanar (n=63) and biplanar (n=54) medial open wedge high tibial osteotomy. The groups were evaluated in age, gender, Body Mass Index (BMI), operation side, operation time, follow-up period, Modified Insall Salvati ratio, Blackburn Peel Index (BPI), Slope, Knee Society Function Score (KSSF), Knee Society Score (KSSK), Visual Analog Scale (VAS), Kellgren Lawrence score, tibiofemoral angle varus, and Tegner score.

RESULTS: Most of the patients in the monoplanar group were operated on the right side, while most patients in the biplanar group on the left side, and the difference between the groups was significant ($p<0.05$). The operation time was significantly longer in the biplanar group, while the duration of follow-up was statistically significantly longer in the monoplanar group ($p<0.05$). The preoperative BPI and Kellgren Lawrence scores were significantly higher in the monoplar group, while BMI, KSSK, and tibiofemoral angle varus scores were statistically significantly higher in the biplanar group ($p<0.05$). Postoperative VAS and Kellgren Lawrence scores were higher in the monoplanar group, and the Modified Insall Salvati ratio, BPI, BMI, KSS function score, KSSK score, tibiofemoral angle varus, and Tegner scores were statistically significantly higher in the biplanar group ($p<0.05$). Postoperatively, the mean VAS score was lower in the biplanar group, and the range of change was greater. In the monoplanar group, the postoperative VAS values were closer to each other and were higher than in the biplanar group. The mean postoperative KSS function score was higher in the biplanar group, and the range of change was higher in the monoplanar group.

CONCLUSIONS: The study results showed that biplanar medial open wedge high tibial osteotomy was more successful in terms of both pain and functional capacity. However, the operation time was longer than the monoplanar method.

Key Words:
Monoplanar, Biplanar, Medial open wedge, Tibial osteotomy.

Introduction

High tibial osteotomy (HTO) is a surgical method that is performed by shifting the load-bearing axis of the lower extremity to the side, based on postoperative valgus alignment, and it is used in the treatment of varus deformity and cartilage damage in the medial compartment and osteoarthritis[1,2]. Valgus regulation is performed with a plate system. HTO, which is based on fixation and alignment principles, can be performed as biplanar or monoplanar[3,4]. Biplanar osteotomy is mostly performed in the coronal and sagittal planes[3]. However, it has been reported[5,6] that patella-femoral problems may occur in osteotomies performed in a single plane.

Although there are studies[7,12,15] in the literature reporting that the results of monoplanar and biplanar medial open wedge tibial osteotomy are similar, there are others[6,17,20] reporting differences. Elmali et al[7] evaluated the results of monoplanar and biplanar medial open wedge tibial osteotomy in gonarthrosis cases with varus deformity and reported that both methods were effective, and there was no significant difference between them. In another study, Türkmen et al[8] reported that the biplanar method is more reliable than the monoplanar method for wider lateral cortex fractures. These and similar studies[6,8,15] indicate that there may be significant differences between bi-

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planar and monoplanar methods in patients who undergo medial open wedge high tibial osteotomy, and the difference between these methods should be examined. The aim of this prospective cross-sectional study was to compare the effects of operation types on pain and functional capacity in patients who underwent monoplanar and biplanar medial open wedge high tibial osteotomy.

Patients and Methods

This prospective, randomized, controlled study was initiated after the approval of the Local Ethics Committee and included 117 patients who underwent monoplanar (n=63) and biplanar (n=54) medial open wedge high tibial osteotomy with at least five years of follow-up. The patients who accepted the surgical treatment were randomized using the online randomization tool Research Randomizer (https://www.randomizer.org/). Detailed explanations of the high tibial osteotomy surgical procedure were provided to the patients, accompanied by illustrations. All possible complications, such as neurovascular damage during and after osteotomy, intra-articular fracture, infection, nonunion at the osteotomy site, delayed union, limited knee mobility, persistent pain, inadequate deformity correction, and development of venous thromboembolism were described in detail. Precautions to prevent these complications and treatment options in case of their occurrence were explained. Informed consent was obtained from all patients, accompanied by their legal representatives and/or immediate family members, after discussing these matters. Patient gender, age, operation side, operation time, follow-up period, Modified Insall Salvati ratio, Blackburn Peel Index (BPI), Slope, Body Mass Index (BMI), Knee Society Function Score (KSSF), Knee Society Score (KSSK), Visual Analog Scale (VAS), Kellgren Lawrence score, tibiofemoral angle and Tegner parameters were compared according to the findings obtained preoperatively and at the final follow-up examination. Preoperative and final follow-up evaluations were made by a physician other than the surgeon. Patients aged 40-65 with medial knee pain and varus deformity, medial compartment osteoarthritis, physically active, suitable for postoperative follow-up and rehabilitation, and non-smokers were included in the study. Patients who did not give consent to participate in the study, those who required secondary surgery after the initial procedure, those who could not be followed up for at least five years, those with a diagnosis of traumatic arthritis, those with inflammatory arthritis, those who developed varus deformity secondary to trauma, those with anterior and/or posterior cruciate ligament injury, those with multiple ligament injuries in the knee, those with neurovascular injury or previous surgery in the same or opposite knee, those with a knee range of motion <90°, those with a flexion contracture ≥15°, those requiring ≥20° overcorrection, those with a mechanical lateral distal femoral angle of over 90 degrees and a mechanical tibial angle of over 95 degrees after correction, those with osteoarthritis affecting the medial, lateral, and anterior compartments of the knee, those with diabetes, those who are immunosuppressed for any reason, or those who have been diagnosed with cancer and are under follow-up were excluded from the study. Patients with medial compartment kissing lesions (Ahlback stage III lesion on the medial tibial surface) and those with lateral meniscus injuries were also excluded from the study.

The surgeries were performed under spinal anesthesia with a high thigh tourniquet on the affected side. Appropriate sterilization and draping were applied. The tourniquet was inflated before arthroscopy. In cases where it was necessary, degenerated meniscus, irregular cartilage sections, and osteophytes were cleaned, and osteochondritis dissecans were removed. Microfracture is performed in cases where the subchondral bone is exposed, and this was applied to all the patients included in the study. A longitudinal 7-8 cm skin incision was made over the midline, just below the joint level, and distally in the knee held in extension. The incision was made from the midline, including the tibial tubercle to which the patellar tendon is attached. On the medial part of the proximal tibia, the short part of the periosteum was cut in the form of an inverted "L" facing posteriorly. The attachment site of the pes anserinus was stripped from the tibia together with the periosteum. Retrotubercle osteotomy is a two-plane osteotomy method. The osteotomy line in the horizontal plane starts 3.5-4 cm distal to the joint line, parallel to the joint in the sagittal plane. A Kirschner wire (K-wire) was advanced from medial to lateral towards the head of the fibula, directly or with the help of a guide, in the oblique direction under fluoroscopy guidance (Figures 1-2). If the first K-wire was appropriate, two or three more K-wires were advanced in the same way. When the direction of the guide wires was confirmed as correct, the medial cortex was cut

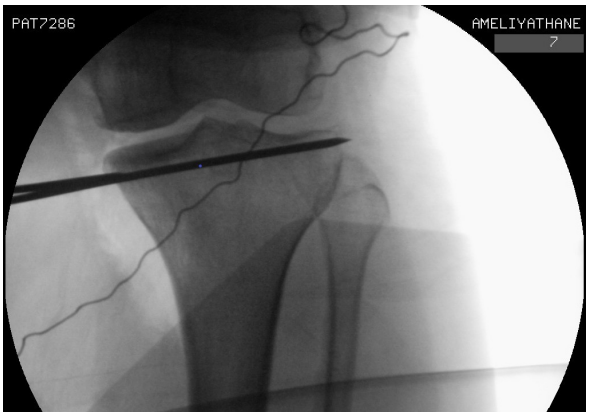

Figure 1. Placement of a first K-wire targeting the fibula head and a second K-wire placed parallel and anterior to the first.

below the wires using a cutting motor with a thin tip. The same cutting operation can be performed with an osteotome with a thin cutting tip. When cutting the medial cortex, the osteotomy should be terminated at a distance of 2/3 of the width of the tibia 1-1.5 cm distal to the articular line and 1 cm from the lateral cortex, leaving sufficient bone stock at the base of the tibial tubercle anteriorly. With the osteotomy performed behind the tibial tubercle in the oblique plane, the tibial tubercle and the patellar tendon attached to it are left in the proximal fragment. The length of this oblique beak should be at least 2.5 cm. The beak part is marked with cautery and first pierced with K-wires in the mediolateral plane. Then, the incision in the oblique plane is completed with a fine-tipped cutting motor or osteotome. The posterior cortex is cut with an osteotome. Controlled distraction can be applied by placing a third and, if necessary, a fourth osteotome between the two osteotomes guided to the osteotomy line under fluoroscopy guidance. An inverted "L"-shaped four-hole plate with an anterior wedge height of 1-2 mm shorter than posterior was applied (Figure 3). The plates are designed in the form of an inverted "L" with four holes and are shaped during the production phase to adapt to the anatomic inclination of the medial side of the upper end of the tibia during application (Figure 4). The screw slots were opened in such a way that the proximal of the osteotomy would be spongy, the distal cortical screw would be applied, and the screw heads would not protrude onto the plate (Figures 5-6). The opening was filled with allograft (Figure 7). The beak-shaped projection where the tibial tubercle is located was fixed to the double cortex tibia with two cortical screws in the anterior-posterior. Bleeding was controlled by opening the tourniquet. During the closure process, only the long leg of the soft tissue connected to the medial part of the proximal tibia with the attachment of the pes anserinus was sutured. After the surgery, a pressurized Jones bandage was applied. First-generation cephalosporin was administered preoperatively and was then continued for two days. Low molecular weight heparin administration was continued during the hospital-

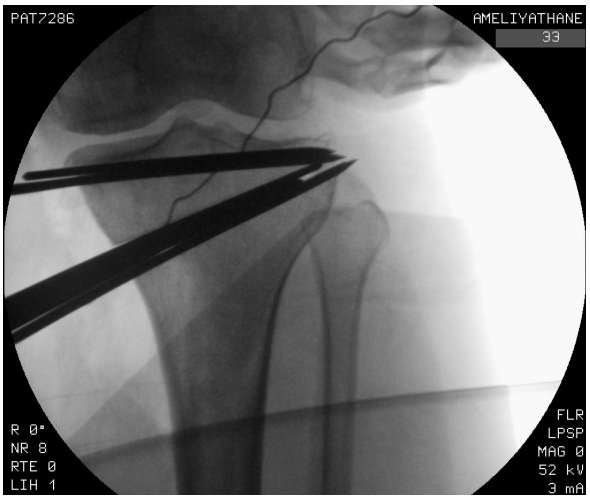

Figure 2. Planning the osteotomy level approximately 3.5-4 cm distal to the lateral tibial joint line, extending towards the lateral hinge located approximately 1 cm below the lateral proximal joint line and about 0.5 cm medial to the lateral cortex.

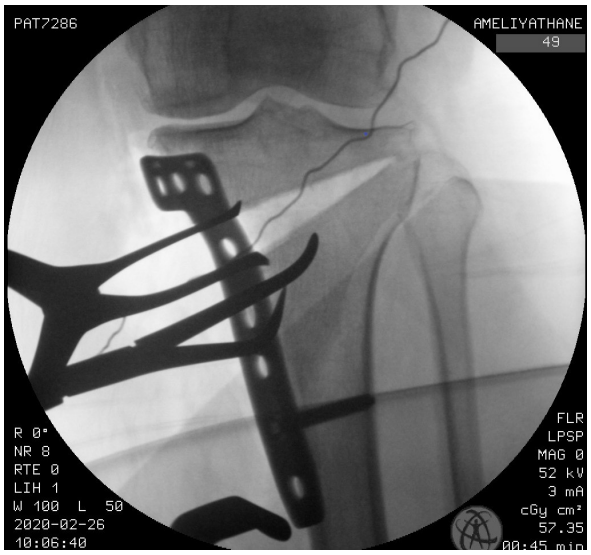

Figure 3. Placement of a 4-hole reversed 'L' shaped plate after resection of the wedge.

Figure 4. Fluoroscopy image showing the placement of a 4-hole reversed 'L' shaped plate on the medial osteotomy, along with two 3.5 mm screws brought in the anterior-posterior direction to stabilize the lengthening osteotomy.

ization period, and 100 mg of acetylsalicylic acid was started after discharge.

After the drains were removed, knee movements were started with a continuous passive movement (CPM) device and at the bedside (without braces). It was aimed to reach 90° knee movement in the first week. In the following days, full extension and flexion movement in the knee joint were targeted. Partial weight-bearing was permitted up to the 12th week and then full weight-bearing with crutches at the end of the 12th week following radiographic checking of microfracture. The use of the crutches was decreased one at a time.

Statistical Analysis

Data obtained in the study were analyzed statistically using SPSS 17 (SPSS Inc., Chicago, IL, USA). Continuous variables were stated as mean and standard deviation values, and categorical variables as numbers and percentages. The Chi-square test was used in the analysis of categorical data. The conformity of the data to normal distribution was analyzed with the Kolmogorov-Smirnov Test. The Independent Samples *t*-test was applied in the evaluation of differences between two groups of data showing normal distribution, and the Paired Samples *t*-test was used for within-group comparisons. The Mann-Whitney U test was used for the difference between the two groups of parameters that did not show normal distribution, and the Wilcoxon Signed Rank test was used for in-group comparisons. All analyses were performed at a 95% confidence interval. A p-value<0.05 was accepted as the level of statistical significance.

Results

The differences between gender and age distributions were not statistically significant in both groups (p>0.05). Most of the patients in the monoplanar group had the intervention on the right side, while the majority of the patients in the biplanar group on the left side, and the differences between the groups were significant (p<0.05). The operation time was significantly longer in the biplanar group, while the duration of follow-up was statistically significantly longer in the monoplanar group (p<0.05) (Table I).

The preoperative BPI and Kellgren Lawrence scores were statistically significantly higher in the

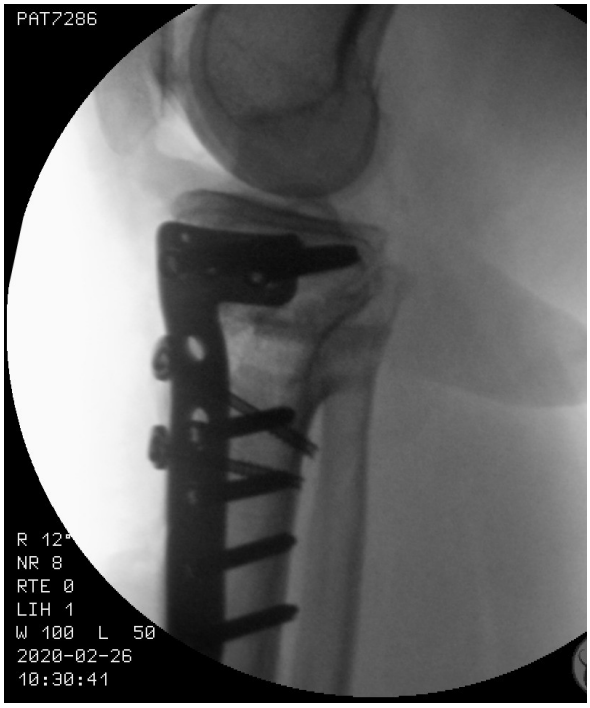

Figure 5. Intraoperative lateral fluoroscopy image.

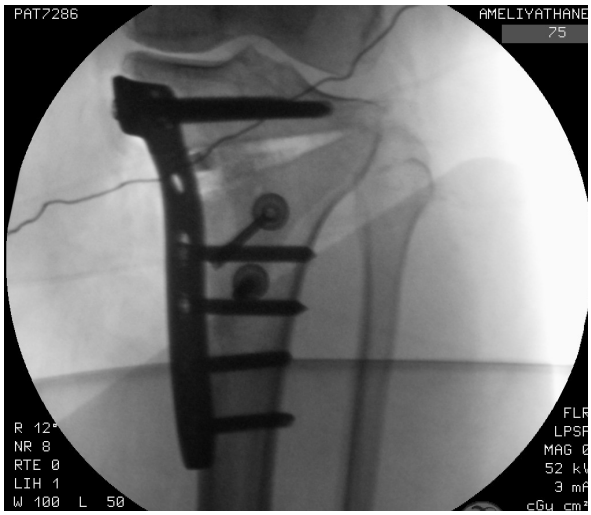

Figure 6. Intraoperative anteroposterior fluoroscopy image.

Figure 7. Filling the opening with an allograft.

monoplar group, and the BMI, KSS and tibiofemoral angle varus scores were statistically significantly higher in the biplanar group ($p<0.05$). Postoperatively, the VAS and Kellgren Lawrence scores were statistically significantly higher in the monoplanar group, and the Modified Insall Salvati ratio, BPI, BMI, KSS function and KSSK score, tibiofemoral angle varus and Tegner scores were statistically significantly higher in the biplanar group ($p<0.05$). Postoperatively, the modified Insall Salvati ratio and BPI decreased in the monoplanar group ($p<0.05$), and the BPI value increased in the biplanar group. (Table II)

According to the analyses of the preoperative to postoperative differences within the groups, the difference in slope was not statistically significant in both groups ($p>0.05$). The Modified Insall Salvati ratio and BPI significantly differed after the operation in both groups ($p<0.05$). While both values decreased in the monoplanar group, the BPI value decreased in the biplanar group. The decrease in the monoplanar group was greater and worse results were obtained. The postoperative values of BMI, KSS function score, KSSK score, VAS, Kellgren Lawrence score, tibiofemoral angle, and Tegner score showed statistically significant differences in both groups compared to the preoperative values ($p<0.05$). The changes in the Modified Insall Salvati ratio, BPI and tibiofemoral angle were greater in the monoplanar group than in the biplanar group. The differences

Table I. Baseline characteristics of the patient groups.

	Monoplanar (n=63)	Biplanar (n=54)	*p*-value
Gender, n (%)			
Male	14 (22.2)	19 (35.2)	0.120[a]
Female	49 (77.8)	35 (64.8)	
Age (years), mean ± SD	56.17±3.66	55.67±4.05	0.477[b]
Side, n (%)			
Right	34 (54.0)	18 (33.3)	0.025[a]
Left	29 (46.0)	36 (66.7)	
Operation duration (mins) mean ± SD	55.44±5.58	**61.67±8.15**	0.000[b]
Follow-up duration (months), mean ± SD	**71.76±5.37**	67.11±6.07	0.000[b]

[a]Chi-Square Test, [b]Independent Samples *t*-test. SD: Standard Deviation.

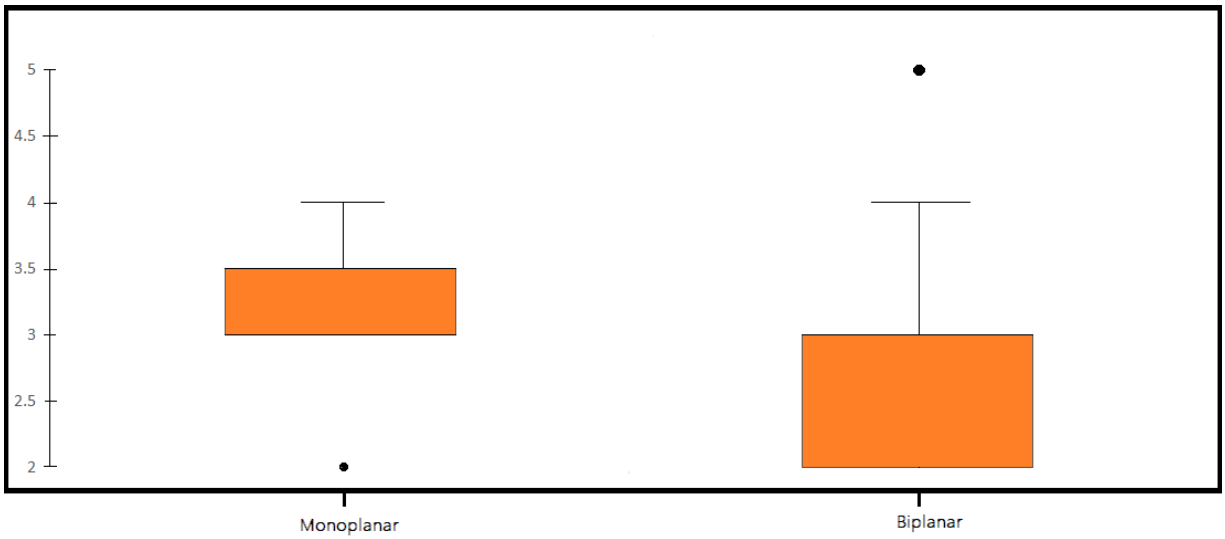

Figure 8. The postoperative mean VAS score was lower in the biplanar group, and the amount of change was greater. In the monoplanar group, the postoperative VAS values were closer to each other and higher.

in BMI, KSS function score, KSSK score, VAS, Kellgren Lawrence score and Tegner score were higher in the biplanar group. The KSS function score, KSSK score and Tegner score were higher in the biplanar group. In parallel, VAS and the Kellgren-Lawrence score were higher in the monoplanar group (Table III).

The postoperative mean VAS score was lower in the biplanar group, and the amount of change was greater. In the monoplanar group, the postoperative VAS values were closer to each other and higher (Figure 8).

The postoperative mean KSS function score was higher in the biplanar group, and the range of variation was higher in the monoplanar group. Therefore, the postoperative KSS function score was higher and consistent in the biplanar group compared to the monoplanar group (Figure 9).

Discussion

Medial open wedge high tibial osteotomy is the method used in the treatment of symptomatic varus alignment. In addition to the advantages of this method, there are also known to be disadvantages, such as decreased patellar height and increased posterior tibial inclination[9,10]. However, with the

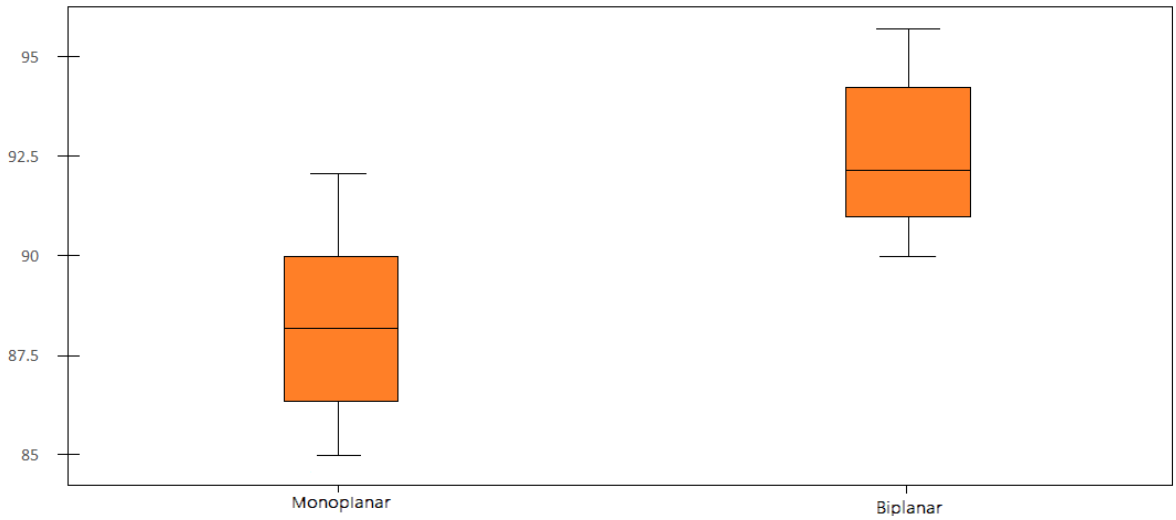

Figure 9. The postoperative mean KSS function score was higher in the biplanar group, and the range of variation was higher in the monoplanar group. Therefore, the postoperative KSS function score was higher and consistent in the biplanar group compared to the monoplanar group.

Table II. Preoperative and postop scores of the patient groups.

	Monoplanar (n=63)	Biplanar (n=54)	*p*-value
Preoperative			
Modified Insall Salvati ratio	1.44±0.09	1.47±0.10	0.163[a]
BPI	0.87±0.15	0.81±0.15	0.031[b]
Slope	7.67±1.93	7.65±1.85	0.883[b]
BMI	27.20±4.20	28.97±4.02	0.022[a]
KSS function score	55.27±10.45	55.11±11.59	0.993[b]
KSSK score	50.56±5.04	52.67±5.27	0.029[a]
VAS	7.37±0.89	7.17±1.09	0.429[b]
Kellgren Lawrence score	3.22±0.58	2.93±0.54	0.006[b]
Tibiofemoral angle	7.00±1.78	8.39±2.19	0.000[a]
Tegner	2.89±0.60	2.67±0.78	0.127[b]
Postoperative			
Modified Insall Salvati ratio	1.37±0.08	1.46±0.09	0.000[a]
BPI	0.69±0.13	0.80±0.14	0.000[b]
Slope	7.51±1.86	7.63±1.71	0.989[b]
BMI	29.53±3.69	31.94±4.01	0.001[a]
KSS function score	88.32±2.28	92.44±1.72	0.000[b]
KSSK score	86.27±2.89	90.20±2.69	0.000[b]
VAS	3.17±0.55	2.80±0.83	0.003[b]
Kellgren Lawrence score	2.44±0.50	1.98±0.60	0.000[b]
Tibia femor angle varus	3.25±1.12	4.94±1.48	0.000[a]
Tegner	4.84±0.70	5.57±1.02	0.000[b]

[a]Independent Samples *t*-test, [b]Mann-Whitney U-test. BPI: Blackburn Peel Index; BMI: Body Mass Index; KSS: Knee Society Score; KSSK: Knee Society Score-Knee; VAS: Visual Analog Scale.

Table III. Mean differences within the groups (preoperative-postoperative difference analysis results).

	Monoplanar (n=63)			Biplanar (n=54)		
	Mean difference	SD	*p*	Mean difference	SD	*p*
Modified Insall Salvati ratio	**-0.07**	0.05	0.000[a]	-0.01	0.01	0.044[a]
BPI	**-0.18**	0.06	0.000[b]	-0.01	0.05	0.021[b]
Slope	-0.16	1.64	0.771[b]	-0.02	0.53	0.796[b]
BMI	2.33	3.35	0.000[a]	**2.97**	4.34	0.000[a]
KSS function score	33.05	10.26	0.000[b]	**37.33**	11.65	0.000[b]
KSSK score	35.71	5.38	0.000[b]	**37.54**	4.46	0.000[b]
VAS	-4.19	1.09	0.000[b]	**-4.37**	1.01	0.000[b]
Kellgren-Lawrence score	-0.78	0.73	0.000[b]	**-0.94**	0.68	0.000[b]
Tibiofemoral angle	-3.75	2.49	0.000[b]	-3.44	3.22	0.000[b]
Tegner	1.95	0.92	0.000[b]	**2.91**	1.19	0.000[b]

[a]Paired Samples *t*-test, [b]Wilcoxon Signed Rank Test. SD: Standard Deviation; BPI: Blackburn Peel Index; BMI: Body Mass Index; KSS: Knee Society Score; KSSK: Knee Society Score-Knee; VAS: Visual Analog Scale.

development of different planar techniques and methods, great progress has been made in resolving these problems.

Studies[9,12,15] in the literature have reported that high tibial osteotomy is effective against the problem of patella height reduction. The gold standard measurement used for patella height is the Insall-Salvati Ratio (ISR), which is calculated by dividing the patellar tendon length by the patellar length. There are studies[11] in literature showing that the ISR varies according to factors such as gender and race. Longino et al[12] reported that the reduction in patella height was minimized in patients who underwent high tibial osteotomy with tibial tubercle osteotomy. In a study by Park et al[13], the ISR was reported to be 1.02 in the preop-

erative open wedge high tibial osteotomy group, and 1.01 in the open wedge high tibial osteotomy and distal tubercle osteotomy group. Postoperatively, the mean value was 0.97 in the open wedge high tibial osteotomy group and 1.00 in the open wedge high tibial osteotomy and distal tubercle osteotomy group. In that study, the differences between the groups were significant before and after the operation, and it was seen that the preoperative to postoperative differences within the groups were significant.

In the current study, the modified ISR was 1.44 preoperatively and 1.37 postoperatively in the monoplanar group and 1.47 and 1.46, respectively, in the biplanar group. Although the decrease was statistically significant in both groups, a greater decrease was observed in the monoplanar group compared to the biplanar group. In addition, postoperative slope changes were not statistically significant in both groups. In other words, the operations did not cause tibial malpositioning in either group.

The slope value was mean 7.67 preoperatively and 7.51 postoperatively in the monoplanar group, and 7.65 and 7.63, respectively, in the biplanar group. There was no significant difference between the two groups in respect of gender and age, thereby indicating that the direct method was effective in patella height change. Consistent with the findings of previous studies[11-13] in the literature, there was a lower decrease in patella height in the biplanar group of the current study.

Clinical studies[1,2,9,10] of open wedge high tibial osteotomy in the literature indicates various demographic characteristics and do not clearly reveal a specific demographic risk pattern. In the current study, female patients were in the majority in both groups, and the difference between the groups was not significant. The mean age of the patients was 56.17 years in the monoplanar group and 55.67 years in the biplanar group, with no significant difference determined between the groups. The operated side was the right side in the majority of patients in the monoplanar group and the left side in the majority of the biplanar group, with a significant difference determined. The operation time was longer in the biplanar group.

There are few studies[14] in the literature that have compared the monoplanar and biplanar methods of medial open wedge high tibial osteotomy, and limited studies[15,16] dealing with the proximal high tibial osteotomy method. Elmali et al[7] examined the clinical and radiological results of proximal tibial osteotomy and reported that the biplanar retrotubercle method was clinically more effective in varus gonarthrosis proximal osteotomies and prevented patella infera and tibial tilt changes. Similarly, in the current study, greater improvement was seen in the biplanar group. Türkmen et al[8] examined a total of 88 knees in 78 patients with high tibial osteotomy who underwent biplanar surgery and reported that both methods were effective in patients with varus gonarthrosis. Erquicia et al[17] examined the results of distal tuberosity osteotomy over a two-year period and reported that the bipolar distal tibial tuberosity osteotomy method was effective in the clinical and radiological treatment of medial compartment osteoarthritis and varus problems. The MRI study conducted by Hada et al[18] demonstrated a significant increase in T2 values of the femoral condyle and groove in patients with early-stage knee osteoarthritis (OA) compared to a healthy control group. Furthermore, in patients with early-stage knee OA, the Whole-Organ Magnetic Resonance Imaging Score (WORMS) scores for femoral articular cartilage and osteophytes were significantly higher than the scores for patellar-articular and tibial-articular cartilage. Yang et al[19] suggested that the deterioration and damage of the femoral articular cartilage are more pronounced than those of the tibial-articular and patellar-articular cartilage, and this is due to the higher stress exerted on the medial patellofemoral joint during flexion motion, making the degeneration of the medial patellofemoral articular surface more susceptible. In the current study, the medial open wedge high tibial osteotomy results were similar to the proximal open wedge high tibial osteotomy results and favored the biplanar method. The biplanar osteotomy was also more advantageous in terms of both pain and KSSF. However, the longer operation time was seen as a disadvantage of the biplanar method. When selecting the most appropriate method, it is beneficial for the clinician to evaluate the clinical advantages and the duration of the operation together.

Longino et al[12] reported that the change in BPI value was lower in the open wedge high tibial osteotomy and tibial tubercle osteotomy group. Wu et al[20] stated that the BPI index did not differ significantly between open and closed wedge high tibial osteotomy. In the current study, the BPI value was 0.87 in the monoplanar group and 0.81 in the biplanar group, and these values decreased to 0.69 in the monoplanar group and 0.80 in the biplanar group postoperatively. The difference in the BPI values of the groups both before and after the operation was statistically significant.

The change in BPI from preoperative to postoperative was also statistically significant within the groups. In both groups, although the within-group changes were significant, the change was greater in the monoplanar group, and thus, the improvement was greater in the biplanar group.

While the mean value of the KSS function score was 55.27 in the monoplanar group and 55.11 in the biplanar group, the final follow-up values were 88.32 in the monoplanar group and 92.44 in the biplanar group. The preoperative difference in KSS function values was not statistically significant, but this difference became significant after the operation. Within both groups, the change in function score from pre to postoperative was also statistically significant. Similarly, the KSSK score also showed significant differences within the group before and after the operation. The preoperative Kellgren Lawrence score was 3.22 in the monoplanar group and 2.93 in the biplanar group, and these values decreased to 2.44 and 1.98, respectively, in the postoperative period. The tibiofemoral angle varus value was measured as 7.00° in the monoplanar group and 8.39° in the biplanar group before the operation, and 3.25° in the monoplanar group and 4.94° in the biplanar group postoperatively. In both groups, the changes were statistically significant from pre to postoperative. When the data were examined in detail, the preoperative varus angle was greater in the biplanar group, and as a greater amount of angular correction was seen, better results were obtained in the biplanar group. Medial open wedge high tibial osteotomy can lead to significant functional limitations due to stiffness, pain, and weakness associated with decreased patellar height. Medial open wedge high tibial osteotomy can lead to significant functional limitations due to stiffness, pain, and weakness associated with decreased patellar height. The biplanar technique has been found to be more effective in reducing the stress on the patellofemoral joint during knee flexion by preserving patellar height. It has also shown improvements in the Blackburn Peel Index (BPI) value, Knee Society Score (KSS) function score, and correction of the tibiofemoral angle. Normal knee anatomy is 3-7 degrees valgus. The angular change and varus degree were higher in the biplanar group at the final follow-up.

Osteotomy is a biological method that aims to shift the load-bearing area from the medial compartment to a more central and lateral region. Proximal tibial osteotomy cannot be performed in the presence of patellofemoral joint problems. In the biplanar osteotomy technique, where the proximal fragment of the tibial tubercle is left, the anatomy of the patellofemoral joint is not disrupted, so patellofemoral problems do not pose a contraindication. In a single-plane osteotomy, as the height of the wedge opened medially increases, the patellar tendon is stretched proportionally, which increases patellofemoral pressure and may lead to patella baja. However, in a biplanar osteotomy, the tibial tubercle and the attached patellar tendon are left in the proximal region, so these problems are not observed during surgery and follow-up. Increased contact surface provides a more stable osteotomy line and prevents tibial slope changes, which are other prominent features of biplanar osteotomy[21].

When the findings obtained in the study were evaluated in general, preoperative BPI and Kellgren Lawrence scores were higher in the monoplanar group, and BMI, KSSK, and tibiofemoral angle varus scores were higher in the biplanar group. The postoperative VAS and Kellgren Lawrence scores were higher in the monoplanar group. The Modified Insall Salvati ratio, BPI, BMI, KSS function score, KSSK score, tibiofemoral angle varus, and Tegner scores were higher in the biplanar group. When the difference between the two methods was generally examined, it can be said that greater success was achieved in the biplanar group.

Limitations

This study had some limitations, primarily, the prospective, randomized, single-center design, as it caused a homogeneous demographic structure. Cross-comparison studies of larger samples in different centers would be able to better reveal the difference between biplanar and monoplanar methods and to decide which method is more appropriate in which situations. Another limitation of the study was that all the risk factors could not be sufficiently questioned due to the prospective randomized nature. Within the framework of these limitations, this study can be considered of value as the first study in the literature to have compared biplanar and monoplanar methods in medial open wedge high tibial osteotomy, to determine the more clinically effective method and to reveal the most appropriate method in terms of pain and functional capacity.

Conclusions

The results obtained in this study demonstrated that more successful results were obtained with

biplanar medial open wedge high tibial osteotomy in terms of both pain and functional capacity, although the operating is longer than the monoplanar method. It can be concluded that the biplanar medial open wedge high tibial osteotomy will be more beneficial for the patient in terms of reducing pain and increasing functional capacity.

Conflict of Interest
The Authors declare that they have no conflict of interests.

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None.

Informed Consent
All patients provided written informed consent for their clinical records to be used for research purposes.

Ethics Approval
Approval for this study was obtained from the Local Ethical Committee of Hitit University (Decision number: 394, date: 20.01.2011).

Availability of Data and Materials
The dataset used during the current study is available from the corresponding author; however, it is not allowed to be shared publicly.

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Authors' Contributions
Each author fulfills each of the authorship requirements. Zehir S: participated in the study design and the acquisition and interpretation of data, performed the statistical analysis, and drafted the final version of the manuscript. Calbiyik M: participated in the study design and the acquisition and interpretation of data, performed the statistical analysis, and drafted the final version of the manuscript.

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