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Research Article

Clinical and radiological outcomes of high tibial osteotomy with combined fixator-assisted nailing and subtubercle tibial osteotomy

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ABSTRACT

Objective: The aim of this study was to assess the clinical and radiological results of our high tibial osteotomy technique combining fixator-assisted nailing and subtubercle tibial osteotomy in varus malalignment.

Methods: This was a retrospective study of a consecutive series of 32 knees in 32 patients ('2 follow-up loss' 12 males and 18 females; mean age at the time of operation: 50.6±7.8 (36–62) years) operated on between 2014 and 2016. Radiographic and clinical measurements were assessed pre- and postoperatively. Kolmogorov-Smirnov, paired t and Wilcoxon rank tests were used in the statistical analyses.

Results: The mean follow-up period was 36.1±8.15 (31–53) months, the mean duration of the hospital stay was 3.6±0.1 (2–6) days, and the mean Kellgren-Lawrence score was 2.4±0.6 (2–4). Time to bony union was an average of 16.17 (12–29) weeks. Compared to the preoperative mechanical medial proximal tibial angle, femorotibial angle and mechanical axis deviation measurements, all the postoperative values showed significant changes (p<0.01). However, there was no statistical difference between the preoperative and postoperative tibial slopes (p>0.05), and the postoperative Caton-Deschamps index did not show a meaningful change (p>0.05). The postoperative visual analog scale, Knee Society Score, and Modified Hospital for Special Surgery Knee Scoring System measures showed significant improvement compared to the preoperative values (p<0.01). The postoperative walking distance increased to 1137.50±845.1 meters, from 359.4±306.2 meters (p<0.01).

Conclusion: This percutaneous technique is minimally invasive, corrects the alignment in two planes, and does not affect patellar height. We believe that this technique could be a promising alternative to other knee preserving surgeries in correcting varus malalignment.

Level of Evidence: Level IV, Therapeutic Study

High tibial osteotomy (HTO) is an effective treatment in the management of gonarthrosis with varus or valgus malalignment, and it is well documented in the literature (1-7). It is commonly performed in the case of symptomatic unicompartmental arthrosis associated with coronal plane malalignment in a stable knee (5, 8, 9). The ultimate goals of this treatment are to unload the diseased articular surfaces and correct angular deformity at the tibiofemoral articulation. Because of the success of the total knee arthroplasty, the indications for this procedure have declined over the last decade; however, it still remains useful in appropriately selected patients with unicompartmental knee disease (5); the main patient group represents physiologically young, active patients with medial compartment osteoarthritis (5, 6, 10). HTO is witnessing a resurgence following the improvements in the surgical technique and fixation devices (11, 12).

Furthermore, various HTO techniques, such as opening wedge, lateral closing wedge, and dome osteotomy with fixation mostly by plate and screws (5, 12, 13), have been described. However, these techniques suffer from complications, such as patella baja, tibial slope malalignment, peroneal nerve palsy, nonunion, medial collateral ligament (MCL) lesions, and implant failure (11, 14, 15). Notably, both the opening-wedge and lateral closing-wedge technique have been reported to change the patellar height by altering the proximal tibial geometry (16). The change in the patellar height, especially height reduction (i.e., patellar baja), can affect the biomechanics of the patello–femoral joint (17). The

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posterior tibial slope after knee prosthesis operations directly affects the anteroposterior (AP) stability, knee joint range of motion (ROM), and joint contact pressure (18).

According to most authors, the opening-wedge HTO technique increases the tibial slope by 3°–4°, and the closing-wedge HTO technique decreases the same by 3°–5° (19). A recent study by Warner et al. employed the subtubercle osteotomy (STO) procedure with the Ilizarov technique for treating symptomatic varus knee deformities (6). They claimed that this technique maintained the patellofemoral relationship, did not require retained implants, and provided accurate coronal- and sagittal-plane corrections. Otherwise, external fixator (EF) treatment modalities are known to reduce patient satisfaction, limit daily activity expectations, and cause discomfort and knee-rehabilitation problems, as well as causing pin-site infections, which might result in osteomyelitis.

Another technique—fixator-assisted nailing (FAN)—has been used in orthopedic deformity surgeries, reporting significant success (20, 21). Because the fixator is used only temporarily during the operation, EF-related side effects can be avoided. Consequently, because of the aforementioned benefits, we used a technique that combined both STO and FAN. This combined technique, which is minimally invasive, involves realignment in both the sagittal and coronal planes, also providing additional biomechanical advantages. This study aims to assess the clinical and radiological outcomes for the acute correction of proximal tibial deformity, and to compare these outcomes with those in the literature.

Materials and Methods

This was a retrospective study of a consecutive series of 32 knees in 32 patients, which were operated on by a single surgeon (ME) between the years 2014 and 2016; in addition, the patients had a minimum 30 months of follow-up, involving well documented and detailed data collection by ME from the beginning of the use of this technique. However, because of the follow-up loss of two patients, only 30 were ultimately included in the study. This study was approved by the Sakarya University School of Medicine Non-Invasive Trial Ethics Committee. The inclusion criteria were idiopathic varus deformity of the proximal part of the tibia, associated with medial joint line pain that substantially interfered with the daily activities of the patients, despite them receiving nonoperative treatments; the patients were aged between 18 and 65 years. The exclusion criteria were concomitant ligamentous instability, chronic tricompartmental arthritis, chronic neoplastic or metabolic disorders, and previous or acute infections of the knee joint. All the patients gave their informed consent.

An independent investigator performed data acquisition on the day before surgery (baseline), at 6–12 weeks, 6–12 months, and at the last follow-up. Preoperatively, long-leg standing AP radiographs were obtained, and the mechanical axis of the lower limb was drawn on the radiograph. Subsequently, the corrected mechanical axis was drawn and quantified. The data collection included the patients' demographic data, hospital-stay duration, follow-up period, and radiographs; the radiographs were used to measure the mechanical-axis deviation (MAD), femorotibial angle (FTA), medial proximal tibial angle (MPTA), and tibial slope. Additionally, the Caton–Deschamps index for the patellar height was determined (22). The radiological measurements showed sufficient intraobserver reliability (23-25). Furthermore, the Kellgren–Lawrence classification was used to assess the degree of arthritis in the knee (26). The fibular head and lesser trochanter were used as landmarks to determine the excessive rotation of the limbs on the radiographs (27). AP and lateral 14×17-inch images of the knee were used to determine the long axis of the tibia. All the radiographic alignment measurements were taken carefully and accurately using an independent radiographic reviewer, who was blinded to the treatment and performed the assessment twice within a 1-week interval. All the measured values were calculated to one decimal place. To eliminate the inter-observer variability, a single radiographic reviewer was used. In the measurements, the whole length of the lower extremity—a true AP and lateral radiograph of the lower leg, covering the whole length of the tibia—was used.

Clinical outcome assessments

The data from the final follow-up and the preoperative evaluation were used for the assessments. The occurrence and type of complications were also noted. An independent researcher, who was blinded to the study design, assessed the clinical outcomes, providing evaluations via the visual analog scale (VAS) score, Knee Society score (KSS), Modified Hospital for Special Surgery (HSS) Knee Scoring System score, and walking distance.

Surgical technique

The FAN technique involves temporary EF for deformity correction, following tibial osteotomy (21). Upon achieving the desired alignment, an intramedullary (IM) nail was inserted to stabilize this position. The STO technique involves the osteotomy level being below the tibial tuberosity.

In our technique, the patient was placed on a radiolucent operative table in the supine position; subsequently, a support was placed under the ipsilateral buttock of the patient. All the operations were performed with the patients under general anesthesia, without paralytics, to improve the detection of potential motor nerve irritation during wire passage; simultaneously, we performed the visual and tactile monitoring of motor flickers in the ankle, foot, and toes. Subsequently, using an image intensifier, the osteotomy level of the proximal tibia was determined to be 1–2 cm distal to the tibial tuberosity in the AP (Figure 1) and the lateral planes. Two small, transverse, 5-mm incisions, one anterolateral and one posteromedial, were made, and subperiosteal dissection was performed using an elevator.

Figure 1. Determination of the osteotomy level

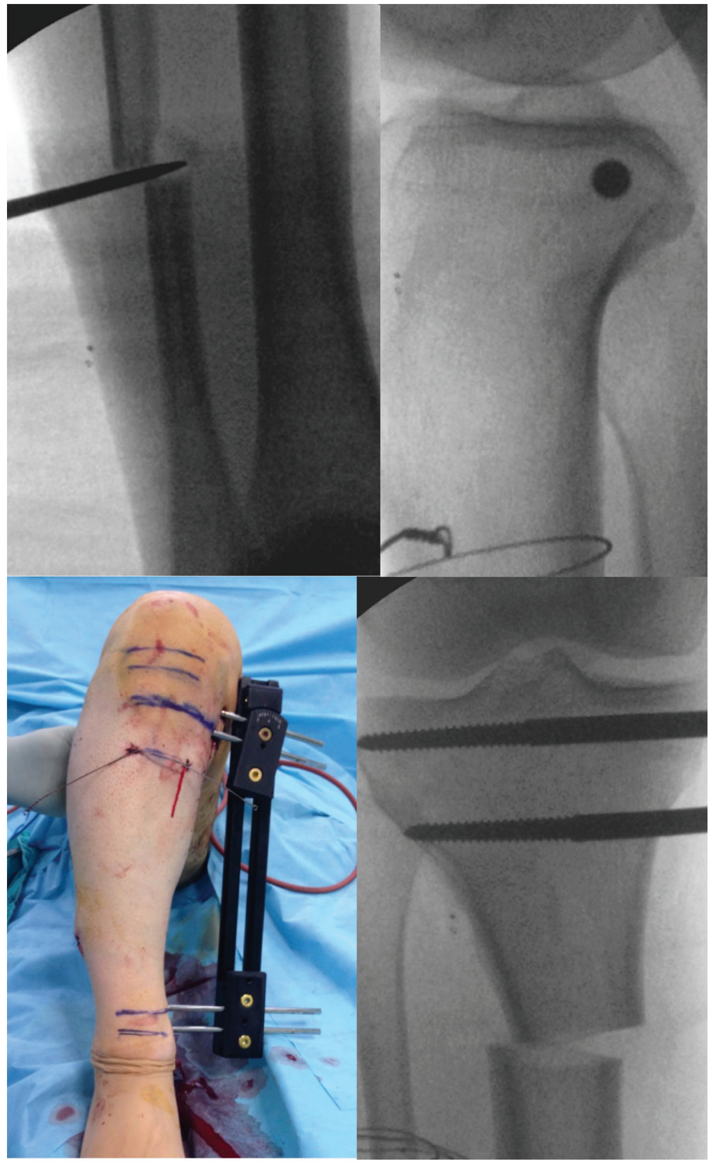

Figure 2. Distal fibula osteotomy and the application of EF

Using a curved vascular clamp, a Gigli saw was passed around the tibia and locked in place. Subsequently, a distal fibula osteotomy was performed to allow for the control of the correction in the AP and rotational planes at approximately the junction of the 1/3-middle and 1/3-distal fibula (Figure 2). Two Schanz screws were inserted into the proximal and distal tibia, 1 cm away from the joint line in the AP plane, parallel to the knee and ankle joints. In the lateral plane, the pins were placed posteriorly. Therefore, once the LRS fixator (Ilerimed, Istanbul, Turkey) had been established, following the alignment control and correction, the EF, with its pins, would not prevent the smooth passage of the IM nail (Figure 2). The alignment was checked under a fluoroscope. Accordingly, using the Gigli saw and under the guidance of the EF, a proximal tibial osteotomy was performed. The distal tibia fragment was translated laterally until the preoperatively calculated correction was achieved. The EF was then tightened in the desired position (Figure 2).

The correction was checked using an alignment guide under fluoroscopic control. First, the proximal end of the alignment wire was placed at the center of the femoral head, with the distal end placed in the middle of the talus. Second, the fluoroscope was positioned on the middle of the knee joint, targeting the lateral eminence of the tibia; if the target was achieved, the EF was tightened. Third, a guide wire was inserted, followed by the insertion of the IM nail (Trigen Meta-nail, Smith and Nephew, London, UK) (Figure 3). The postoperative alignment compared against preoperative X-ray images (Figure 4) showed the desired position, with minimal slope change in the sagittal plane (Figure 5). Fourth, a block screw medial to the IM nailing route was placed in most of the cases, to prevent the loss of valgus correction of the nail. In a small number of patients, the block screw was placed in the proximal tibia for central nail positioning (Figure 5). Finally, upon fixing the IM nail in the desired position using locking screws, the LRS fixator was removed.

Postoperative protocol

The patients were allowed to start partial (30%) weight bearing immediately in the postoperative period for the first 3 weeks; within 3–4 weeks, the weight bearing was increased progressively until

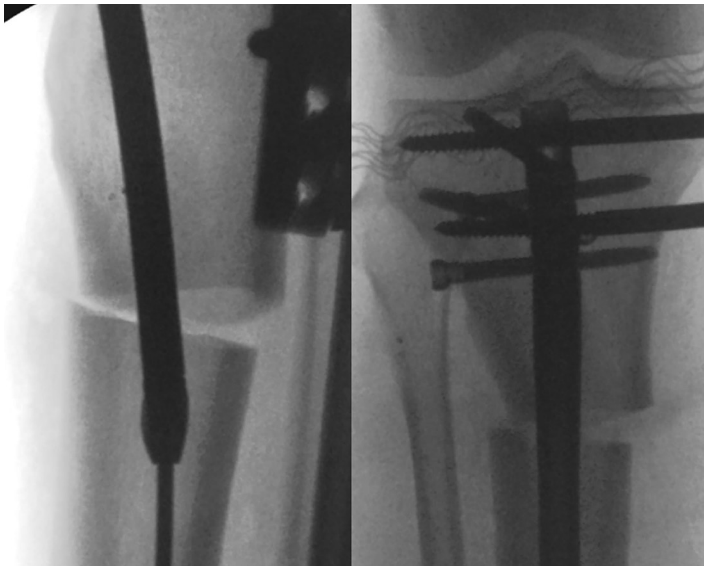

Figure 3. Insertion of IM nail in the desired alignment and stabilization

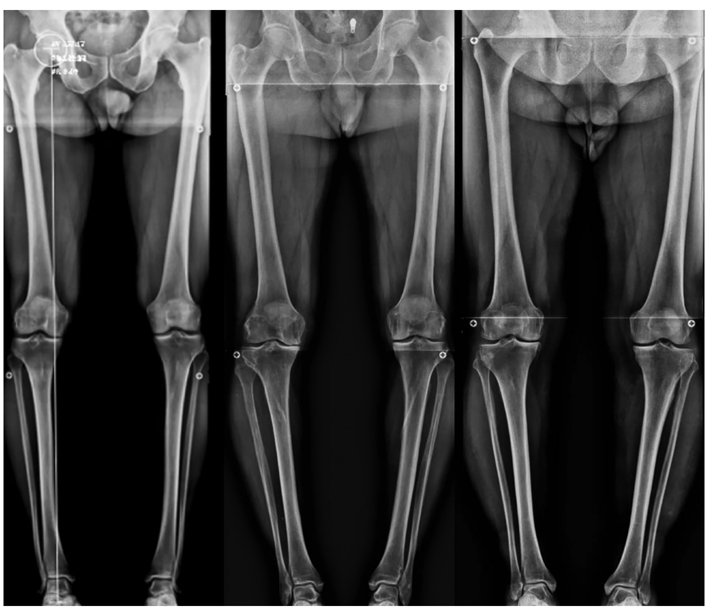

Figure 4. Preoperative long-leg alignment and sample X-rays

achieving full weight bearing at 6–8 weeks. From the first postoperative day, all the patients received physiotherapy and gait training.

Statistical Analysis

All the measurements were performed twice, one week apart, by an independent reviewer, for all the patients; the average values were used for the statistical calculations. The reliability of the measurements was assessed by examining the intraobserver reliability by using the intraclass correlation coefficient. The means, ranges, standard deviations, and 95% confidence intervals are presented, where applicable. The normal distribution of the parametric data was assessed using the Kolmogorov–Smirnov and paired t tests. For non-parametric data, the Wilcoxon rank test was used for comparison (IBM Corp., Armonk, NY, USA). A p-value less than 0.05 was considered statistically significant.

Figure 5. Postoperative long-leg alignments and minimal tibial slope change is depicted postoperatively in the lateral view.

Results

As previously mentioned, two patients could not be included in this study because they were lost to follow-up; therefore, 30 patients (94% follow-up rate; 12 males [40%], 18 females [60%]) who received the described operation were included. The mean age at the time of surgery was 50.6±7.8 (36–62) years, mean follow-up period 36.1±8.15 (31–53) months, mean hospital stay 3.6±0.1 (2–6) days, and mean Kellgren–Lawrence score 2.4±0.6 (2–4). The mean bone union time was 16.17 (12–29) weeks. The demographic data for each patient are presented in Table 1. All the patients achieved full knee extension at their last follow-up, and no patient required narcotic medications for knee pain on the operated side.

The mean preoperative FTA was 9.5±3.0° (6.5–13.5°). The intraobserver reliability ranged from 0.89 to 0.96. Compared with the preoperative mMPTA, FTA, and MAD measurements, all the postoperative values showed significant changes ($p<0.01$) (Table 2). However, no statistical difference was observed between the pre- and postoperative values of the tibial slope ($p>0.05$). Additionally, the postoperative Caton–Deschamps index did not show any meaningful changes ($p>0.05$) (Table 2). In six patients, we changed and corrected an external rotation, by performing derotation between 5° and 10°.

Table 1. Demographic data of all the patients

Patient No	Age	Side	Gender	Kellgren-Lawrence Clas-sification	Hospital stay (day)	Follow-up peri-od (month)	Time to Union
1	58	R	M	2	3	53	12
2	45	L	M	3	3	49	20
3	59	R	M	2	3	48	16
4	58	R	M	3	3	52	14
5	44	R	M	3	3	47	13
6	36	L	F	2	2	48	29
7	58	L	F	3	3	31	16
8	46	R	F	2	3	44	17
9	57	R	F	2	3	52	18
10	62	R	M	2	4	31	12
11	57	L	M	2	4	32	13
12	55	L	F	3	4	31	15
13	54	R	F	4	3	31	16
14	46	L	M	2	4	31	13
15	44	L	F	2	5	33	14
16	40	R	F	2	6	31	13
17	43	L	F	2	3	31	15
18	59	R	M	3	5	31	16
19	58	R	F	2	4	31	17
20	44	L	F	2	3	31	16
21	61	L	F	3	5	32	22
22	42	L	F	2	2	31	15
23	43	R	M	2	3	32	12
24	43	R	F	2	4	31	16
25	59	L	F	3	5	33	18
26	57	R	F	3	4	31	19
27	43	R	F	2	3	31	17
28	46	L	M	2	4	32	18
29	44	L	F	2	3	31	15
30	57	R	M	3	4	31	18

Additionally, the postoperative VAS, KSS, and modified HSS scores showed significant improvement compared with the preoperative values (p<0.01). The postoperative walking also distance increased from 359.4±306.2 to 1137.50±845.1 m (p<0.01) (Table 1).

However, one patient with poor bone quality demonstrated no progression in radiological union at the end of the three months of the follow-up; therefore, the distal screws were removed to obtain dynamic compression. Eventually, osseous union was obtained at six months postoperatively, following the primary operation. Deep venous thrombosis was observed in one patient, and it was resolved via low-molecular-weight heparin treatment.

Discussion

High tibial osteotomy is the gold standard treatment for medial compartment osteoarthritis of the knee in young people, and it offers several advantages. HTO realigns the mechanical axis of the lower extremity by shifting the weight-bearing zones to the unaffected parts of the knee, thus decreasing pain, improving function, and delaying knee deterioration and, potentially, the need for arthroplasty (6, 28). Several studies have demonstrated the benefits of HTO (6, 29). Although the functional outcome and survival rate are better in patients aged <55 years, adequate preoperative functional scores might provide satisfactory survival and functional outcomes (30). In this study, we showed that the combination of

Table 2. Evaluation of preoperative (preop) and postoperative (postop) measurements

	Preop	Postop	
	Mean±SD	**Mean±SD**	**p**
mMPTA	83.9±2.7	92.5±2.2	10.001**
FTA	9.5±3.0	-1.7±1.4	10.001**
MAD	33.6±9.8	-3.7±4.9	10.001**
Tibial Slope	9.8±4.5	9.6±2.5	20.063
Caton-Deschamps index	0.9±0.1	0.9±0.1	10.261
VAS	8.4±1.3	1.7±1.5	20.001**
KSS	60.6±11.7	92.4±4.5	10.001**
Modifiye HSS score	60.7±9.9	93.8±4.9	10.001**
Walking distance	359.4±306.2	1137.5±845.1	20.001**

[1]Paired samples t test
[2]Wilcoxon signed ranks test
**p<0.05*
***p<0.01*
MPTA: medial proximal tibia angle; FTA: femoro–tibial angle; MAD: mechanical-axis deviation; VAS: visual analog score; KSS: Knee Society score; HSS: Hospital for Special Surgery

FAN and STO for the treatment of medial compartment osteoarthritis produced favorable results, with a low rate of complications and significantly improved radiographic measurements for alignment in the coronal and sagittal planes, as compared with preoperative values, thus verifying our hypothesis.

For all the techniques described for HTO, the coronal and sagittal alignments should be thoroughly evaluated, as these are critical to achieving long-term results (31). However, there are risks of increasing the tibial slope, lowering the patella, decreasing knee extension, and increasing the anterior cruciate ligament tensile load (32). Other potential risks are the need for bone graft, delayed union or nonunion, MCL tightness, and increased patellar height (5, 11, 14, 21). The lateral closing-wedge osteotomy is also familiar to some surgeons. Its advantages are the greater potential for correction, possibly faster healing, and no need for bone grafting; however, the risks are peroneal nerve injury due to concomitant fibular osteotomy, need for bone cutting, correction in only one plane, shortening of the leg, bone stock loss, and difficulties in conversion to arthroplasty (5).

We did not have a control group to compare our results with. However, in the literature, other studies in which plate fixation was employed are available for comparison. For example, Brosseta et al. demonstrated satisfactory outcomes using a locked plate fixation (TomoFix) in 51 cases (33). They corrected various alignments from varus to 1.2° of valgus. In our study, we achieved an average of 1.7°. They obtained bone union in 4.2 months, which was similar to that in our study, in which it was obtained in an average period of 16.17 weeks. In a study by Tuncay et al., the authors evaluated three different approaches—mobile-bearing unicompartmental knee arthroplasty, opening-wedge osteotomy, and dome-type high tibial osteotomy—for knee arthritis (34). All the three treatment approaches produced satisfactory results. The results of the opening wedge-type HTO, using locking plate fixation, showed an average correction of 28° in MAD, along with the corrections of 9.7° in FTA and 5.6° in MPTA. In our study, the values were only slightly different; the correction in MAD was 29.9°, and in FTA and mMPTA, this was 11.2° and 8.6°, respectively (Table 2).

In our study, no patient experienced any unintended changes in the posterior slope. Additionally, two patients (6.7%), who had knee flexion contracture and increased posterior tibial slope, underwent accurate sagittal-plane correction with the release of the flexion contracture. In this study, the tibial slope was 9.8±4.5° preoperatively and 9.6±2.5° postoperatively, showing no statistically significant difference. The main advantage of the technique we used is that it corrects the abnormal slopes while maintaining the ideal slopes. This is similar to the results from a case series published by Gunes et al. and Warner et al., where both used EFs (18, 6).

The preoperative height of the patella may govern the selection of the appropriate HTO technique (35). Portner et al. demonstrated patella baja in 21% of the patients undergoing opening-wedge osteotomy, and patella alta in 13% of patients with closing-wedge osteotomy; the change in the patellar height was minimal using the combined osteotomy (35). Loia et al. (30) observed a decrease in the distance between the patella and tibiofemoral joint line in 82% of 32 patients, who had undergone opening-wedge osteotomy (30). HTO performed above the tibial tubercle changes the patellofemoral relationship, whereas STO does not change this relationship (6). Obtaining the coronal and sagittal alignment simultaneously, and solving patellar-height and posterior-slope problems with these wedge osteotomies, is fairly difficult (6, 30, 32, 35). Herein, there was no statistically significant difference between the preoperative and postoperative measurements of the patellar height. This result might be attributed to the osteotomy level being below the tibial tuberosity (6).

Nelissen et al. (36) reported a complication rate of 45% in their series of medial opening-wedge HTOs, and the complications were mostly associated with both intrinsic instability at the osteotomy site and surgical technique; for the closing-wedge HTO, the complication rate was reported to be between 5.6% and 34% (37). In the series of Warner et al. , the Ilizarov EF technique was used, and the complication rate was 8% of 72 cases, and most of the complications were associated with pin-site infections (6). The main advantage of our study compared with those of Sen et al. and Warner et al. is that we used EF only for acute corrections, and that after IM nailing the EF was removed (38, 6). Therefore, we avoided pin-site-related complications. Additionally, the EF is a barrier to returning to daily activities, and it causes discomfort to patients while decreasing the knee ROM. In our series, the complication rate was low (3%), probably because of the minimally invasive nature of the technique and the fact that all the surgeries were performed using small skin incisions.

This study was a small series and had some limitations. First, there may have been a limitation of assessor bias, as the surgeons assessed their own results. Second, there was no comparison group to determine the relative success of the technique. Other limitations to consider when contemplating using this technique are the following: first, the surgical time, which was probably longer than that for other techniques, and, second, there might be a longer period of exposure to radiation. This technique also requires a longer learning curve. Although there was no documentation of serious infection in our case, and Schanz pins were inserted only temporarily during the operation, yet there is a potential risk of infection around the pin-site. Future studies with longer follow-ups, prospective cohort studies, and randomized comparative studies are, therefore, required.

The technique used in this study offers many advantages such as the following: it is percutaneous and minimally invasive; osteotomy is performed below the tibial tuberosity, so the patellar height is not affected; alignment can be corrected in two planes; the anatomical axis can be maintained. Therefore, this technique might be a promising alternative to other knee-preserving surgeries.

Ethics Committee Approval: Ethics committee approval was received for this study from the Non-Invasive Trial Ethics Committee of the Sakarya University School of Medicine.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Author Contributions: Concept - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.; Design - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.; Supervision - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.; Resources - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.; Materials - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.; Data Collection and/or Processing - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.; Analysis and/or Interpretation - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.; Literature Search - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.; Writing Manuscript - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.; Critical Review - L.B., M.E., D.G., A.C.E., A.Ç.U., A.K.

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