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ORIGINAL ARTICLE

Predicting the need for medial augmentation for primary total knee arthroplasty with varus deformity

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ABSTRACT

Objectives: This study aims to compare the radiographic results with and without postoperative metal augmentation in varus knee patients with primary total knee arthroplasty (TKA) with a hip-knee-ankle (HKA) angle >10° and to determine a cut-off value using radiographic parameters to predict the need for metal augmentation.

Patients and methods: Between October 2022 and April 2024, a total of 87 knees (51 right and 36 left) of 82 patients (11 males, 71 females; mean age: 68.7±8 years; range, 53 to 86 years) who underwent primary TKA were retrospectively analyzed. The patients were divided into two groups as patients who underwent primary TKA with and without tibial metal augmentation. There were 39 patients and 42 knees in the group with metal augmentation and 43 patients and 45 knees in the group without metal augmentation. The HKA angles and amount of preoperative planned tibial resection (ETR) were evaluated. Cut-off values for preoperative HKA angle and ETR were determined using receiver operating characteristic (ROC) analysis.

Results: The mean pre- and postoperative HKA angles were 18.98±4.42° and 6.58±3.48°, respectively and the mean ETR was 13.91±3.02 mm. Both groups were comparable in terms of postoperative HKA angles p=0.283). The mean preoperative HKA and ETR were significantly higher in TKAs with augmentation (p<0.001 for both). The probability of needing augmentation was approximately six times higher in knees with a preoperative HKA angle of >20.6° (OR=5.909, 95% CI: 2.065-16.91, p<0.001) or ETR of >12.52 mm (OR=5.816, 95% CI: 2.202-15.359, p<0.001).

Conclusion: In TKA with advanced varus deformity, tibial metal augment is a method that can be used to provide soft tissue balance. The need for metal augmentation should be kept in mind, particularly if the preoperative evaluation indicates that the HKA angle exceeds 20.6° or ETR exceeds 12.5 mm.

Keywords: Gap balance, hip-knee-ankle angle, metal augment, proximal tibial resection, varus knee.

The knee with varus deformity is a challenging condition in which the medial and lateral ligamentous structures of the knee are affected, sometimes bone loss of the medial compartment of the proximal tibia and/or distal femur complicates reconstruction of the knee in total knee arthroplasty (TKA) in varus knee.[1,2] According to the hip-knee-ankle angle (HKA angle) and the condition of the ligamentous structures, additional techniques such as release of the medial structures and cement application, cement-screw application, bone graft (autograft and allograft), metal augment application have been proposed.[1-6]

In the current literature, various patient-specific techniques are used in the treatment of varus knees to achieve a rectangular gap in flexion and extension.[1,3,4] The widely accepted opinion is that soft tissue releases should be performed first, a rectangular gap should be achieved after femoral and tibial resections, and metal augmentation should be used if there is a >5 mm bone defect in the medial tibia or if bony resection of more than

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5 mm from the medial joint line or 10 mm from the lateral joint line is needed.[1,2]

Preoperative planning before TKA is the mainstay of the procedure.[7] The need for a metal augmentation can be predicted by performing the necessary preoperative measurements for implant preparation.[2,7]

A quantitative estimation for the need of metal augmentation according to preoperative measurements has not yet been established in the literature. In the present study, we hypothesized that, in varus knee TKA, metal augmentation could be required at a higher rate in patients who had high HKA angle and high amount of proximal tibial resection in preoperative planning. We, therefore, aimed to compare the radiological results of with and without postoperative metal augmentation for primary TKAs with a HKA angle >10 degrees and for which we considered a need for metal augmentation in preoperative measurements and to determine a cut-off value using radiographic parameters to predict the need for metal augmentation.

PATIENTS AND METHODS

Study design and study population

This single-center, retrospective clinical observational study was conducted at Ankara Etlik City Hospital, Department of Orthopedics and Traumatology between October 2022 and April 2024. Medical data of the patients over the age of 18 years with varus alignment (HKA angle >10 degrees) who had pre- and postoperative appropriate knee radiographs and who were operated with the NexGen® Posterior Stabilized (Zimmer Biomet, Warsaw, IN, USA) brand total knee prosthesis in our clinic were screened. Inclusion criteria were as follows: >18 years of age and patients in whom we planned to use tibial augmentation in preoperative measurements in radiographs to the extent that we would explain later. Exclusion criteria were as follows: having a history of femur, tibia or knee circumferential fractures, previous unicondylar knee replacement, total hip arthroplasty or high tibial osteotomy. Finally, a total of 87 knees (51 right and 36 left) of 82 patients (11 males, 71 females;

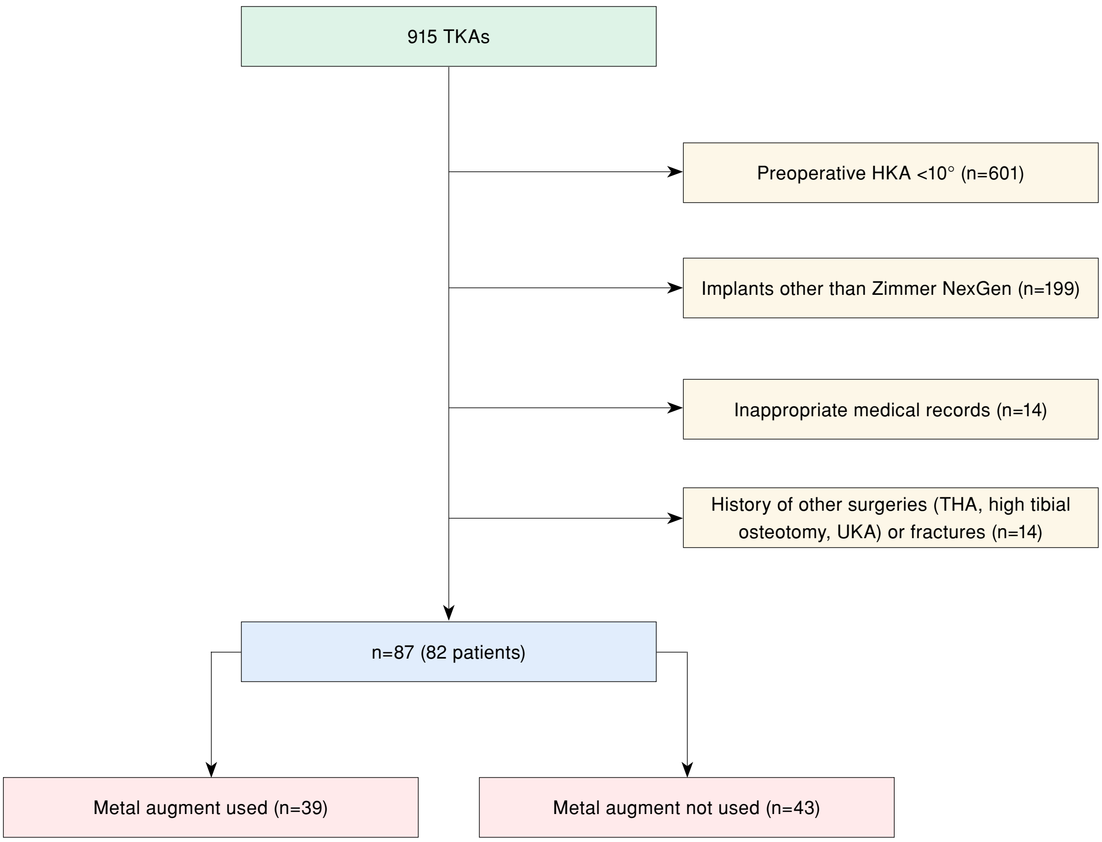

FIGURE 1. Study flowchart.
TKAs: Total knee arthroplasties.

mean age: 68.7±8 years; range, 53 to 86 years) were included. The patients were divided into two groups as patients who underwent primary TKA with and without tibial metal augmentation. There were 39 patients and 42 knees in the group with metal augmentation and 43 patients and 45 knees in the group without metal augmentation. The study flowchart is shown in Figure 1. A written informed consent was obtained from each patient. The study protocol was approved by the Ankara Etlik City Hospital Ethics Committee (date: 26.06.2024, no: BADEK-2024-515). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical technique

The patients were operated under spinal or general anesthesia depending on the opinion of the anesthesiologist. All patients were given ceftriaxone 1 g 30 min before surgery and continued until 48 h postoperatively. Tranexamic acid was administered to all patients. The patients were operated without a tourniquet.

All TKAs were performed using a midline skin incision and medial parapatellar arthrotomy. Since a standard posterior stabilized (PS) prosthesis was used, the cruciate ligaments were cut and the menisci were excised. All osteophytes in the femur and tibia were first excised for soft tissue release. In patients in whom we predicted that adequate gap symmetry could not be achieved, the deep medial collateral ligament (MCL) was lifted from the tibial attachment site with the help of a Cobb retractor. First, femoral cuts were made with the preoperative planned angle (2-12° valgus individualized by measuring the valgus cut angle [VCA]).[8] After resection of the distal femur, the tibia was subluxated anteriorly. Tibial cuts were made perpendicular to the anatomical axis of the tibia.

Intraoperatively, the proximal tibial plateau resection was planned to be 10 mm from the uppermost point of the lateral tibial plateau or 2 mm from the lowermost point of the medial tibial plateau. If it was considered that gap symmetry could not be achieved, the semimembranosus tendon was loosened additionally. Gap symmetry was re-evaluated. In cases where gap symmetry could not be achieved, the superficial MCL was loosened with pie-crusting.

First, extramedullary rod was used to determine the coronal alignment,[9] and if proximal cut was decided to be more than 10 mm from the lateral tibial subchondral bone and more than 5 mm from the medial subchondral bone or if the bone defect in the medial tibial plateau was >5 mm, an intramedullary rod was placed, followed by metal augmentation. If the isolated medial tibial plateau bone defect was <5 mm, the defect was filled with cement.

The gap space was checked in flexion and extension. After making sure that the rectangular gap space was provided at 0° extension and 90° flexion, the trial components were placed and patellar tracking was checked. Standard PS implants were placed in the femur and tibia using polymethylmethacrylate cement.

Active and passive motion was started the next day and full weight bearing was allowed. The patients were given enoxaparin sodium for one month postoperatively.

Imaging studies and evaluation

Pre- and postoperative radiographs were taken in two directions (anteroposterior and lateral) and leg length radiographs with the patient standing at a distance of 100 cm from the source with the detector parallel to the ground plane and the center of the radiograph directed to the patellofemoral joint line.[10] Measurements were performed using the hospital PACS system (Innbiotec DICOM Viewer, Innbiotec Software, Dubai, UAE).

For preoperative planning, HKA angle, VCA (Figure 2), and the amount of estimated tibial resection (ETR) (Figure 3) were measured.[7] Patients in whom we planned to use metal augmentation were defined as those who required resection >5 mm from the medial joint line or >10 mm from the lateral joint line according to preoperative measurements on AP radiograph[7] and/or those in whom the bone defect was >5 mm from the joint line or >50% of the tibial plateau on AP and lateral radiographs.[11]

All measurements were performed by two blinded orthopedic surgeons not involved in the surgeries using radiographs. After three weeks, repeat measurements were performed to determine intra- and inter-rater reliability.

Demographic data including age, sex, body mass index (BMI), and the affected side, pre- and postoperative HKA angle, VCA, pre- and postoperative tibial slopes, preoperatively planned ETR amount, range of motion and Knee Society Scores (KSS) at the final visit if more than six months of follow-up was available and complications were evaluated in both groups.

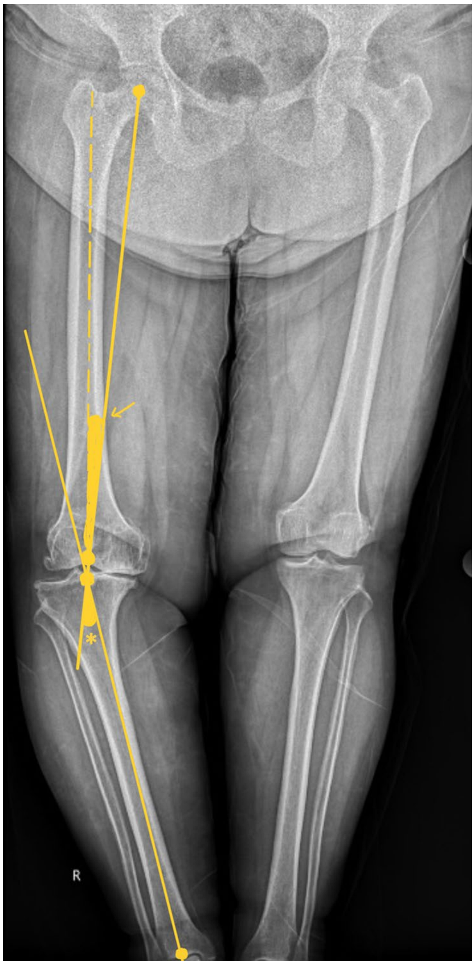

FIGURE 2. Standing anteroposterior alignment X-ray. Hip-knee-ankle angle (HKA angle) (asterisk - *) was measured as the angle between the line from the midpoint of the femoral head to the femoral intercondylar notch and the line from the tibial interspinous process to the midpoint of the tibial plafond. Valgus cut angle (VCA) (arrow) was measured as the angle between mechanical and anatomical axis of femur.

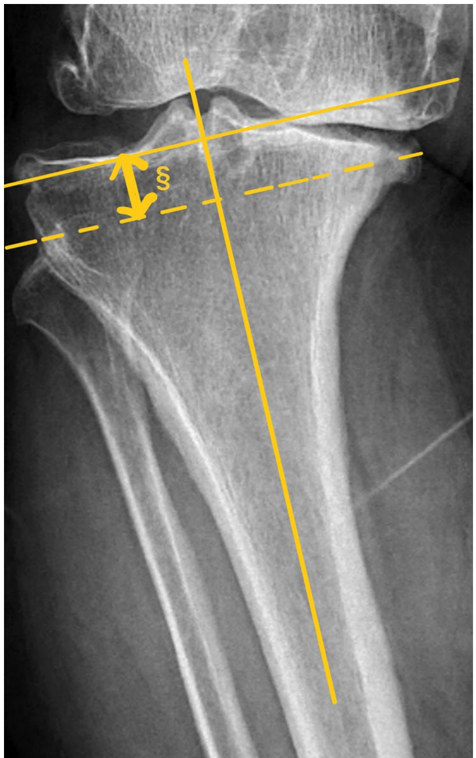

FIGURE 3. Weight-bearing anteroposterior knee X-ray. Estimated proximal tibial resection (ETR) (section sign - §) was measured as the amount planned to be removed from lateral plateau after measuring 2 mm distal to the medial defect, perpendicular to the anatomical axis of the tibia.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to evaluate the conformity of the data to normal distribution and normal distribution conditions were met for all numerical data. Continuous variables were expressed in mean ± standard deviation (SD) or median (min-max), while categorical variables were expressed in number and frequency. Differences between numerical values were analyzed using independent samples t-test and categorical values were analyzed using Fisher exact test. Inter- and intra-rater reliability of measurements were determined using intraclass correlation (ICC) and presented as combined ICC. The receiver operating characteristic (ROC) analysis with Levene's test was used to determine cut-off values. Post-hoc power analysis was performed using G*Power version 3.1 software (Heinrich Heine University Düsseldorf, Düsseldorf, Germany). A *p* value of <0.05 were considered statistically significant.

RESULTS

The mean HKA angle of the patients enrolled in the study was 18.98±4.42°, the mean VCA was 5.8±1.31°, and the preoperative ETR was 13.91±3.02 mm. The combined ICC value for all measurements was 0.84. The mean age (69±7.9 *vs.* 68.4±8.1), BMI (31.1±4.7 *vs.* 32±5.9) VCAs (5.82±1.25 *vs.* 5.78±1.38°) and tibial slopes (9.9±2.7 *vs.* 10.2±2.6°) were similar in two groups (p=0.73, p=0.446, p=0.81, and p=0.664, respectively).

TABLE I
Baseline demographic, clinical, and functional data of patients

	All patients (n=82)			Metal augment used (n=39)			Metal augment not used (n=43)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			68.7±8			69±7.9			68.4±8.1	0.730*
Sex										
Male	11	13.2		6	15.4		5	11.6		0.656†
Body mass index (kg/m²)			31.6±5.3			31.1±4.7			32±5.9	0.446*
	All procedures (n=87)			Metal augment used (n=42)			Metal augment not used (n=45)			
			Mean±SD			Mean±SD			Mean±SD	*p*
Preoperative hip-knee-ankle angle			18.98±4.42°			20.66±4.91			17.43±3.18	**<0.001***
Preoperative tibial slopes			10±2.7°			9.9±2.7°			10.2±2.6°	0.664*
Valgus cut angle			5.80±1.31°			5.82±1.25°			5.78±1.38°	0.810*
Tibial resection planned (mm)			13.91±3.02			14.98±3.3			12.91±2.31	**<0.001***
Postoperative hip-knee-ankle angle			6.58±3.48°			6.16±2.6°			6.97±4.1°	0.283*
Postoperative tibial slopes			7.1±2.3°			7.3±2.1°			6.8±2.5°	0.351*
	Follow-up for more than 6 months (n=52)			Metal augment used (n=23)			Metal augment not used (n=29)			*p*
			Mean±SD			Mean±SD			Mean±SD	
Postoperative Knee Society score			90.3±5.6			89.8±6			90.8±5.2	0.392*
Postoperative Knee Society functional score			89.9±6.6			88.8±6.4			90.9±6.7	0.143*
Postoperative range of motion			91.3±10.3°			90.3±10.1°			92.2±10.5°	0.386*

SD: Standard deviation; * Independent samples t-test; † Fisher exact test.

The mean preoperative HKA angle (20.66±4.91° vs. 17.43±3.18°) and the ETR (14.98±3.3 *vs.* 12.91±2.31 mm) were significantly higher in TKAs with augmentation than those without (p<0.001 for both). The mean overall postoperative HKA angle was 6.58±3.48° for all patients. There was no significant difference between the postoperative HKA angle values of TKAs with and without augmentation (6.16±2.6° *vs.* 6.97±4.1°, p=0.283). Postoperative tibial slopes did not differ between the groups (7.3±2.1° *vs.* 6.8±2.5°, p=0.351).

The KSS and range of motion data were available for 52 knees with more than six months of follow-up (median 10.5 months, metal augment used in 23, not used in 29). There was no significant difference in terms of the mean KSS (89.8±6 *vs.* 90.8±5.2, p=0.392), KSS functional scores (88.8±6.4 *vs.* 90.9±6.7, p=0.143) and ranges of motion (90.3±10.1° *vs.* 92.2±10.5°, p=0.386) between the groups. Four patients had superficial wound dehiscence which was resolved with medical treatment and wound dressing in each group. One patient in the group that tibial augment was used had her polyethylene insert changed due to clinical suspicion of infection. None of the patients had fractures or bacterial growth in culture (Table I).

The post-hoc power analysis revealed a power (ß) of 91.5% for preoperative HKA and 98.5% for ETR analyses. According to the ROC analysis of patients requiring metal augmentation as a result of intraoperative evaluation, the odds of requiring metal augmentation increased 5.9-fold (odds ratio [OR]=5.909, 95% confidence interval [CI]: 2.065-16.91, area under the curve [AUC]=0.695, 95% CI: 0.579-0.801, sensitivity of 0.5, specificity of 0.87, p<0.001) in patients who had a preoperative HKA angle value greater than 20.6°. The patients who had ETR of more than 12.52 mm were 5.8 times more likely to require metal augmentation (OR=5.816, 95% CI: 2.202-15.359, AUC=0.71, 95% CI: 0.589-0.816, sensitivity of 0.81, and specificity of 0.578, p<0.001) (Figures 4 and 5).

DISCUSSION

Poor clinical and radiologic results are expected in varus TKA with inadequate soft tissue balance.[1,4,12] Preoperative planning in TKA helps in estimating implant sizing, as well as need for additional procedures similar to soft tissue release and/or augmentation.[7] Although we believe that preoperative planning can provide an idea whether we need metal augmentation or not, some of the patients in whom we anticipated a need for metal augmentation after preoperative planning did not require metal augmentation after intraoperative soft tissue releases. This leads to unnecessary time loss and material requisition.

In the present study, we identified patients during preoperative planning who were considered candidates for metal augment but did not receive it intraoperatively. Despite this, we achieved comparable postoperative alignment in these patients to those who underwent metal augmentation. However, our analysis demonstrated a preoperative HKA angle greater than 20.6° and an ETR greater than 12.5 mm

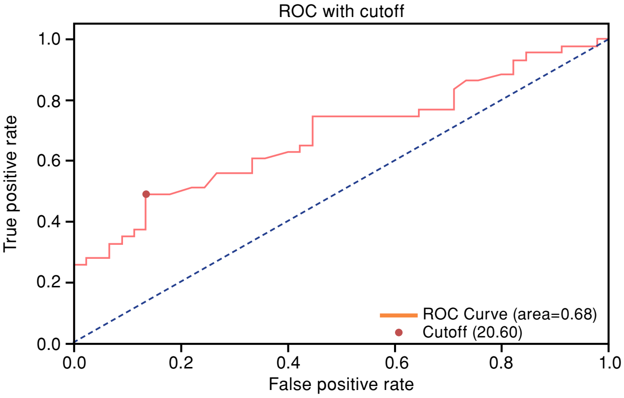

FIGURE 4. Results of receiver operating characteristic analysis with Levene's test for hip-knee-ankle (HKA) angle (OR=5.909, 95% CI: 2.065-16.91), AUC=0.695, 95% CI: 0.579-0.801), sensitivity=0.5, specificity=0.87, p<0.001).

ROC: Receiver operating characteristic; OR: Odds ratio; CI: Confidence interval; AUC: Area under the curve.

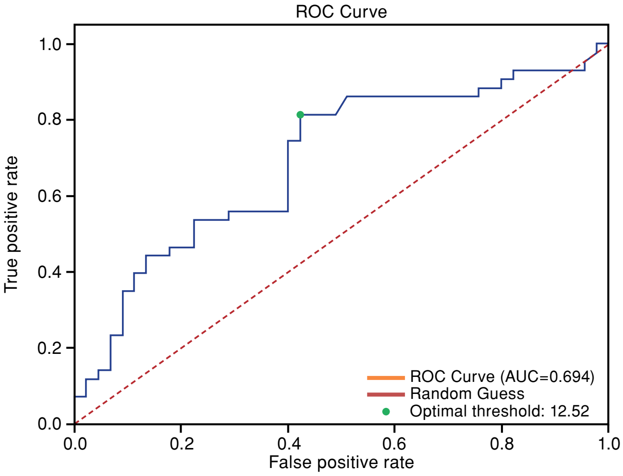

FIGURE 5. Results of receiver operating characteristic analysis with Levene's test for estimated amount for tibial resection (ETR) (OR=5.816, 95% CI: 2.202-15.359), AUC=0.71, 95% CI: 0.589-0.816), sensitivity=0.81, specificity=0.578, p<0.001).

ROC: Receiver operating characteristic; OR: Odds ratio; CI: Confidence interval; AUC: Area under the curve.

were associated with a nearly six-fold increase in the probability of augmentation being used. These findings highlight the importance of these thresholds in guiding surgical decision-making and predicting the need for augmentation.

We preferred to include patients who had a greater than common deformity in our study. In these cases, gap imbalance is expected[13] and additional corrective interventions may be required intraoperatively.[1,6,14] In their study, Mullaji et al.[14] recommended corrective osteotomy in patients who had a preoperative HKA angle of 15° or more. We believe that, for this group of patients, the metal augmentation option should be considered in a prepared manner. There are no previous studies that have established sharp cut-off points to predict this requirement.

In the current study, there was no significant difference in the postoperative mechanical alignment of TKAs with and without tibial metal augmentation. Regardless of the correction method used, since the main thing is to provide the correct gap balance after bone resections,[12] surgeries are completed by making sure that this balance is achieved in all cases; therefore, the need for augmentation is determined intraoperatively. However, we believe that it would be more beneficial to be able to anticipate this requirement preoperatively, as it may eliminate problems such as time related to material procurement and the challenge of decision-making during surgery.[15]

Previous studies have shown that postoperative residual varus may remain in patients who have advanced preoperative HKA.[16-18] In our patients, the mean postoperative HKA angle was 6.58±3.48°. However, it has been shown in the literature that clinical results are more favorable in patients with postoperative mild varus deformity.[19] The fact that there was no significant difference between the groups in the degrees of postoperative HKA angles in TKAs with and without metal augmentation in our study can be explained by the fact that soft tissue balance and bone cuts are made in a certain congruency independent of the use of additional implants in varus TKA and the emphasis on the rectangular gap.[12]

While the use of metal augmentation is recommended in the existing literature for revision TKA or primary TKA with defects,[3,7,20,21] we preferred metal augmentation in varus TKA patients to ensure tibial alignment, rectangular gap, minimize soft tissue loosening and preserve the joint line in our study. Of note, the use of metal augmentation for soft tissue management in varus TKA has not been adequately investigated in the literature.

Although metal augmentation is mentioned as a step in the algorithms proposed[2,7] to achieve soft tissue balance, further studies are needed to evaluate its effectiveness. In the current study, we routinely followed this template in knees with advanced varus deformity and provided appropriate soft tissue balance, and this approach yielded similar clinical (in terms of KSS and ranges of motion) and radiological outcomes, whether tibial augment was used or not.

Since the thickness of the combined (polyethylene + metal) tibial component should be at least 10 mm and complications can be seen if the amount of resection exceeds 10 mm,[2,7] we used cut-off as 10 mm in our preoperative evaluation to predict the possibility of need for metal augmentation. Previous studies have shown that a significant proportion of these resections exceed 10 mm in varus knees.[22] However, we found in our study that the likelihood of needing metal augmentation for stabilization increased six-fold, if the ETR exceeded 12.5 mm preoperatively.

The main limitations to our study include its single-center, retrospective design with a relatively small sample size. In addition, evaluations were performed only radiographically, and clinical outcomes, particularly implant loosening, could not be evaluated for every patient due to short term follow-up. Also, the center of deformity was unable to be assessed as intra- or extra-articular. These evaluations may be the subject of further studies.

In conclusion, in TKA with advanced varus deformity, placement of tibial metal augment is a method that can be used to provide soft tissue balance. In our study, the likelihood of requiring tibial metal augments was approximately six times higher if the preoperative evaluation showed that HKA angle exceeded 20.6° or the planned proximal tibial resection exceeded 12.5 mm. Further large-scale, prospective studies are needed to establish more reliable conclusions on this subject.

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, analysis and/or interpretation: E.B.D., F.B.; Control/supervision: H.A.A., M.A.; Data collection and/or processing: M.F.S., F.B.; Literature review: E.B.D., Y.A.; Writing the article: E.B.D., M.F.S.; Critical review: M.A., Y.A. References and fundings: No funding has been recieved. Materials: Analyses were performed using clinical data.

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