

The Effect of Lower-Limb Coronal Alignment Correction and Component Positioning on Coronal Ankle Alignment After Total Knee Arthroplasty

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Abstract

Aim: Total knee arthroplasty (TKA) performed for varus gonarthrosis may affect coronal ankle alignment while correcting lower-extremity coronal alignment. This study aimed to evaluate the effect of the magnitude of coronal alignment correction and component positioning after TKA on ankle joint alignment and to investigate clinically meaningful threshold values.

Materials and Methods: This retrospective radiographic study included 134 knees that underwent primary TKA. The hip-knee-ankle angle (HKAA), femoral and tibial component angles, ground-plafond, ground-talus, lateral distal tibial angle (LDTA), and talus-plafond angles were measured on preoperative and postoperative weight-bearing anteroposterior long-leg radiographs. The postoperative-preoperative difference was calculated for each parameter. Wilcoxon, Mann-Whitney U, Kruskal-Wallis, Spearman correlation, multivariable linear regression, and ROC analyses were used.

Results: HKAA increased from $167.87 \pm 5.12^\circ$ to $176.16 \pm 2.98^\circ$ after TKA ($p < 0.001$). The ground-plafond angle decreased from $7.06 \pm 3.48^\circ$ to $3.25 \pm 2.21^\circ$, the ground-talus angle from $7.27 \pm 3.52^\circ$ to $3.38 \pm 2.35^\circ$, and the talus-plafond angle from $2.99 \pm 2.15^\circ$ to $2.65 \pm 2.18^\circ$ (all $p < 0.001$); LDTA did not change (from $87.93 \pm 2.70^\circ$ to $88.14 \pm 2.41^\circ$; $p = 0.166$). The magnitude of HKAA correction correlated with the change in ground-plafond angulation ($\rho = -0.562$; $p < 0.001$) and was an independent predictor ($\beta = -0.355$; $p < 0.001$; $R^2 = 0.328$). A $\geq 6^\circ$ mechanical alignment correction predicted a $\geq 3^\circ$ change in the ground-plafond angle (AUC=0.778; 95% CI: 0.701-0.855; sensitivity 88.5%; specificity 57.4%). A $\geq 2^\circ$ absolute femoral component deviation predicted deterioration in talus-plafond alignment (AUC=0.725; 95% CI: 0.595-0.855; sensitivity 76.2%; specificity 60.2%). No significant threshold value was identified for the tibial component.

Conclusion: After mechanically aligned TKA, measurable changes occur in coronal ankle alignment. The main determinant of this change is the magnitude of HKAA correction from the preoperative deformity to postoperative alignment rather than the final postoperative axis value. Femoral component alignment was also found to be influential, particularly on the talus-plafond relationship, whereas no consistent and independent effect of tibial component alignment could be demonstrated. These findings indicate that femoral component positioning should also be considered in TKA planning with respect to coronal ankle congruity.

Introduction

Total knee arthroplasty (TKA) is one of the most effective surgical procedures for reducing pain, improving function, and restoring lower-extremity alignment in advanced knee osteoarthritis. In the classical mechanical alignment approach, the femoral and tibial components are aimed to be positioned perpendicular to the mechanical axes and the hip-knee-ankle angle (HKAA) is targeted to approach 180° ; however, coronal alignment philosophies and ideal targets remain debated in the current literature [1].

In varus gonarthrosis, chronic medial deviation of the mechanical axis increases medial compartment loading and may lead to compensatory changes in the alignment of the distal tibia, ankle, subtalar joint, and hindfoot. Therefore, correction of coronal plane deformity at the knee may alter load transfer and joint orientation in ankle joint alignment [2] [3] [4].

Previous studies have reported that valgus compensatory alignment may develop at the ankle and hindfoot in varus knee osteoarthritis, and that this may be associated with subtalar joint flexibility and hindfoot adaptation [3] [4]. The severity of deformity, subtalar joint mobility, ankle joint adaptation, talar tilt, and pre-existing ankle osteoarthritis may influence the direction and magnitude of the ankle response after TKA [5] [6] [7] [8].

Alignment of the ankle joint after TKA has been investigated using different parameters, including tibial plafond inclination, talar inclination, tibiotalar tilt, ankle joint line orientation, and ground-referenced angular measurements [9].

Current studies show that changes in coronal ankle alignment may occur after correction of the lower-extremity mechanical axis, but that these changes are not always parallel to clinical outcomes. Mid-term clinical and radiological improvement in ankle symptoms has been reported in patients undergoing TKA for varus knee osteoarthritis. In contrast, symptoms may persist or worsen in patients with preoperative talar tilt, a lateralized gait pattern, or pathological distal loading characteristics [10] [11].

Recent studies indicate that the response in ankle joint alignment after TKA may vary according to the surgical alignment philosophy. Shichman et al. reported that changes in tibial plafond inclination, talar inclination, and tibiotalar tilt were limited after inverse kinematic alignment [12]. Khalifa et al. showed that realignment of the ipsilateral ankle joint line may occur after unilateral TKA, whereas no marked compensatory change may be observed on the contralateral side [13]. Yamaguchi et al. reported that despite improvement at the tibial plafond and talus levels after mechanical alignment, hindfoot alignment did not normalize in all patients [14].

An important issue that remains insufficiently clarified in the current literature is whether the change in coronal ankle joint alignment after TKA is more closely related to the magnitude of mechanical axis correction or to the coronal position of the femoral and tibial components. Even when the global mechanical axis of the lower extremity is within acceptable limits, the femoral and tibial components may deviate from neutral alignment to different degrees. Therefore, assessment of HKAA or the mechanical axis alone may not be sufficient to explain the response occurring at the ankle and foot levels. To our knowledge, no study has simultaneously evaluated the effects of femoral component alignment, tibial component alignment, and the magnitude of HKAA correction on coronal ankle alignment in the same analytical model in patients undergoing mechanically aligned TKA. This study aimed to evaluate the effect of the magnitude of lower-extremity mechanical axis correction and component positioning on coronal ankle alignment in patients undergoing TKA for varus gonarthrosis and to investigate clinically meaningful threshold values. The hypothesis of the study was that, after mechanically aligned TKA, the magnitude of HKAA correction and the coronal positions of the femoral

and tibial components would affect coronal ankle alignment, and that HKAA and component positioning closer to neutral alignment would be associated with better restoration of coronal ankle congruity.

Materials and Methods

Study Design and Patient Selection

This retrospective radiographic study was conducted at ---- and was approved by the ---- Clinical Research Ethics Committee (Decision No: E1-23-3329). The study was performed in accordance with the principles of the Declaration of Helsinki. The medical records and radiographic images of patients who underwent primary total knee arthroplasty (TKA) for varus gonarthrosis between March 2019 and December 2023 were reviewed retrospectively. In all cases, the surgical indication was advanced primary knee osteoarthritis with varus deformity in the coronal plane.

The same type of prosthesis was evaluated in all patients (posterior-stabilized [PS] knee system; Vanguard, Zimmer Biomet, USA).

Patients with a diagnosis of primary knee osteoarthritis, preoperative varus alignment, elective primary TKA, and preoperative and postoperative standing full-length lower-extremity radiographs suitable for radiological evaluation were included.

Quantitative assessment of coronal alignment was performed on long-leg anteroposterior radiographs obtained with the patient bearing weight on both lower extremities and with the extremities positioned in appropriate rotation. For radiographic evaluation, clear visualization of the femoral head center, knee joint center, ankle joint center, femoral and tibial component borders, distal tibial plafond, and talar dome was required. Radiographs with marked rotation, flexion error, image truncation, or technical inadequacy that could impair measurement reliability were excluded. Secondary osteoarthritis, non-varus deformity, previous osteotomy or the presence of an implant that could affect lower-extremity alignment, marked ankle deformity or a history of ankle surgery, revision TKA, periprosthetic fracture, deep infection, component loosening, or the need for revision surgery during follow-up were accepted as exclusion criteria.

During the study period, a total of 186 knees were screened for eligibility. After application of the exclusion criteria, 52 knees were excluded. Of these cases, 18 were excluded because preoperative or postoperative standing full-length radiographs were missing or unsuitable for measurement, 10 because the postoperative follow-up period was shorter than 24 months or no suitable follow-up radiograph was available, 8 because of secondary osteoarthritis or non-varus deformity, 7 because of previous osteotomy, fracture malunion, or the presence of an implant affecting lower-extremity alignment, 4 because of ankle arthrodesis, total ankle arthroplasty, or marked ankle deformity, and 5 because of revision TKA, periprosthetic fracture, deep infection, component loosening, or the need for revision surgery during follow-up. Consequently, 134 knees with preoperative and postoperative standing full-

length lower-extremity radiographs suitable for measurement were included in the final radiographic analysis. The patient selection process is summarized in the STROBE flow diagram (Fig. 1).

Radiographic Measurements

All radiographic measurements were performed on full-length anteroposterior radiographs obtained with both lower extremities weight-bearing, while the patient was appropriately positioned and the extremities were in appropriate rotation to avoid misinterpretation of coronal alignment. Measurements were performed by the same investigator using the Picture Archiving and Communication System (PACS). To assess intraobserver reliability, all radiographic measurements were repeated by the same observer after 48 hours in a randomly selected 30% subgroup of the study population. To reduce recall bias, the initial measurement results were not accessible during the second measurement. Measurement consistency was assessed using the intraclass correlation coefficient (ICC) [15]. HKAA was evaluated using the mechanical axes between the center of the femoral head and the knee joint center, and between the knee center and the ankle center [1]. The HKAA was measured medially. The magnitude of HKAA correction was calculated by subtracting the preoperative HKAA value from the postoperative HKAA value. Postoperative HKAA within $\pm 3^\circ$ of neutral was accepted as alignment within the neutral range, whereas values outside these limits were accepted as HKAA outliers. Cases with an exact HKAA of 180° were not evaluated as a separate main analysis group because of the small number of patients and were included in the neutral-range group within $\pm 3^\circ$.

Femoral component alignment was measured by the relationship between the femoral component joint surface and the femoral mechanical axis, and tibial component alignment was measured by the relationship between the tibial component base and the tibial mechanical axis. Coronal ankle alignment was evaluated using the ground-plafond, ground-talus, LDТА, and talus-plafond angles. The ground-plafond angle was used to indicate the orientation of the distal tibial plafond relative to the ground, the ground-talus angle to indicate the position of the talar dome relative to the ground, LDТА to indicate the coronal anatomical alignment of the distal tibia, and the talus-plafond angle to indicate the intra-articular tibiotalar relationship. The primary outcome was the change in the ground-plafond angle; secondary outcomes were changes in the ground-talus, LDТА, and talus-plafond angles (Fig. 2) (Fig. 3).

Measurement Direction and Deviation Definitions

Component deviations were calculated by subtracting the neutral value of 90° from the measured component angle, and 90° was accepted as neutral in component analyses. In the assessment of the tibial component, the angle formed medially between the tibial component and the tibial mechanical axis was used. Negative deviation indicated varus placement below 90° , whereas positive deviation indicated valgus placement above 90° . In the assessment of the femoral component, the angle formed laterally between the femoral mechanical axis and the femoral component was used. Negative deviation indicated valgus-oriented femoral component placement below 90° , whereas positive deviation indicated

varus-oriented femoral component placement above 90°. The femoral and tibial components were grouped according to the magnitude of deviation from neutral as within $\pm 2^\circ$, exactly neutral, and outside $\pm 2^\circ$. The $\pm 2^\circ$ group included deviations within 2° from neutral in both the varus and valgus directions.

HKAA within $\pm 3^\circ$ was accepted as neutral alignment; values below 180° indicated varus/medial deviation, and values above 180° indicated valgus/lateral deviation. Varus angulation in the HKA angle was expressed as a negative value, and valgus angulation as a positive value [16]. Changes in ankle angles were calculated by subtracting the preoperative value from the postoperative value; therefore, negative values indicated postoperative reduction in the relevant angle, whereas positive values indicated an increase.

Outcome Measures

The primary outcome measure of the study was defined as the preoperative-postoperative change in the ground-plafond angle. Secondary outcome measures were changes in the ground-talus angle, LDTA, and talus-plafond angle. In addition, the relationships of HKAA correction magnitude, femoral component deviation, and tibial component deviation with coronal ankle angle changes were evaluated.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics software. Continuous variables were presented as mean $\pm$ standard deviation and median values, and categorical variables as numbers and percentages. The normality of data distribution was assessed using the Shapiro-Wilk test. Because the assumption of normal distribution was not met in the majority of distributions, non-parametric tests were used for comparisons. The Wilcoxon signed-rank test was applied for comparison of preoperative and postoperative measurements within the same cases. The Mann-Whitney U test was used for comparisons between two independent groups, and the Kruskal-Wallis test was used for comparisons among three independent groups. In variables with significant differences in the Kruskal-Wallis test, pairwise Mann-Whitney comparisons with Bonferroni correction were performed. Relationships between continuous variables were assessed using Spearman correlation analysis. Multivariable linear regression analysis was used to identify variables independently affecting ankle angle changes. ROC curve analysis was performed to determine clinically meaningful threshold values, and optimal cut-off points were determined using the Youden index. A p value of < 0.05 was considered statistically significant in all analyses.

Results

Preoperative HKAA was $167.87 \pm 5.12^\circ$ and postoperative HKAA was $176.16 \pm 2.98^\circ$ ($p < 0.001$); the mean correction was $8.29 \pm 4.65^\circ$. The postoperative femoral component angle was $89.60 \pm 2.80^\circ$, and the tibial component angle was $89.88 \pm 1.97^\circ$. Femoral component deviation was $-0.40 \pm 2.80^\circ$, and tibial component deviation was $-0.12 \pm 1.97^\circ$ (Table 1).

The ground-plafond angle decreased from $7.06 \pm 3.48^\circ$ to $3.25 \pm 2.21^\circ$, with a change of $-3.81 \pm 3.09^\circ$ ($p < 0.001$). The ground-talus angle decreased from $7.27 \pm 3.52^\circ$ to $3.38 \pm 2.35^\circ$, with a change of $-3.89 \pm 2.77^\circ$ ($p < 0.001$). The talus-plafond angle decreased from $2.99 \pm 2.15^\circ$ to $2.65 \pm 2.18^\circ$, with a change of $-0.34 \pm 0.91^\circ$ ($p < 0.001$). The change in LDTA was not significant: from $87.93 \pm 2.70^\circ$ to $88.14 \pm 2.41^\circ$, with a change of $0.21 \pm 1.63^\circ$ ($p = 0.166$) (Table 1).

In the group within $\pm 3^\circ$ of HKAA, the ground-plafond difference was $-3.74 \pm 2.85^\circ$, whereas it was $-3.90 \pm 3.38^\circ$ in the group outside $\pm 3^\circ$ ($p = 0.959$). The ground-talus difference was $-3.72 \pm 2.29^\circ$ and $-4.10 \pm 3.28^\circ$ ($p = 0.453$), and the LDTA difference was $0.07 \pm 1.34^\circ$ and $0.38 \pm 1.93^\circ$ ($p = 0.230$), respectively. The talus-plafond difference was $-0.50 \pm 0.82^\circ$ in the group within $\pm 3^\circ$ of HKAA and $-0.13 \pm 0.98^\circ$ in the group outside $\pm 3^\circ$, and this difference was significant ($p = 0.006$) (Table 2).

In the femoral component analysis, the change in the ground-plafond angle differed significantly among the groups ($p = 0.006$). The ground-plafond change was $-4.32 \pm 2.83^\circ$ in the group with femoral component alignment within $\pm 2^\circ$, $-2.45 \pm 3.46^\circ$ in the group outside $\pm 2^\circ$, and $-3.92 \pm 3.01^\circ$ in the exactly neutral group. The significant difference was between the groups within $\pm 2^\circ$ and outside $\pm 2^\circ$ ($p_{\text{adj}} = 0.005$). The ground-talus and LDTA changes did not differ significantly ($p = 0.504$ and $p = 0.487$). The talus-plafond change differed significantly ($p < 0.001$); the differences were between the groups within $\pm 2^\circ$ and outside $\pm 2^\circ$, and between the outside $\pm 2^\circ$ and exactly neutral groups ($p_{\text{adj}} = 0.003$ and $p_{\text{adj}} < 0.001$) (Table 2).

In the tibial component analysis, the change in the ground-plafond angle differed significantly ($p = 0.029$): it was $-4.28 \pm 3.14^\circ$ in the patient group with tibial component alignment within $\pm 2^\circ$, $-3.52 \pm 2.61^\circ$ in the exactly neutral patient group, and $-2.13 \pm 3.48^\circ$ in the patient group with alignment outside $\pm 2^\circ$. The ground-talus and LDTA changes did not differ significantly ($p = 0.599$ and $p = 0.214$). The talus-plafond change also differed significantly ($p = 0.019$): it was $0.20 \pm 1.15^\circ$ in the patient group with tibial component alignment outside $\pm 2^\circ$, $-0.39 \pm 0.88^\circ$ in the group with alignment within $\pm 2^\circ$, and $-0.42 \pm 0.81^\circ$ in the exactly neutral group. However, tibial component deviation was not a consistent or independent determinant in the correlation, regression, or ROC analyses (Table 2).

In the regression analysis, the ground-plafond model was significant ($R^2=0.328$; $F = 15.74$; $p < 0.001$), and HKAA correction magnitude was an independent predictor ($\beta=-0.355$; $p < 0.001$). Postoperative HKAA and tibial component deviations were not significant in this model. The ground-talus model was not significant ($R^2=0.035$; $p = 0.324$). The LDTA model did not reach significance ($R^2=0.058$; $p = 0.098$); femoral component deviation showed weak significance ($\beta=-0.126$; $p = 0.036$). The talus-plafond model was significant with low explanatory power ($R^2=0.075$; $p = 0.039$), and postoperative HKAA was an independent variable ($\beta=-0.069$; $p = 0.015$).

In the ROC analysis, $\geq 6^\circ$ HKAA correction predicted a $\geq 3^\circ$ ground-plafond change (AUC = 0.778; 95% CI: 0.701–0.855; $p < 0.001$; sensitivity 88.5%; specificity 57.4%). A $\geq 2^\circ$ absolute femoral component deviation predicted talus-plafond worsening (AUC = 0.725; 95% CI: 0.595–0.855; $p < 0.001$; sensitivity

76.2%; specificity 60.2%). No cut-off was identified for the tibial component or ground-talus (Table 3) (Fig. 4). Intraobserver reliability analysis showed excellent agreement for all measurements (ICC > 0.90).

Discussion

The main finding of this study was that the coronal ankle alignment response in patients undergoing TKA for varus gonarthrosis cannot be explained solely by whether postoperative HKAA is within the neutral range. While the magnitude of HKAA correction was identified as the strongest independent predictor of change in the ground-plafond angle, the absolute deviation of the femoral component from the neutral position showed a significant threshold value for predicting deterioration in the talus-plafond relationship. Taken together, these two findings indicate that the coronal plane response of the ankle joint after TKA is a multilevel process influenced by both global coronal axis correction and component positioning. These results support our study hypothesis that the magnitude of HKAA correction and component positioning may affect coronal ankle alignment.

In the present study, significant reductions were observed in the ground-plafond, ground-talus, and talus-plafond angles after TKA, indicating coronal plane improvement in the ankle joint. In contrast, no significant change was detected in LDTA. This result shows that the coronal ankle response after TKA does not occur to the same extent in all radiographic parameters. Lee and Jeong reported that radiographic changes may occur in the ankle joint after TKA and that a high degree of coronal correction in particular may be associated with ankle joint changes [5]. Similarly, Gürsu et al. showed that acute correction of the knee axis after TKA in varus gonarthrosis can significantly alter ankle joint line orientation [6].

Because the ground-plafond angle reflects the orientation of the distal tibial articular surface relative to the ground and the global loading plane, its strongest relationship with HKAA correction magnitude may be biomechanically expected. In multivariable analysis, the model explaining the change in the ground-plafond angle was significant, and only HKAA correction magnitude remained as a strong independent predictor in this model, supporting that reorientation of the distal tibial plafond relative to the ground is primarily associated with global coronal correction. Shichman et al. also reported that coronal alignment correction after TKA may affect tibial plafond and talar inclination [8]. The report by Khalifa et al. of ipsilateral ankle joint line realignment after unilateral TKA also supports that knee axis correction may be reflected in ankle joint alignment [13].

In contrast, although the ground-talus angle decreased significantly after surgery, it did not show a significant correlation with HKAA correction magnitude and could not be explained in the multivariable model. This suggests that talar position does not depend solely on correction in knee HKAA. Norton et al. reported that compensatory hindfoot changes may develop in response to coronal knee deformity in advanced knee osteoarthritis and that a substantial portion of this compensation occurs at the subtalar joint and hindfoot levels [4]. Jeong et al. also showed that compensatory changes after TKA occur not only at the ankle, but also at the subtalar joint and foot levels [7].

The more limited change in the talus-plafond angle compared with the ground-plafond and ground-talus angles indicates that TKA does not directly and uniformly alter tibiotalar joint congruity. In the systematic review by Feng et al., the ankle response after TKA was emphasized to be heterogeneous, and parameters such as the tibial plafond, talar tilt, tibiotalar relationship, and hindfoot compensation may be affected at different levels [9]. Yamaguchi et al. also reported that although improvement at the tibial plafond and talus levels was observed after mechanically aligned TKA, hindfoot alignment did not completely normalize in all patients [14]. Therefore, the talus-plafond relationship should be considered a distinct tibiotalar congruity parameter that cannot be explained solely by HKAA correction.

One of the original aspects of this study is the separate evaluation of the relationships between femoral and tibial component positions and ankle angle changes in addition to HKAA correction magnitude. Femoral component deviation was associated with both ground-plafond and talus-plafond changes in univariable analyses. The more limited improvement in the ground-plafond angle in patients whose femoral component alignment was outside $\pm 2^\circ$ suggests that component positioning may affect ankle joint alignment. Matassi et al. emphasized that coronal alignment philosophies and component positioning in TKA remain controversial and that mechanical alignment targets are being re-evaluated with patient-specific approaches [1]. In this context, not only global HKAA but also component-level coronal deviations should be evaluated with respect to ankle joint alignment.

However, in multivariable analysis, femoral component deviation did not remain an independent predictor of ground-plafond change. Therefore, the effect of the femoral component on the ground-plafond angle should most likely be interpreted as a shared effect related to global mechanical axis correction. In contrast, femoral component deviation may have a separate importance with respect to the talus-plafond relationship. The finding that a threshold of $\geq 2^\circ$ for absolute femoral component deviation was significant in predicting deterioration of talus-plafond alignment is one of the most noteworthy findings of this study.

Because the talus-plafond angle reflects the intra-articular tibiotalar relationship, femoral component positioning may affect tibiotalar congruity rather than directly affecting the ground-plafond change. Rühling et al. reported that increased ankle pain after TKA was associated with a preoperative lateralized gait pattern and talar tilt [10]. Choudhury et al. also showed that increased medial talar tilt may be important in terms of ankle pain and predisposition to ankle osteoarthritis after TKA [11]. These findings suggest that talus-related parameters may have not only radiographic but also potential clinical importance.

The magnitude of postoperative HKAA correction showed a strong correlation with the ground-plafond change and remained an independent predictor in regression analysis. This finding indicates that, for the response at the ankle level, the magnitude of correction from the preoperative deformity to postoperative alignment may be more determinant than the final axis value. The finding that $\geq 6^\circ$ HKAA correction predicted a $\geq 3^\circ$ change in the ground-plafond angle in ROC analysis also supports this interpretation.

The finding by Gürsu et al. that the change in ankle joint line orientation after TKA was associated with correction of the knee axis is consistent with this result [6].

The alignment philosophy used in TKA may also affect the ankle response. Shichman et al. reported that after TKA performed according to inverse kinematic alignment principles, changes in tibial plafond inclination, talar inclination, and tibiotalar tilt remained limited despite a more pronounced change in the knee axis in patients with severe varus deformity [12]. In the present study, the magnitude of HKAA correction did not predict a statistically significant change in tibiotalar tilt. This finding supports the findings of our study.

In the group with tibial component alignment outside $\pm 2^\circ$, improvement in the ground-plafond angle was smaller and the talus-plafond change was more unfavorable. However, angular deviation of the tibial component did not show a consistent relationship with ankle angle changes in correlation analysis, was not identified as an independent predictor in multivariable regression analysis, and did not form a significant threshold value in ROC analysis. Therefore, in the present data, the effect of tibial component positioning on the coronal ankle response does not appear to be as determinant as HKAA correction magnitude and femoral component deviation.

The most important clinical interpretation of these findings is that coronal ankle alignment after TKA cannot be evaluated solely by asking whether the postoperative axis is neutral. In patients with varus gonarthrosis, while HKAA correction magnitude determines reorientation of the distal tibial plafond relative to the ground, femoral component angular deviation greater than 2° may be a potential risk marker for tibiotalar congruity. Because femoral component deviation of $\geq 2^\circ$ from neutral was associated with deterioration in the talus-plafond relationship, the effect of component positioning on ankle joint congruity should not be overlooked. The systematic review by Feng et al., demonstrating clinical and radiological ankle changes after TKA in knees with varus deformity, supports the importance of ankle joint alignment in clinical follow-up [9].

This study has several limitations. First, it has a retrospective design, and the timing of radiographic follow-up was not standardized. Second, the evaluation was performed only on two-dimensional standing long-leg radiographs; hindfoot alignment views, lateral radiographs, subtalar joint mobility, or three-dimensional imaging methods were not used. Third, ankle pain, functional scores, and patient-reported outcomes were not evaluated; therefore, the clinical relevance of the observed radiographic changes cannot be directly demonstrated. Fourth, the number of patients in some subgroups, particularly the component outlier groups, was limited. Finally, the $\geq 2^\circ$ threshold determined for femoral component deviation was derived from ROC analysis and should be validated in larger independent cohorts.

Nevertheless, the study has several strengths. In all cases, HKAA, femoral and tibial component positions, and coronal ankle angles were evaluated together on preoperative and postoperative weight-bearing long-leg radiographs. In addition, ankle alignment was examined not with a single parameter but with different measurements reflecting the distal tibial plafond, talus, LDTA, and tibiotalar relationship.

The combined use of HKAA correction magnitude, component deviations, correlation, multivariable regression, and ROC analyses allowed a more detailed assessment of the ankle response after TKA.

Conclusion

Measurable radiographic changes in coronal ankle alignment occur after TKA performed for varus gonarthrosis. The main determinant of the change in the ground-plafond angle is the magnitude of HKAA correction; $\geq 6^\circ$ HKAA correction may predict a $\geq 3^\circ$ ground-plafond change. In addition, an absolute deviation of the femoral component by $\geq 2^\circ$ from neutral was associated with talus-plafond malalignment. No consistent independent effect or significant cut-off was identified for tibial component deviation. These findings indicate that, in mechanically aligned TKA, coronal ankle joint alignment is affected by the magnitude of HKAA correction and femoral component alignment. During surgery, importance should be given to achieving neutral alignment of HKAA and the femoral component.

Declarations

Ethics Approval

This study was approved by the Ankara Bilkent City Hospital Clinical Research Ethics Committee (Decision No: E1-23-3329). The study was conducted in accordance with the principles of the Declaration of Helsinki. Owing to the retrospective design of the study, the requirement for informed consent was waived by the ethics committee.

Consent for Publication

Not applicable.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author Contributions

Mehmet Önüt: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft.

Sualp Turan: Conceptualization, Methodology, Supervision, Validation, Writing – review and editing.

Both authors read and approved the final manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Clinical trial number: not applicable

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Tables

Tables 1 to 3 are available in the Supplementary Files section.

Figures

STROBE Flow Diagram

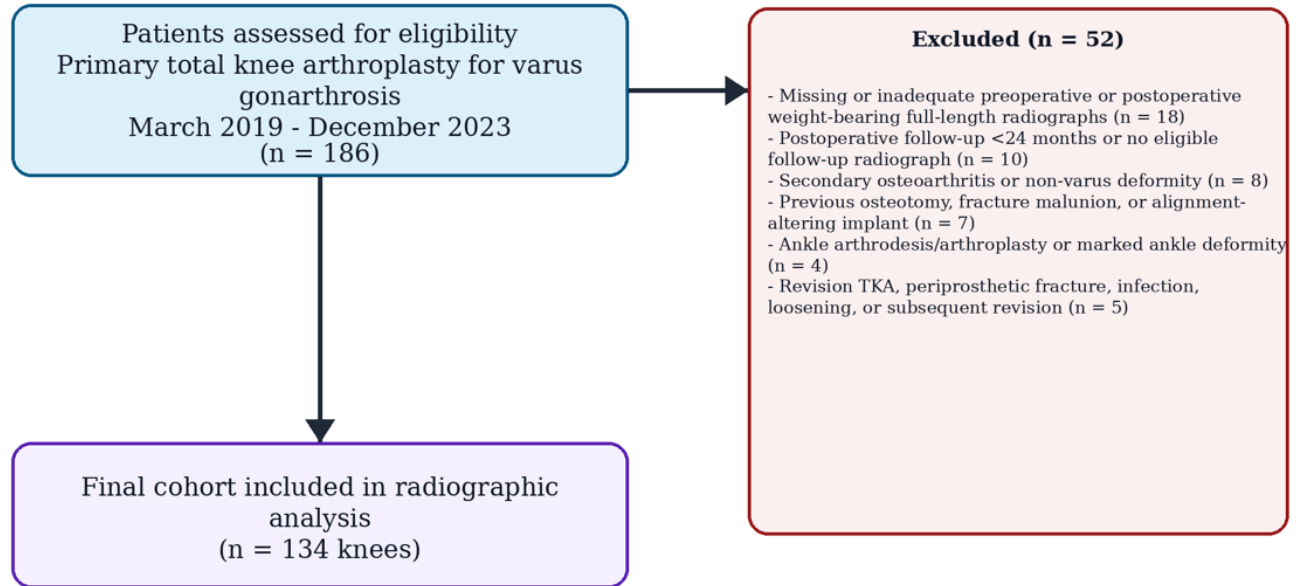


Figure. STROBE flow diagram of patient selection for the final radiographic analysis.
TKA, total knee arthroplasty.

Figure 1

STROBE flow diagram of patient selection.

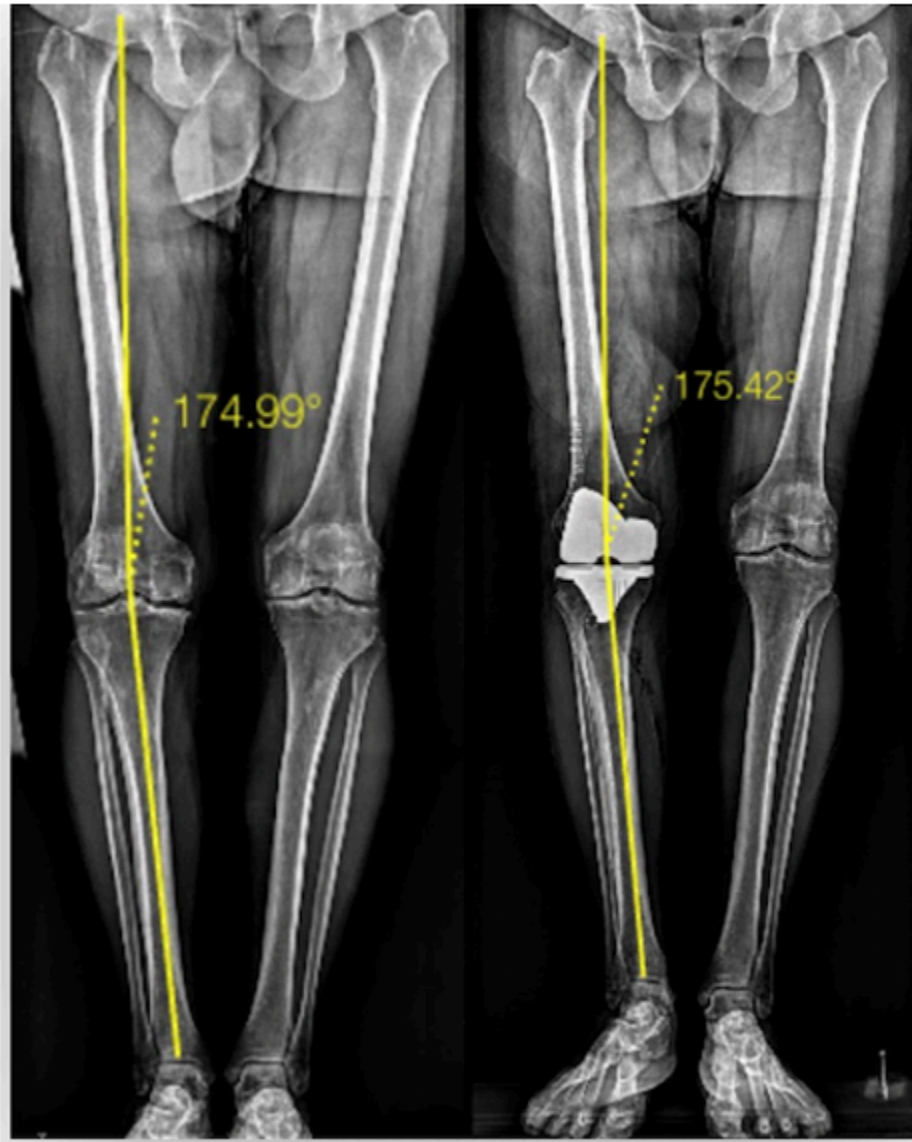


Figure 2

Preoperative and postoperative HKAA measurement on weight-bearing long-leg radiographs.

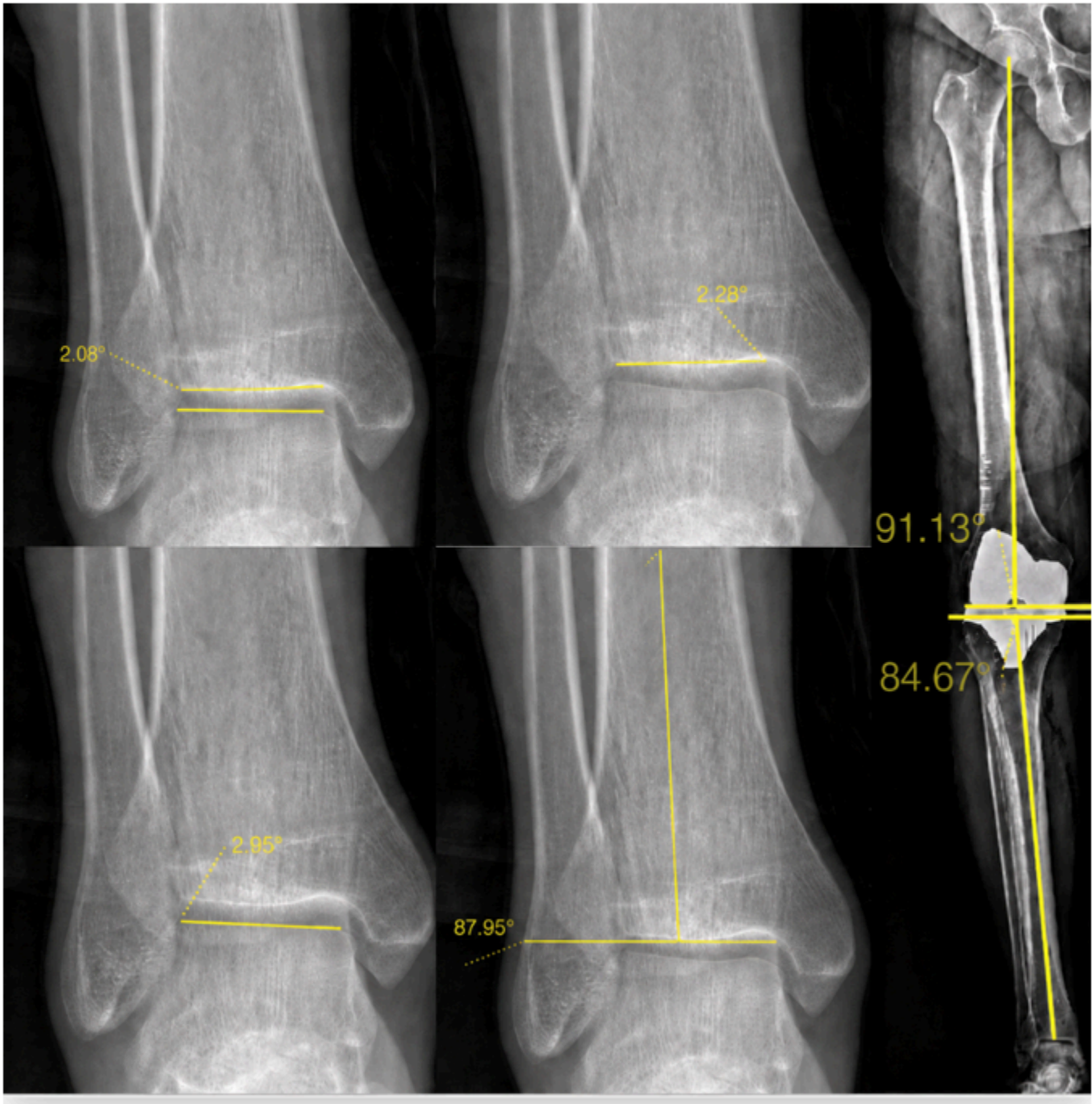


Figure 3

Measurement of ankle alignment parameters and component angles on weight-bearing radiographs.

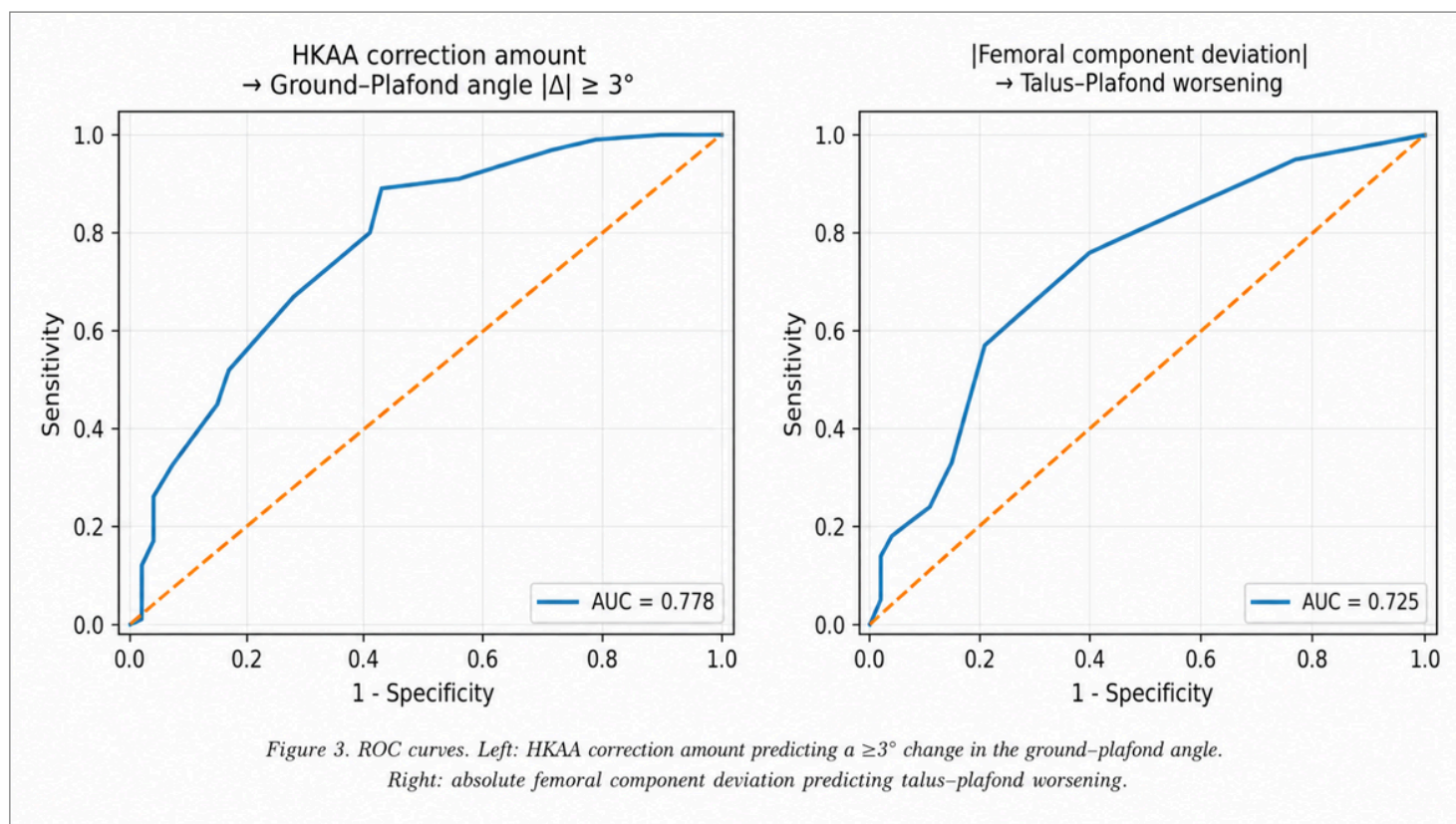


Figure 4

ROC analysis of mechanical axis correction and femoral component deviation.

Supplementary Files

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- [Table123.docx](#)