RESEARCH ARTICLE

Predictive Radiographic Factors for Soft Tissue Release and Distal Femoral Cut Angle for Appropriate Biomechanics in Total Knee Arthroplasty

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Abstract

Objectives: Total knee arthroplasty (TKA) relies on precise soft tissue releases and bone cuts for balanced weight distribution. Challenges include the lack of predictors to guide the extent and timing of soft tissue release. This study examines the relationship between radiographic parameters and the distal femur valgus cut angle (VCA), and their correlation with the medial soft tissue release (MSTR) stage in TKA patients. The goal is to identify predictors that aid in achieving optimal biomechanics and tissue balance.

Methods: In this prospective cohort study, we examined preoperative standard lower limb three-joint views of 62 limbs (57 patients) to explore the relationship between radiographic parameters, the stage of MSTR, and VCA. Univariate and multivariate linear regression analyses, along with various statistical tools, were used to identify relationships and determine cut-off values.

Results: A notable positive correlation was observed between VCA and medial hip offset (MHO), as well as between VCA and femoral length (FL), with both correlations yielding P < .001. Patients with shorter femurs and an MHO greater than 4.35 cm required a distal femoral cut angle of 6 degrees or more, while those with longer femurs and an MHO less than 4.35 cm needed an angle of less than 6 degrees (sensitivity: 83%, specificity: 80%). Additionally, the joint line congruency angle (JLCA), varus angle (VA), and lateral distal femoral angle (LDFA) showed significant correlations with the stage of MSTR. Among these variables, the VA emerged as the most accurate predictor, with a sensitivity of 91.7% and a specificity of 100%.

Conclusion: Increasing the LDFA to above 93.5°, JLCA to above 7.5°, and the VA to above 19° would heighten the probability of requiring extensive MSTR. Additionally, MHO and FL are the most crucial predictive factors for determining the VCA.

Level of evidence: II

Keywords: Arthroplasty, Collateral ligaments, Lower extremity, Medial hip offset, Valgus cut

Introduction

The objective of mechanical alignment in total knee arthroplasty (TKA) is to maximize the longevity of the prosthesis, decrease wear, and ensure even load distribution by positioning the femoral and tibial components perpendicular to their respective mechanical axes. Medial soft tissue release (MSTR) targets the constricted medial tissues surrounding the knee joint, aiming to correct imbalances and achieve balanced flexion and extension gaps to optimize joint function. Proper soft tissue releases and precise bone cuts result in an even

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distribution of body weight across the medial and lateral compartments of the femur and tibia following TKA.[1] With varus osteoarthritis recognized as the most prevalent deformity following TKA, finding the appropriate MSTR, and the femoral valgus cut angle (VCA), defined as the angle formed between the femur's mechanical and anatomical axes, are two critical steps in mechanical alignment technique for knee replacement surgery.[2,3]

Despite the introduction of numerous MSTR techniques during TKA, no convenient or practical predictors have been suggested that can effectively visualize the extent of release, as well as its optimal timing and sequence during the procedure.[4,5] Several investigations have explored the relationship between MSTR and the statistical features of the tibiofemoral joint; however, most of these methods are primarily utilized in research settings due to various issues, such as safety concerns related to fluoroscopy and the high costs associated with knee analysis system. Additionally, they are often employed only in specific cases.[6,7]

With the jury still out on the discussion regarding the importance of soft tissue balancing, the introduction of easy-to-use, cost-effective, and safe predictors for MSTR would greatly assist surgeons in making the necessary preparations, such as selecting the proper type of prosthesis (e.g., constrained condylar knee (CCK) prosthesis). Furthermore, accurate estimation of MSRT helps prevent excessive bone cut, thereby reducing the likelihood of requiring a CCK prosthesis.

In this study, the aim is to investigate the relationship between radiological parameters and VCA, detect any correlations between the radiographic parameters and the stage of MSTR, and ultimately find the most valuable predictors.

Materials and Methods

Study Design and Patient Selection

This prospective cohort study was carried out from February 2017 to June 2019. We included patients with knee joint osteoarthritis classified as types 3 and 4 according to the Kellgren-Lawrence classification[8] and those with varus knee alignment who underwent TKA using the mechanical alignment method. Patients with bony deformities in their lower limbs, joint-related inflammatory diseases (e.g., rheumatoid arthritis and malignancies), or a history of surgery on the ipsilateral knee joint, hip joint, femur, or tibial shaft were excluded. After applying the eligibility criteria, 57 patients (62 limbs) were enrolled, and demographic data, including body mass index (BMI), age, and gender, were collected. The four stages of MSTR are defined as follows: the first stage involves the release of the deep MCL; the second stage includes the release of the posterior oblique ligament (POL) and the semimembranosus direct arm; the third stage entails the release of the anterior portion of the superficial MCL; and the fourth stage consists of the release of the pes anserinus at the tibia.

Eventually, patients were categorized into two groups: the first group consisted of patients in stages 1 and 2 of medial release, while the second group comprised those in stages 3 and 4. The radiological parameters were subsequently analysed in both groups.

Radiographic Assessment

A standard protocol was established for obtaining a standing radiograph, with the distal femoral trans-epicondylar plane positioned precisely parallel to the cassette, the patella posed exactly forward, and a distance of 230 cm maintained between the X-ray tube to the cassette.[9] Radiological parameters including varus angle (VA), joint line congruency angle (JLCA), femoral neck-shaft angle (NSA), femoral length (FL), medial proximal tibial angle (MPTA), mechanical lateral distal femoral angle (mLDFA), femoral anatomical-mechanical angle (AMA), medial hip offset (MHO), and the VCA were measured using Bardakos *et al.*'s method.[10] The measurements were performed using a Windows-based application (Marcopacs). The validity of these measurements was confirmed by comparing our data with established population studies.

The standard lower limb three-joint view (alignment view) was obtained preoperatively and two months after TKA surgery to measure the parameters, which were then assessed by two blinded expert knee surgeons. The mean of the two measurements was calculated to minimize statistical errors. The center of the femoral head was determined using Mose circles, while the center of the distal femur was identified as the uppermost point of the intercondylar notch, where the alignment rod is inserted during surgery [Figure1].[9]

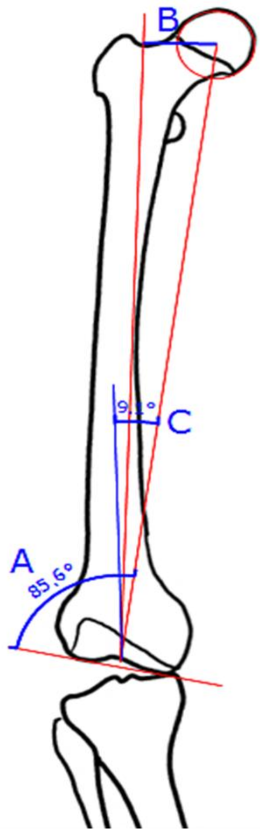

Figure 1. Radiographic parameters. A: Medial lateral distal femoral angle (mLDFA), B: Medial hip offset (MHO), C: Distal anatomical mechanical axis (dAMA)

The mechanical axis of the femur is defined by a line connecting the center of the femoral head to the center of the distal femur. The axis that extends from the piriformis fossa to the center of the distal femur is considered the anatomical axis of the femur. However, due to the design of intramedullary measurement devices used in TKA, we utilized the anatomical axis of the distal third of the femur to measure VCA of the distal femur. After a line is drawn perpendicular to the anatomical axis of the femur and passing through the hip center of rotation (HCR), the distance between these two points is defined as MHO [Figure 1B]. The tibial mechanical axis is defined as the line connecting the center of the tibial plateau to the center of the tibial plafond. The MPTA is the angle formed between the tibial mechanical axis and the tangent line of the tibial articular surface of the tibial plateau on the medial side. The mLDFA is the angle between the femoral mechanical axis and the tangent line on the lateral side of the distal femoral articular surface [Figure 1A]. The JLCA is the angle between the tangent lines on the articular surfaces of the distal femur and the proximal tibia. The anatomical-mechanical axis angle (AMA) is the angle between the femoral mechanical and anatomical axes, while the VA is the angle between the mechanical axes of the femur and tibia. Finally, the distal third anatomical-mechanical angle (dAMA) is the angle between the mechanical axis and the anatomical axis of the distal third of the femur [Figure 1C]. Some of the more significant angles are depicted in [Figure 2].

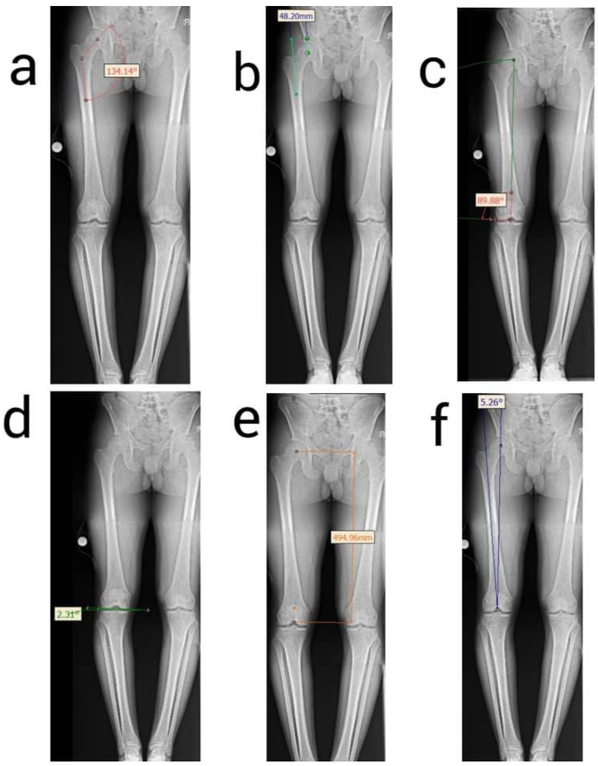

Figure 2. Anatomical and mechanical characteristics of femoral bone and knee joint. Respectively, a: Neck shaft angle (NSA), b: Medial hip offset (MHO), c: Lateral distal femoral angle (LDFA), d: Joint line congruency angle (JLCA), e: Femoral length (FL), f: Valgus cut angle (VCA)

Radiographic characteristics were standardized to ensure consistency and comparability across measurements. This process involved adjusting the data to achieve a mean of zero and a standard deviation of one, thus minimizing unit inconsistencies. Normalization was performed by subtracting the mean from each parameter and dividing by its standard deviation, which maintained uniform scales and reduced variability arising from differences in measurement units. Outliers were identified and removed using Z-score analysis, eliminating data points with Z-scores exceeding three. Missing values were addressed through multiple imputation methods to ensure a complete dataset without introducing bias.

Statistical Analysis

Drawing from related studies and considering an alpha level (α, the probability of making a Type I error) of 0.05, along with a power of 80% (corresponding to β = 0.20, the probability of making a Type II error), the required sample size was determined to be 62 participants. This sample size calculation was based on the expected effect size and the variability observed in similar studies.[5,11,12] To examine the relationships among the distal femoral cut angle, radiographic parameters, and demographic data, Pearson correlation, t-tests, and linear regression analyses were employed. The significance level for all tests was set at α = 0.05.

Once the data were gathered, statistical analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY). The primary dependent variable, VCA, was assessed using a linear mixed model, a regression technique designed to analyse the relationship between a dependent variable and independent variables in clustered or grouped data sets. To investigate the relationships among the distal femoral cut angle, radiographic parameters, and demographic data, Pearson correlation, t-tests, and linear regression analyses were employed.

To ensure that the dataset used for the analysis remained balanced and free from overfitting or inappropriate test conditions, we evaluated the distribution of the dataset across four distinct groups, categorized by various stages of MSTR. The distribution of patients across these stages was as follows: Stage 1 (n=20), Stage 2 (n=30), Stage 3 (n=8), and Stage 4 (n=4). To further validate the dataset's balance, the mean and standard deviation of key radiographic parameters were calculated across these groups, finding no significant skewness or kurtosis that could indicate an imbalance in the dataset. The statistical metrics for sensitivity, specificity, negative predictive value (NPV), and positive predictive value (PPV) were derived from this balanced dataset.

Results

Participants

A total of 62 limbs from 57 patients, with an average age of 68.6 years (range: 42-92), were studied in this process. The demographic characteristics and pre-operative radiographic measurements of these patients are presented in [Table 1].

Table 1. Demographic and radiographic features of TKA patients

Variable	Average ± SD (range)	Gender		
		Male	Female	P. value
Age (mean)	68.6 ± 9.14 (42-92)	68.66	68.63	0.570
BMI	29.58 ± 3.89 (20-37)	25.3	30.1	0.001
VCA (°)	6 ± 0.92 (3-8)	6	6	0.954
NSA (°)	127.1 ± 5.99 (115-138)	126.5	127.19	0.651
MHO (cm)	4.69 ± 0.62 (3.2-6.9)	5.02	4.65	0.196
LDFA (°)	91.46 ± 2.93 (85-98).	92.13	91.36	0.642
FL (cm)	42.96 ± 3.22 (38-52)	42.7	46.9	0.002
JLCA (°)	5.71± 2.89 (2-15)	4.63	5.87	0.371

Correlation between Radiographic Parameters and VCA

To determine the correlation between radiographic parameters and VCA, both univariate and multivariate linear regression methods were applied. The process commenced with a univariate analysis, and parameters with a p-value of less than 0.25 were subsequently included in the multivariate linear regression analysis. The NSA and MHO exhibited a significant correlation with VCA according to the univariate correlation analysis [Figure 3A and 3B] additionally, a negative trend was observed between FL and VCA [Figure 3C].

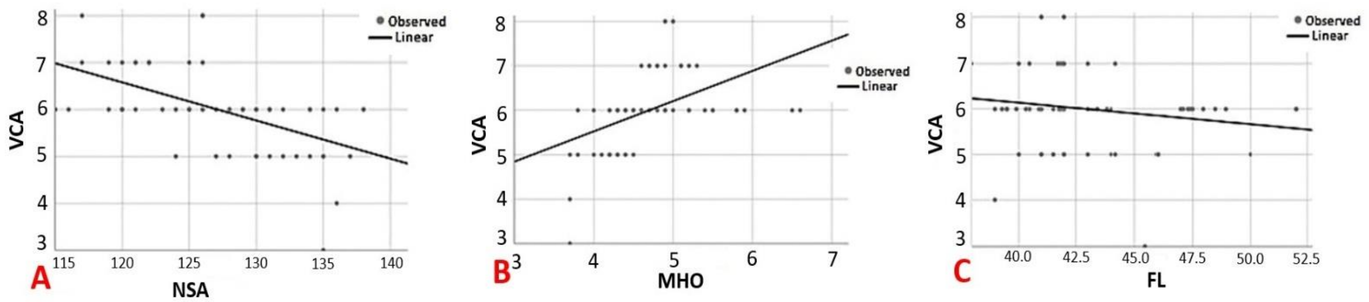

Figure 3. A: Negative correlation between neck shaft angle (NSA) and valgus cut angle (VCA); B: positive correlation between medial hip offset (MHO) and VCA; C: Negative correlation between femoral length (FL) and VCA

Multivariate analysis was conducted on the NSA, FL, and MHO. After controlling for the effects of intervening variables, such as age, gender, and BMI, FL and MHO were identified as independent factors. A significant negative correlation was observed for FL (P < .001), while a significant positive correlation was found for MHO (P < .001) [Table 2]. Based on the VCA of the distal femur, the patients were categorized into two groups. The common range of anatomical mechanical axis deviation is 3 to 7 degrees.[13] However, some research suggests a difference across genders, with females exhibiting a slightly smaller differential.[14] Nevertheless, our study did not find any significant correlation between age or gender and the stage of MSTR. Effectively, individuals with a VCA of 6° or more were categorized into the first group, while 5° or less constituted the second group. The cut-off values for the relationship between MHO and VCA were identified. Using receiver operating characteristic (ROC) curve analysis, it was found that patients with an MHO greater than 4.35 cm had a VCA of 6° or more, whereas those with an MHO of 4.35 cm or less had a VCA of 5° or less (Sensitivity (SEN): 83%, Specificity (SPE): 80%) [Figure 3A]. By plotting the true positive rate (sensitivity) against the false positive rate (1-specificity) for various cut-off points, the ROC curve provides a visual representation of the diagnostic accuracy of each parameter. The area under the curve (AUC) quantifies the overall ability of the test to differentiate between various stages of MSTR and different values of VCA. ROC curve analysis was employed to identify the optimal cut-off points for the radiographic parameters to maximize both sensitivity and specificity. However, it was not possible to determine the exact cut-off point for the FL.

The intraclass correlation coefficient (ICC) was calculated to assess interobserver agreement and reliability in the evaluation of NSA, FL, MHO, JLCA, and LDFA. This analysis revealed a high level of consistency between the two evaluators [Table 3].

Table 2. Correlation of various radiographic parameters with VCA using univariate and multivariate linear regression

Radiographic Parameters	VCA				
	Univariate analysis		Multivariate analysis		
	Coefficient	*P-value*	*Coefficient (SE [b])*	*95% CI [c]*	*P-value*
MHO	0.609	< 0.001	0.533 (0.139)	0.255 – 0.810	< 0.001
NSA	-0.566	< 0.001	-0.186 (0.119)	-0.423 – 0.052	0.123
FL	-0.182	0.156	-0.470 (0.106)	-0.682 – -0.258	< 0.001
JLCA	-0.031	0.809	----	----	----

Table 3. ICC a values for interobserver reliability of VCA, FL, femoral offset, and NSA

Radiographic Parameters	ICC	95% CI [b]
FL	0.962	0.936-0.977
MHO	0.988	0.981-0.991
NSA	0.986	0.976-0.991
LDFA	0.980	0.967-0.988
JLCA	0.972	0.953-0.983

[a]: Intraclass Correlation Coefficient; [b]: Confidence Interval

Correlation between Radiographic Parameters and the Stage of Medial Release

The evaluation of five pre-operative angles revealed that the MPTA, LDFA, VA, and JLCA significantly correlate with the stage of MSTR in TKA patients. Specifically, a decrease in pre-operative MPTA and an increase in LDFA, JLCA, and VA are associated with a higher demand for extensive MSTR during TKA [Table 4]. It is worth mentioning that the Analysis of Variance (ANOVA) test was applied to evaluate the correlation among MPTA, VA, and the stage of medial release, while the Kruskal-Wallis test was employed for LDFA, JLCA, and AMA due to their non-normal distribution.

Table 4. Measurement of various preoperative radiographic parameters across 4 stages of medial soft tissue release: mean (standard deviation)

Variable	Stage 1 (n=20)	Stage 2 (n=30)	Stage 3 (n= 8)	Stage 4 (n= 4)	P. value
LDFA	89.50 (2.36)	91.35 (2.32)	95.13 (1.55)	94.75 (2.21)	<0.001
MPTA	86.60 (2.062)	83.83 (3.28)	82.12 (2.47)	82.25 (1.25)	<0.001
JLCA	4.50 (1.39)	5.03 (1.71)	7.88 (3.64)	12.50 (3.10)	<0.001
VA	7.25 (2.80)	13.30 (3.10)	21.25 (3.61)	24.25 (1.70)	<0.001
AMA	5.92 (1.03)	6.11 (1.36)	6.38 (0.91)	5.75 (2.06)	0.793

To evaluate the predictive value of pre-operative measurements of MPTA, LDFA, VA, and JLCA for determining the level of MSTR during TKA surgery in patients with varus knees, we assessed positive predictive values (PPV), negative predictive values (NPV), SEN, and SPE for each angle [Table 5]. Patients were categorized into two groups according to the stage of medial release. The first group included patients with stages 1 and 2 of medial release, while the second group comprised those with stages 3 and 4. Optimal cut-off points were determined to maximize both SEN and SPE on a ROC curve. [Figure 3B]. The necessity of stage 3 or 4 medial release (group 2) was evaluated based on the determined cut-off points. Increasing pre-operative LDFA, VA, and JLCA were positively correlated with stages 3 and 4 of medial release, while a decrease in MPTA was observed [Table 5]. According to the area under the curve (AUC) for each angle [Figure 3], VA demonstrated the best overall performance in predicting the need for extensive medial release during TKA surgery (SEN: 91.7 % and SPE: 100%). A higher AUC indicates superior diagnostic performance. The AUC for each radiographic parameter was calculated, with VA showing the highest AUC among all parameters. This finding indicates that VA is the most effective diagnostic indicator for predicting the necessity of extensive MSTR.[14] Specifically, a VA greater than 19° was associated with higher stages of MSTR [Figure 4].

Any patient with VA greater than 19° requires stage 3 or 4 of MSTR. The LDFA was identified as the second most predictive angle, while MPTA demonstrated the lowest predictive value in post hoc analysis and ROC curve analysis [Table 5]. With the exception of one patient who required the third stage of MSTR despite having a pre-operative VA < 19° and LDFA > 93.5°, all other participants with a pre-operative VA < 19° experienced lower stages of MSTR, regardless of their pre-operative LDFA. Since we applied the mechanical alignment method during TKA, obtaining an acceptable normal alignment has been considered the main goal, as well as an indicator of appropriate bone cuts and soft tissue releases during the procedure. Therefore, we also assessed the radiographic parameters six months post-TKA. According to our results, the LDFA, JLCA, and VA decreased to 91° ± 1.8°, 0.032° ± 0.25°, and 2.2° ± 3.2°, respectively, while the MPTA increased to 89.3° ± 1.8° six months after TKA.

Table 5. Cut-off point values for various angles along with their corresponding sensitivity and specificity

Variable	Cut-off point (°)	Sensitivity (%)	Specificity (%)	NPV (%)	PPV (%)	The area under the curve
LDFA	93.5	91.7	90.0	68.7	97.8	0.933
MPTA	84.5	62.0	91.7	36.7	96.9	0.228
JLCA	7.5	75.0	94.0	75.0	94.0	0.837
VA	19	91.7	100	100	98.0	0.979

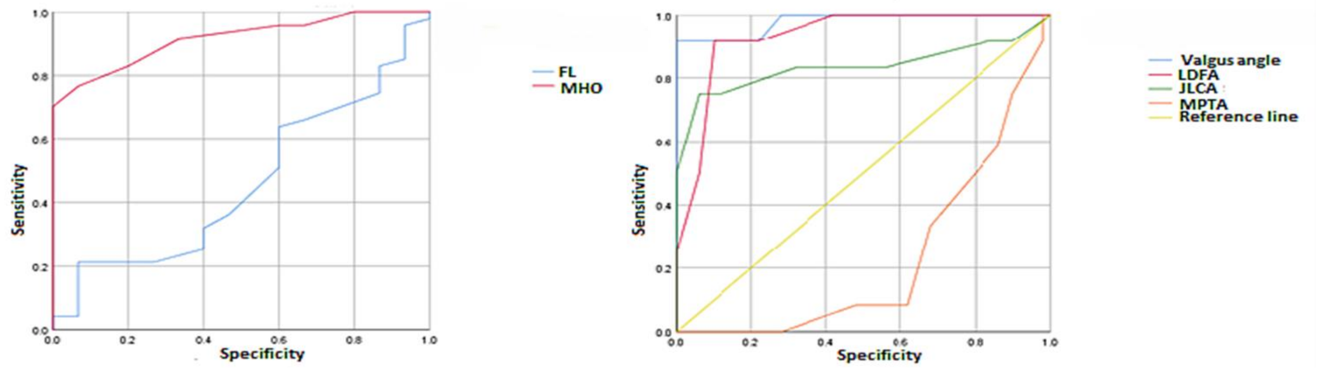

Fig. 4 A: Receiver operating characteristic (ROC) curve to evaluate the effect of pre-operative radiological parameters on the rate of distal femoral valgus cut. The blue graph shows the femoral length (FL), and the red graph shows the medial hip offset (MHO). B: ROC curve analysis of four pre-operation radiographic parameters to predict medial soft tissue release (MSTR) stage during total knee arthroplasty (TKA) surgery. The blue curve, indicating varus angle (VA) had the best performance, and the orange curve, indicating medial proximal tibial angle (MPTA) had the lowest value to predict the stage of release.

Discussion

MSTR and bone cuts play a substantial role in achieving proper alignment, which is associated with patient satisfaction and postoperative outcomes. However, the timing of the surgery, the extent of the release, and the sequence of these procedures are subjects of debate in numerous studies.[5,11,15-18] Over time, the development of novel equipment, such as intraoperative computerized navigation systems, has the potential to improve alignment and balancing. Nevertheless, the optimal predictive factors that are both cost-effective and user-friendly remain unknown.[4,19-22]

The primary hypothesis of our study was to evaluate the predictive value of pre-operative radiographic parameters in estimating the amount of soft tissue release required during TKA. This release has a crucial role in balancing the gaps following bone cuts. Inadequate soft tissue release and improper restoration of medial and lateral balance in the knee flexion and extension gaps can reduce the longevity of the artificial joint and negatively impact patient satisfaction post-surgery.[12,23-26] Based on our results, there is a significant relationship between the stage of MSTR and increased LDFA, JLCA, and VA. Among the radiographic parameters assessed, the highest predictive value for soft tissue release is associated with VA, while the lowest predictive value is linked to MPTA.

Verdonk *et al.*[27] similarly demonstrated that an increase in pre-operative VA would significantly results in extensive MSTR. However, they neither found a cut-off value for VA, nor did they investigate other important parameters such as MHO, FL, JLCA, and LDFA. Moon *et al.*[24] also claimed that there is a significant correlation between the extent of MSTR and pre-operative VCA. Conversely, Lee *et al.*[28] and Ahn *et al.*[29] revealed that MSTR is associated with the difference in pre-operative valgus and varus stress angles, as well as the pre-operative sum of mechanical valgus and varus stress angles, respectively. In the most recent study conducted by Sajjadi *et al.*,[30] the cut-off values for VA and MPTA affecting the extent of MSTR were determined to be 19° and 81°, respectively. Based on our investigation, these measurements were found to be 19° and 84.5°, which are extremely close to the previously reported values. In addition, in both studies, the predictive value of VA was greater than that of MPTA. We also demonstrated that by increasing JLCA and LDFA to more than 7.5° and 93.5°, respectively, the need for stages 3 and 4 of MSTR increases; however, the predictive values of both parameters were lower than that of VA.

In connection with the previous findings, some authors have demonstrated that distractive stress radiograph assessment is the most predictive method for determining the MSTR stage.[31,32] However, a significant drawback of this method is that it exposes patients to high doses of radiation and is not cost-effective. In summary, considering all the aforementioned arguments, our study is the most comprehensive to date, establishing various pre-operative radiographic features to estimate the extent of MSTR, along with their predictive power and value.

Predicting the stage of MSTR using radiographic cut-off points is a cost-effective, easy-to-use, and readily available method. This approach enables surgeons to prepare the necessary equipment for surgery and plan for CCK backup provision when needed. In the current study, the VCA was measured individually to ensure proper alignment during surgery. The average angle measured was 6° (ranging from 3 to 8°), which is comparable to the findings reported by Drexler *et al.* in 2017 (5.76°)[33] and Wang *et al.* in 2010 (5.1°).[34]

Different values for the VCA have been reported in previous studies. Bardakos *et al.* stated that a fixed angle of 5-6° may yield acceptable results in most patients.[10] In contrast, Dunn *et al.*[35] claimed that the suitable distal femoral cut angle is 7° for varus knees, 4-5° for valgus knees, and 6-7° for knees with neutral or normal alignment.

Several studies have demonstrated the relationship between pre-operative radiographic parameters and VCA, the inverse relationship with NSA, and the positive correlation with MHO.[10,33,34] Moreover, Bardakos *et al.*[10] reported that a 10 mm increase in MHO corresponds to a 1.2 mm increase in the distal femoral cut valgus. They also found that individuals with a VCA of less than 4° exhibited a higher NSA compared to others. A significant concern in the previous studies is the lack of multivariate analysis, which is necessary to eliminate the distorting effects of other variables. Furthermore, most of these studies were performed retrospectively,[10,33] which increases the potential for selection bias.

Despite the significant effects of FL and MHO demonstrated in our study, the role of NSA was not significant in the multivariate analysis. We also identified the cut-off point for the relationship between MHO and VCA, showing that patients with shorter femurs and an MHO greater than 4.35 cm require a distal femoral cut angle of 6° or more. In contrast, those with longer femurs and an MHO less than 4.35 cm need a cut angle of less than 6° (SEN: 83%, SPE: 80%). A recent study on the sexually dimorphic parameters of the femur reported that the mean femur length was significantly greater in males (4.36 cm) than in females (4.02 cm), with highly significant differences (p-value < 0.001) in the length ranges and standard deviations.[36]

This prospective cohort study investigated patients with knee osteoarthritis who underwent TKA to assess the relationship between radiographic parameters, the extent of MSTR, and VCA. Radiographs were analysed preoperatively and two months postoperatively, with both univariate and multivariate regression identifying significant predictors of MSTR and VCA. It is essential to note that a full-length radiograph of the femur is required to account for femoral curvature, as the distal femoral cut cannot be accurately estimated based solely on MHO in patients with high curvature. A true anteroposterior (AP) view and a three-joint view are necessary for accurate VCA calculations; however, an AP view of the pelvis may be used when a three-joint view is not possible due to deformity or mobility issues. These findings provide valuable predictive markers for surgical planning and highlight the importance of proper radiographic assessment to ensure accurate bone cuts and soft tissue balance.

LIMITATIONS & STRENGTH

With regard to the study design, the primary advantage of the current investigation is its prospective cohort design, which minimizes bias in patient selection and data analysis. Furthermore, all radiographic and associated data for the patients were independently measured by two individuals.

However, our study was not without limitations. We did not consider the flexion contracture or the long-standing deformities in patients prior to surgery. These factors can affect the extent of release during TKA. Additionally, it is important to note that the findings and significant statistical relationships mentioned in this study have been demonstrated to be clinically relevant and are supported by recent developments.[2,13,36]

Conclusion

Regarding the radiographic parameters, an LDFA greater than 93.5°, JLCA exceeding 7.5°, and VA greater than 19° are indicative of stages 3 and 4 of MSTR. Furthermore, decreasing the MPTA to less than 84.5° would increase the possibility of extensive MSTR. Among the aforementioned parameters, VA is the most valuable predictor of the extent of MSTR (SEN: 91.7%, SPE: 100%) while MPTA is considered as the least significant factor. Conversely, patients with a shorter femur and an MHO greater than 4.35 cm require a distal femoral cut angle of 6° or more, while those with a longer femur and an MHO less than 4.35 cm need a distal femoral cut angle of less than 6°.

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Declaration of Informed Consent: The study was conducted using CT scan images obtained as part of routine clinical practice, thus no patient consent was required.

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