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Different Radiological Indices of Patellar Height Predict Patients' Diverse Outcomes Following Total Knee Arthroplasty

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Background: Total knee arthroplasty (TKA) is a common surgical procedure for patients with knee osteoarthritis. The patellar component plays a crucial role in knee biomechanics and can influence postoperative outcomes. This study aimed to investigate the relationship between radiological indices of patellar height and patient outcomes following TKA.

Methods: A retrospective analysis was conducted on patients who underwent TKA for osteoarthritis. Radiographic measurements of patellar height, including the Insall-Salvati (IS) ratio, modified Blackburne-Peel (mBP) ratio, Caton-Deschamps ratio, and plateau-patellar angle (PPA), were obtained. Clinical outcomes were assessed using the Knee Society Score (KSS) and the Forgotten Joint Score-12 (FJS-12). Patient satisfaction and postoperative complications were also evaluated. Statistical analyses, including correlation analysis and multiple regression models, were performed to determine the association between radiological indices and patient outcomes.

Results: The study included 330 cases that met the inclusion criteria. The analysis revealed significant correlations between different radiological indices of patellar height and patient outcomes. Lower postoperative PPA was correlated with worse KSS and range of motion scores. A decreased mBP ratio was associated with poorer FJS-12 responses and higher risks of dissatisfaction and patellar clunk or crepitus. Increased IS ratio was linked to a lower likelihood of incidental giving way of the knee. Advanced age was associated with reduced dissatisfaction and incidental giving way probabilities.

Conclusions: The findings of this study demonstrate that radiological indices of patellar height can predict patient outcomes following TKA. Assessing patellar height using various radiographic measurements provides valuable information for surgical planning and prognostic evaluation. Understanding the impact of patellar height on clinical outcomes can aid in optimizing TKA procedures and improving patient satisfaction. These findings emphasize the importance of considering patellar height as a predictive factor in TKA and highlight its potential role in guiding postoperative management and rehabilitation strategies.

Keywords: *Total knee arthroplasty, Patella height, Patient outcome assessment, Patella clunk, Patient satisfaction*

Osteoarthritis is the most common joint disease in adults worldwide, and osteoarthritis of the knee has the highest global prevalence of 16%.[1] In addition, the likelihood of knee osteoarthritis is associated with life expectancy and body mass index, especially in the post-industrial era where the prevalence of knee osteoarthritis is 2.1-fold higher than that in the early industrial era.[2] For patients with advanced knee osteoarthritis, the most successful and cost-effective treatment is total knee arthroplasty (TKA),

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which corrects the knee deformity and restores the biological force line of the lower extremity.

In TKA, there are 3 articular components of the knee, including polyethylene insertion, the tibia, femur, and patella. Of these, the patella acts as a mechanical lever for the patellofemoral joint, increasing the torque of the quadriceps muscle and the efficiency of quadriceps knee extension by 50%. The patella also increases the surface area of the knee extension contact force and helps to recruit extensor muscle strength.[3)] Accordingly, the alterations of patellar height are one of the most important factors affecting the prognosis of TKA, which could result in postoperative patellofemoral joint-related complications such as anterior knee pain, maltracking, fracture, avascular necrosis, and patellar clunk.

Conventional radiographs, which are a necessary component of the radiological outcome assessment after TKA for many orthopedic surgeons, can simply be used to evaluate those parameters. The benefit of utilizing a ratio is that elements such as magnification, physical size, and flexion angle no longer influence the values. The most common clinical measurements of patellar height by radiography are the Insall-Salvati (IS) ratio, modified Blackburne-Peel (mBP) ratio, Caton-Deschamps (CD) ratio, and plateau-patellar angle (PPA). However, to date, there have been rare studies that link simultaneously different radiological indicators and the clinical outcome of TKA. Furthermore, to better explore the effect of patellar height on clinical outcome, continuous variables rather than categorical variables were selected in the analysis, considering that biomechanics was altered after TKA and it was unclear if the identical cutoff points discerned pathological from normal values. The aim of this study was to compare the radiological detection indices of the patella in patients with different satisfaction and complications after TKA and to analyze the application of indices of patellar height in clinical outcomes prediction of TKA patients.

METHODS

The study was approved by the ethics committee of the First Hospital of Jilin University (No. 2022-KS-140), and the need for informed consent was waived by the ethics committee since only anonymized patient data were used for the study. The study was performed in accordance with the Declaration of Helsinki.

Patients

This study retrospectively analyzed patients who underwent total knee replacement surgery and met our inclusion criteria in orthopedics department from September 2019 to October 2021. The process for patient selection is presented in Fig. 1. Inclusion criteria were as follows: (1) All cases had osteoarthritis and underwent primary TKA without patellar resurfacing. (2) The Surgical implants were posterior-stabilized and cemented, produced by Smith & Nephew plc. (3) Complete preoperative and postoperative follow-up data of the patients were available. (4) TKAs were performed by the same surgeon (JL).

Exclusion criteria were as follows: (1) The patients had abnormal preoperative patellar position that required therapeutic intervention in addition to TKA. (2) History of previous trauma of quadriceps muscle. (3) History of developmental malformation and fracture of the patella. (4) Neuromuscular lesions of the knee joint. (5) History of previous non-TKA surgery around the knee joint. (6) Ineligible medical imaging data. A total of 423 knee arthroplasties were performed in the selected period. Of these, 330 cases were enrolled in the study based on the inclusion criteria (226 patients, 21.3% men).

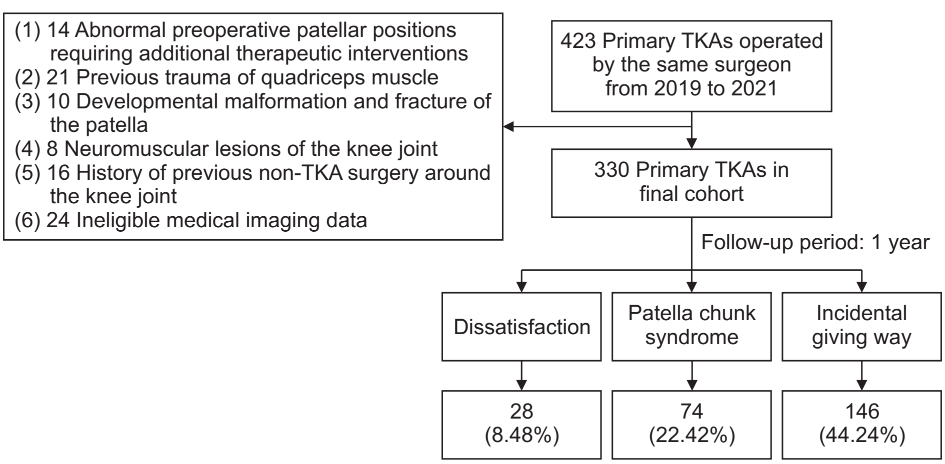

Fig. 1. Flowchart illustrating the study cohort and patients excluded from the analysis. TKA: total knee arthroplasty.

Clinical and Radiographic Measurement

An unbiased and trained study nurse measured range of motion (ROM) with a goniometer. The measurements were taken with a 5° accuracy. All radiographs were evaluated by 3 orthopedic surgeons (ZB, SL, and XS) and using the average value. For results of the same case that had a large discrepancy, discussion was held after measurement by a superior surgeon (JL). The precision of digital radiographic measurement was beyond 2 decimals. Radiographic assessments were performed using the PACS system Digimizer image analysis software (MedCalc Software).

The IS ratio, mBP ratio, CD ratio, and PPA were applied to measure patellar height on true lateral radiographs in approximately 30° of flexion and in weight-bearing conditions to guarantee a tensed patellar tendon at full length. The cutoff points are shown in Table 1. A true lateral radiograph was obtained, showing superimposition of the 2 posterior femoral condyles, resulting in the appearance of a single posterior femoral condyle. The IS ratio was calculated as the ratio of the distance between the most distal point of the patellar articular surface and the insertion of the patellar tendon to the length of the patella. The mBP ratio was measured as the length of an orthogonal line from the joint line divided by the patellofemoral joint surface. This parameter represents a composite variable that combines 3 radiological variables (patellar height, posterior tibial slope, and joint-line elevation) into a single ratio. PPA was calculated by connecting the line tangential to the medial tibial plateau and the line extending from the posterior extent of the medial tibial plateau to the inferior articular border of the patellar. The CD ratio was calculated using the length of the patellar articular surface and the separation between the inferior edge of the patellar articular surface and the anterosuperior angle of the tibial plateau surface.

Clinical Outcome Assessment

We used the Knee Society Score (KSS) and Western Ontario and the Forgotten Joint Score-12 (FJS-12) score to evaluate patient-reported outcome at 1-year follow-up.

Table 1. Cutoff of 4 Methods for Patellar Height Measurement

Measurement method	Patella baja	Normal patella	Patella alta
IS ratio	< 0.8	0.8–1.2	> 1.2
mBP ratio	< 0.54	0.54–1.06	> 1.06
PPA (°)	< 21	21–29	> 29
CD ratio	< 0.6	0.6–1.2	> 1.2

IS: Insall-Salvati, mBP: modified Blackburne-Peel, PPA: plateau-patellar angle, CD: Caton-Deschamps.

KSS included items concerning the subjective feeling of patients not only during daily living and standard activities but also during advanced and recreational activities. The FJS-12 has 12 items and is scored using a 5-point Likert response format, with raw results translated to a 0–100 point scale. Lower score indicates worse outcome. Subjective satisfaction was assessed by using the visual analog scale method to evaluate patients' satisfaction with surgical outcome, satisfaction with surgical relief of joint pain, satisfaction with improvement in life and quality of life, and satisfaction with improvement in quality of sports and recreational activities, with the 4 scores taken as an unweighted average, and finally, subjective satisfaction was categorized into 2 classifications: satisfaction and dissatisfaction. Postoperative complications, including patellar clunk or crepitus (PCC) and incidental giving way, were evaluated.

Statistical Analyses

Statistical analyses were conducted using SPSS software version 26.0 (IBM Corp.) and GraphPad Prism 8 (GraphPad Prism Software). The normality of the data was assessed using the Shapiro-Wilk test and histograms. Normally distributed continuous data are reported as mean standard deviation, non-normally distributed continuous data are reported as medians and interquartile ranges, and categorical data are presented as numbers and percentages (%). Group comparisons were performed using variance analysis, and post-hoc analysis was conducted using the least significant difference *t*-test. Independent *t*-tests were used for normally distributed continuous data, Mann-Whitney *U*-tests were used for non-normally distributed continuous data, and chi-squared tests were used for categorical data. Spearman's correlation analysis was employed to examine the correlation between radiographical data and the KSS, FJS-12 scores, dissatisfaction, and complications in TKA patients. Additionally, a stepwise multiple linear regression model was employed to comprehensively analyze the influence of patellar indices on KSS and FJS-12 scores. The univariate analysis included patellar height-related data and independent variables with a significance level of $p < 0.05$ were included in the multivariate logistic regression analysis. Multivariate logistic regression analysis was used to identify independent influencing factors of dissatisfaction and complications. The prognostic value of patella-related data in TKA patients was evaluated using receiver operating characteristic (ROC) curve analysis, with the area under the curve (AUC) calculated. Statistical significance was defined as $p < 0.05$.

RESULTS

The mean age of patients was 63.64 years (SD, 9.48; range, 31–84 years), and mean BMI was 26.05 kg/m^2 (SD, 4.80; range, 16.82–56.43 kg/m^2). A total of 102 patients (45.1%) had bilateral TKA.

Clinical and Radiographic Measurement

ROM increased significantly from the preoperative examination to the 1-year follow-up. The patellar height detection method, mBP ratio, significantly decreased from 0.821 preoperatively to 0.711 postoperatively. Concurrently, patients exhibited significantly higher KSS and FJS-12 postoperatively compared to preoperative values. The KSS improved from a preoperative score of 45 to a postoperative score of 95 (Z = 10.947, $p < 0.001$). The FJS-12 score exhibited a notable improvement from a preoperative mean of 30 to a postoperative mean of 90 (Z = 10.726, $p < 0.001$). Postoperatively, the incidence of patellar PCC was 22.4% (74 cases), dissatisfaction was reported in 8.48% (28 cases), and incidental giving way was noted in 44.24% (146 cases). Detailed clinical and radiographic results are presented comprehensively in Table 2.

Table 2. Pre- and Postoperative Clinical and Radiographic Measurements

Measurement	Preoperative	Postoperative	Z/t	*p*-value
PPA	24.000 ± 3.917	24.000 ± 3.875	1.346	0.178
mBP ratio	0.821 ± 0.197	0.711 ± 0.208	4.236	< 0.001*
IS ratio	1.054 ± 0.222	1.086 ± 0.222	1.690	0.091
CD ratio	1.026 ± 0.193	1.015 ± 0.197	1.570	0.087
KSS	45 (38–58)	95 (88–99)	10.947	< 0.001*
FJS-12 score	30 (15–45)	90 (75–95)	10.726	< 0.001*
ROM	90 (80–90)	110 (95–120)	5.760	< 0.001*

Values are presented as mean ± standard deviation or median (interquartile range).
PPA: plateau-patellar angle, mBP: modified Blackburne-Peel, IS: Insall-Salvati, CD: Caton-Deschamps, KSS: Knee Society Score, FJS-12: forgotten joint score-12, ROM: range of motion.
*Statistically significant.

Spearman's Correlation Analysis

Postoperative IS ratio was negatively correlated with PCC ($r = -0.162$, $p = 0.039$) and incidental giving way ($r = -0.259$, $p = 0.001$). Postoperative PPA was negatively correlated with KSS ($r = -0.17$, $p = 0.026$) and positively correlated with dissatisfaction ($r = -0.197$, $p < 0.011$). Postoperative mBP ratio was positively correlated with FJS-12 ($r = 0.233$, $p = 0.003$) and ROM ($r = 0.153$, $p = 0.05$) and negatively correlated with dissatisfaction ($r = -0.259$, $p = 0.001$), PCC ($r = -0.232$, $p = 0.003$), and incidental giving way ($r = -0.22$, $p = 0.005$). Age was negatively correlated with dissatisfaction ($r = -0.226$, $p = 0.004$) and incidental giving way ($r = -0.215$, $p = 0.006$). There were no significant correlations between clinical outcomes and any of the

Table 3. Spearman's Correlation between Radiographic Measurements and Postoperative Clinical Outcome

Variable	KSS	FJS-12	ROM	Dissatisfaction	PCC	Incidental giving way
Preoperative IS ratio	–0.009 (0.906)	–0.092 (0.244)	0.089 (0.255)	0.002 (0.976)	–0.107 (0.174)	–0.105 (0.179)
Preoperative mBP ratio	0.010 (0.901)	–0.008 (0.915)	0.061 (0.435)	0.020 (0.796)	0.056 (0.474)	0.034 (0.666)
Preoperative PPA	0.084 (0.287)	–0.122 (0.119)	–0.085 (0.282)	–0.050 (0.521)	0.038 (0.631)	–0.070 (0.371)
Preoperative CD ratio	0.021 (0.164)	0.045 (0.125)	0.054 (0.264)	0.060 (0.341)	0.061 (0.529)	0.143 (0.353)
Postoperative IS ratio	0.064 (0.415)	0.007 (0.926)	0.133 (0.089)	–0.086 (0.273)	–0.162 (0.039*)	–0.259 (0.001*)
Postoperative mBP ratio	0.136 (0.084)	0.233 (0.003*)	0.153 (0.050*)	–0.259 (0.001*)	–0.232 (0.003*)	–0.220 (0.005*)
Postoperative PPA	–0.170 (0.026*)	0.056 (0.477)	0.129 (0.100)	–0.197 (0.011*)	–0.114 (0.146)	–0.149 (0.057)
Postoperative CD ratio	0.102 (0.254)	0.231 (0.233)	0.126 (0.156)	–0.216 (0.063)	–0.153 (0.075)	–0.192 (0.059)
BMI	0.061 (0.434)	–0.067 (0.397)	0.021 (0.786)	–0.061 (0.437)	–0.050 (0.524)	–0.017 (0.832)
Age	0.043 (0.587)	–0.095 (0.224)	–0.132 (0.093)	–0.226 (0.004*)	–0.129 (0.099)	–0.215 (0.006*)

Values are presented as Spearman's rank correlation coefficient (*p*-value).
KSS: Knee Society Score, FJS-12: forgotten joint score-12, ROM: range of motion, PCC: patellar clunk or crepitus, IS: Insall-Salvati, mBP: modified Blackburne-Peel, PPA: plateau-patellar angle, CD: Caton-Deschamps, BMI: body mass index.
*Statistically significant.

indices ($p > 0.05$). The details are shown in Table 3. The 4 patellar height measurements assessed both preoperatively and postoperatively were correlated with each other. However, other preoperative characteristics were not correlated with the postoperative radiographical indices of patellar height.

Stepwise Multiple Linear Regression and Logic Regression Analysis

Table 4 displays the results of the stepwise multiple linear regression analysis, which aimed to investigate the relationship between predictor variables and clinical outcomes. The Table includes 3 models: postoperative KSS, FJS-12, and ROM. KSS was positively associated with postoperative PPA ratio, explaining 4.5% of the variance (R^2 = 0.045, F = 8.768, p = 0.004). FJS-12 was positively associated with postoperative mBP ratio, explaining 3.1% of the variance (R^2 = 0.031, F = 6.239, p = 0.013). ROM was positively associated with postoperative PPA, explaining 2.8% of the variance (R^2 = 0.028, F = 5.761, p = 0.018). Postoperative PPA ratio, mBP ratio, and PPA emerged as significant predictors of KSS, FJS-12, and ROM, respectively.

Table 4. Stepwise Multiple Linear Regression for KSS, FJS-12, and ROM

Model (standardized)	β	R^2	F	p-value
KSS = 71.83 + 0.789 × postoperative PPA	0.789	0.045	8.768	0.004*
FJS-12 = 65.564 + 23.352 × postoperative mBP ratio	23.352	0.031	6.239	0.013*
ROM = 84.995 + 0.994 × postoperative PPA	0.994	0.028	5.761	0.018*

KSS: Knee Society Score, FJS-12: forgotten joint score-12, ROM: range of motion, PPA: plateau-patellar angle; mBP: modified Blackburne-Peel.
*Statistically different.

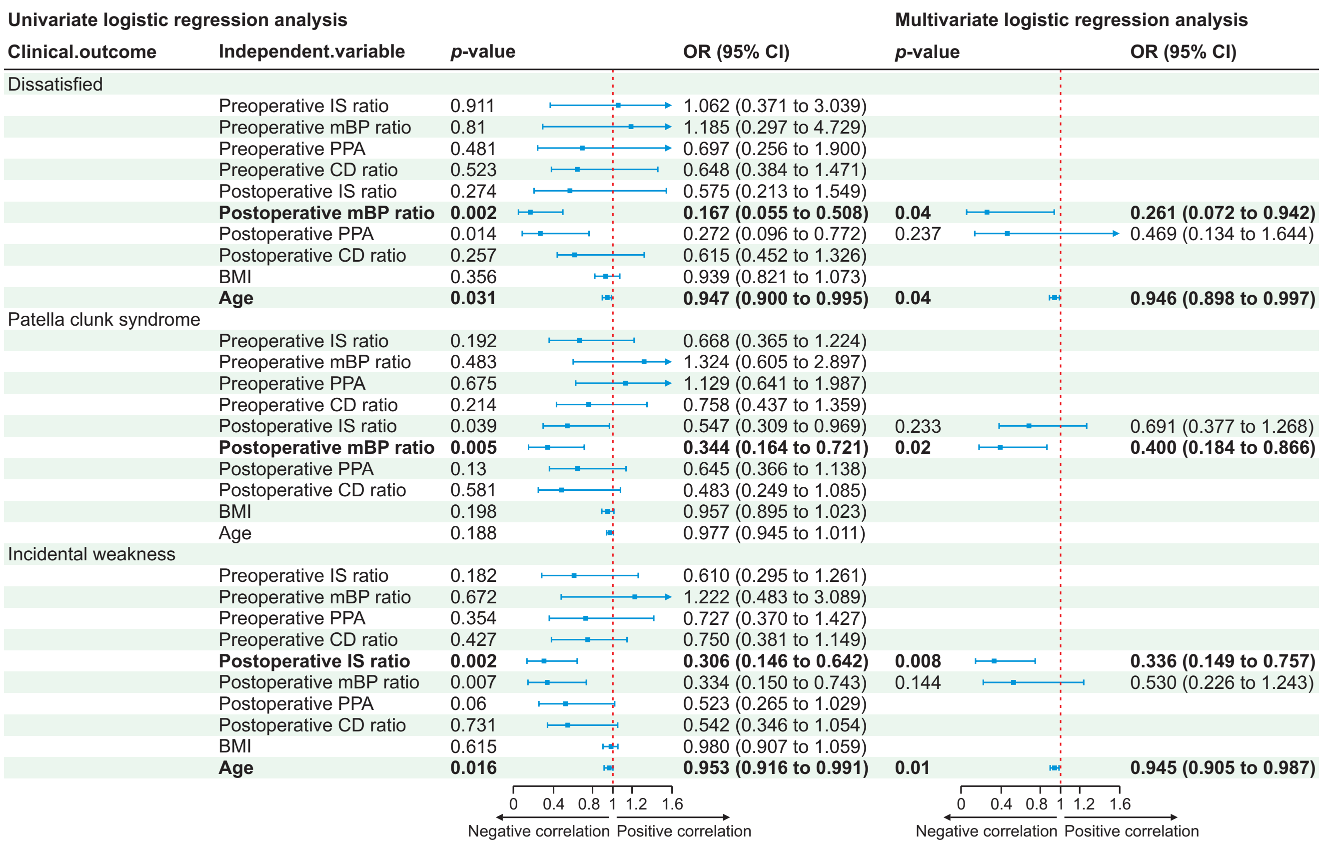

Fig. 2. Univariate and multivariate logistic regression analyses of variables affecting dissatisfaction, patellar clunk or crepitus, and incidental giving way of the knee. OR: odds ratio, CI: confidence interval, IS: Insall-Salvati, mBP: modified Blackburne-Peel, PPA: plateau-patellar angle, CD: Caton-Deschamps, BMI: body mass index. A $p < 0.05$ was considered statistically significant.

Table 5. ROC Curve Distribution of the Radiographic Measurements, Age, and Radiographic Measurements Combined with Age in Predicting Clinical Outcomes

Variable	Dissatisfaction				PCC				Incidental giving way			
	AUC	95% CI	Cut-off	*p*-value	AUC	95% CI	Cut-off	*p*-value	AUC	95% CI	Cut-off	*p*-value
mBP ratio	0.771	0.655–0.89	0.577	0.001*	0.632	0.546–0.718	0.576	0.004				
IS ratio									0.652	0.559–0.745	1.184	0.005*
Age	0.733	0.593–0.873	58.500	0.004*					0.646	0.558–0.735	68.500	0.007*
mBP ratio–age	0.808	0.692–0.924	0.612	0.0001*								
IS ratio–age									0.703	0.613–0.792	0.322	0.0002*

ROC: receiver operating characteristic, PCC: patellar clunk or crepitus, AUC: area under the curve, CI: confidence interval, mBP: modified Blackburne-Peel, IS: Insall-Salvati.
*Statistically different.

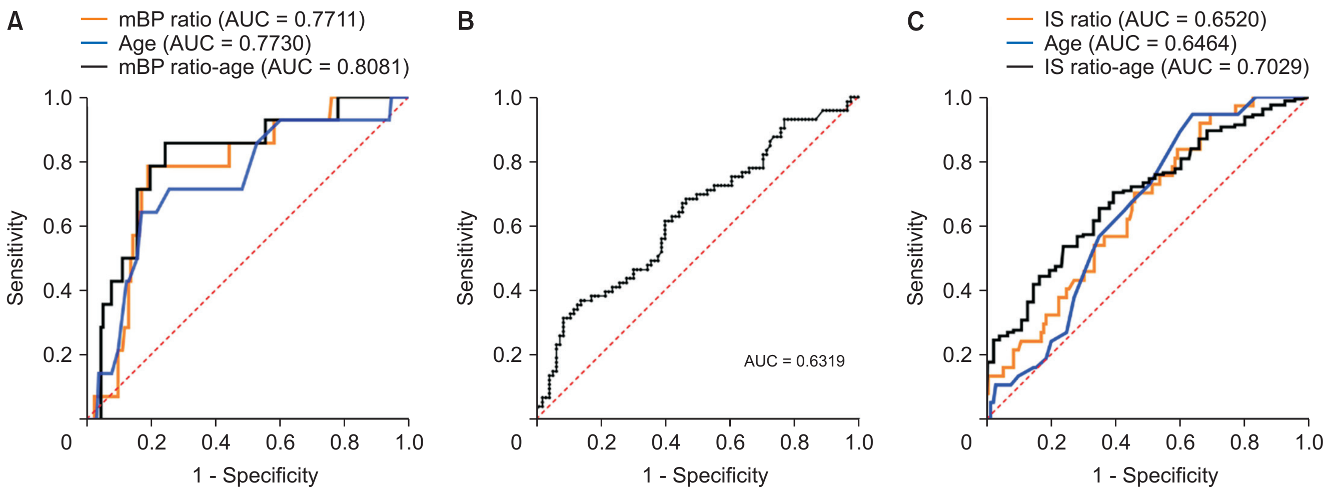

Fig. 3. Receiver operating characteristic (ROC) curve distribution. (A) The modified Blackburne-Peel (mBP) ratio, age, and their combination in predicting dissatisfaction. (B) MBP ratio in predicting patellar clunk or crepitus. (C) Insall-Salvati (IS) ratio, age, and their combination in predicting incidental giving way of the knee. AUC: area under the curve.

Occurrence of complications was used as the dependent variable in analyses. Independent variables included meaningful patient factors: age, BMI, and pre- and postoperative patellar height indices. Univariate analysis results showed that postoperative mBP ratio, PPA, and age were related to patient dissatisfaction ($p < 0.05$). Postoperative mBP ratio was also related to patellofemoral crepitation ($p < 0.05$). Additionally, postoperative IS ratio, mBP ratio, and age were related to incidental giving way, as detailed in Fig. 2.

Multivariate logistic regression analysis was performed with occurrence of complications as the dependent variable. Independent factors from univariate analyses with $p < 0.05$ were included. Using a stepwise method, postoperative mBP ratio (odds ratio [OR], 0.261; 95% confidence interval [CI], 0.072–0.942; $p = 0.04$) and age (OR, 0.946; 95% CI, 0.898–0.997; $p = 0.04$) emerged as independent predictors of dissatisfaction. Postoperative mBP ratio (OR, 0.4; 95% CI, 0.184–0.866; $p = 0.02$) independently predicted patellofemoral crepitation. Additionally, postoperative IS ratio (OR, 0.336; 95% CI, 0.149–0.757; $p = 0.008$) and age (OR, 0.945; 95% CI, 0.905–0.987; $p = 0.01$) independently predicted incidental giving way, as shown in Fig. 2.

ROC Curve

Occurrence of complications was the state variable. ROC analysis assessed predictive factors from univariate analyses ($p < 0.05$). For dissatisfaction, postoperative mBP ratio (AUC, 0.771; $p < 0.001$) and age (AUC, 0.733; $p =$

0.004) had high predictive values at cutoffs of 0.577 and 58.5, respectively. Their combination yielded the highest predictive value (AUC, 0.808; $p < 0.001$). For PCC, the postoperative mBP ratio (AUC, 0.632; $p < 0.001$) was predictive at a cutoff of 0.576. Regarding incidental giving way, the postoperative IS ratio (AUC, 0.652; $p = 0.004$) and age (AUC, 0.646; $p = 0.006$) had high predictive values at cutoffs of 1.1184 and 68.5, respectively. Their combination yielded the highest predictive value (AUC, 0.703; $p < 0.001$). Detailed results are reported in Table 5 and Fig. 3.

DISCUSSION

TKA effectively treats advanced knee osteoarthritis, relieving pain and restoring mobility. However, the outcomes of TKA vary between patients. Identifying prognostic factors is important for optimizing surgical outcomes. Patellar height critically influences knee biomechanics and impacts TKA success through roles in stability, mechanics, load distribution, tendon function, ROM, and long-term durability. Therefore, this study focused on radiographic patellar height indices in predicting outcomes of patients after TKA.

To comprehend the clinical significance of preoperative patellar height in facilitating the optimal reconstruction of postoperative patellar height, it is imperative to elucidate the association between variations in preoperative and postoperative patellar height and their impact on early clinical outcomes. The patella, situated anteriorly in the knee joint, serves as a pivotal anatomical structure, augmenting the moment arm of the quadriceps mechanism at the anterior knee, thereby enhancing the efficiency and power of knee extension. Additionally, the patella plays a crucial role in guiding the extensor mechanism, ensuring its proper alignment in the central anterior position of the knee. Notably, the posterior surface of the patella is coated with a layer of articular cartilage, which confers low friction properties to the contact surfaces, consequently reducing wear rates.[4)] When the patellar height is excessively elevated, it can lead to undesirable consequences such as patellar instability and heightened patellofemoral contact pressures.[5)] These consequences have been implicated in patellofemoral dysfunction and the manifestation of pain.[6)] Moreover, a significant reduction in the distance between the inferior pole of the patella and the articular surface of the tibia can result in continuous patellar-trochlear contact during extension, leading to impingement, anterior knee pain, and joint stiffness.[7)] Furthermore, a diminished patellar height can result in a shortened moment arm, subsequently contributing to extensor lag and limiting the ROM.[8)] In instances where the preoperative patellar height is excessively elevated, the surgeon can employ various strategies to prevent unfavorable outcomes. These measures include minimizing the amount of tibial bone resection during surgery, ensuring precise sizing and alignment of prosthetic components, and meticulously balancing the soft tissues to avoid excessive tension on the quadriceps mechanism, thereby averting weakness or disruption of the medial patellofemoral ligament.[9)] Conversely, when the patella is determined to be too low preoperatively, corrective actions can be taken intraoperatively. These include adopting a single fixed radius of curvature femoral component to address the shortened moment arm of the extensor mechanism.[10)] It is also feasible to rectify patellar height by reducing the amount of femoral osteotomy and avoiding the use of thick polyethylene spacers, thereby restoring patellofemoral kinematics and improving the clinical prognosis.[11)]

KSS, FJS-12, and ROM all significantly improved postoperatively, demonstrating the effectiveness of the TKA procedure. The mBP ratio was the only measure of patellar height to show a significant decrease in the postoperative period among the 4 assessment methods. Previous studies also indicated that the mBP ratio significantly decreased[12)] and the other indices did not change statistically after TKA.[13)] The mBP ratio incorporated patellar height, joint line position, and posterior tibial slope, as it was defined.[14)] In this sense, BPR served as a composite radiological index that represents all 3 of these anatomical variables within a single ratio measurement. Therefore, the mBP ratio can be more sensitive than other methods to reflect the biomechanical changes of the joints during TKA. The IS ratio increased postoperatively, though not significantly. This might be because the IS ratio measured patellar tendon length as the most widespread method, but the IS ratio was influenced by patellar morphology, which was surgically modified by resurfacing or removing osteophytes during TKA, potentially impacting postoperative values.

We found by Spearman's correlation analysis that postoperative clinical outcomes and complications were not related to preoperative patellar height index and BMI, but rather to postoperative patellar height index. This suggests, to some extent, that surgery could play a role in patient prognosis by influencing postoperative patellar height and thus patient prognosis. We also confirmed that there was a positive, albeit weak, correlation between postoperative patellar height and preoperative patellar height, suggesting to some extent that preoperative patellar height might influence postoperative patellar height.

To explore further the causal effect of patellar height on the clinical outcomes after TKA, we did the regression analysis. In the stepwise multiple line regression, the mBP ratio was the only independent predictor for FJS-12, which is in line with a previous study where the mBP ratio emerged as a significant positive independent predictor of 1-year follow-up FJS-12 scores and flexion ROM.[15] As FJS-12 was demonstrated as a more sensitive patient-reported outcome measurement tool for detecting differences in patients. Meanwhile, the mBP ratio was not an independent predictor of KSS and ROM as suggested in previous studies.[16,17] The mBP ratio is commonly used to identify pseudo patella baja (PPB), a radiographic diagnosis of apparently low patellar height after TKA. However, the relationship between PPB and clinical outcomes remains unclear. Several studies have reported decreased patellar height as a common radiographic finding after TKA, with PPB incidence ranging widely from 25% to 92%.[18] While some authors found PPB negatively impacted KSS and ROM, others did not report significant associations.[11] This inconsistency in previous findings highlights the need for more research elucidating the impacts of postoperative mBP ratio changes. Surprisingly, postoperative PPA independently predicted KSS and ROM scores. PPA has been shown to be a reproducible and reliable measure of patellar height both before and after TKA, exhibiting high levels of intra- and interobserver agreement.[19] Nonetheless, no prior studies have explored relationships between clinical outcomes and PPA. While the mBP method also spatially relates the patella to the joint line like PPA,[19] PPA may have a more direct correlation with KSS and ROM. This is because PPA involves a single measurement rather than the mBP ratio's additional steps of measuring patellar and tendon lengths before calculation. As PPA entails less complex measurement, it could provide a more straightforward assessment of how patellar position impacts postoperative function. However, to further elaborate the relationship between the patella-plateau angle and clinical outcomes, additional studies would be needed.

Our findings suggest the mBP ratio and age independently predict patient dissatisfaction after TKA. ROC analysis demonstrated dissatisfaction decreases as patellar height (mBP ratio) and age increase. The combination of these 2 factors yielded the highest predictive accuracy for detecting potential dissatisfaction, underscoring their combined clinical utility as prognostic indicators of poor postsurgical satisfaction outcomes. Previous TKA satisfaction research focused on scores, with few examining patellar height's objective influence. As the FJS-12 strongly correlates with satisfaction,[20] the mBP index may sensitively reflect how patellar height changes impact subjective feelings measured by FJS-12, thereby predicting satisfaction. Additionally, we identified that satisfaction increases with age, which is consistent with research showing that patient-reported satisfaction rates were 86% in younger patients and 91% in older patients following TKA,[21] possibly because of longstanding osteoarthritis, severe bone damage, and declining functional demands on the knee over time. In contrast to our results, Clement et al. found age < 55 years was not an independent predictor of function or satisfaction after TKA.[22] The discrepancy may be explained by their pre-grouping of patients compared to our use of age as a continuous variable in ROC analysis, which identified 58.5 as the cutoff value for predicting satisfaction. Differences in statistical approaches could account for inconsistent conclusions regarding age effects between the studies. The mBP ratio was the sole independent predictor of PCC following TKA. This association may be explained by mBP ratio's established ability to detect postoperative changes in joint line elevation relative to the patella.[23] Indeed, Hwang et al.[24] previously demonstrated increased joint line elevation correlates with higher PCC risk. Besides, the posterior tibial slope was also suggested to play a role in the development of patellar clunk.[25] As mBP incorporates joint line assessment and posterior tibial slope, it likely had the strongest predictive power for PCC in this study given surgical factors like elevated joint position influence PCC development. Patients commonly describe incidental giving way as an episodic weakness during daily activities. Previous studies showed this often stems from quadriceps dysfunction,[26] which can persist after TKA due to preoperative weakness and postoperative strength loss.[27] Our results identified IS ratio and age as independent predictors. The IS ratio measures patellar tendon length, and recent studies found reduced quadriceps force needed to overcome flexion moments in patella alta.[28] Therefore, a higher IS ratio may lower giving way incidence by mechanically enhancing knee extension. Age was also negatively associated with giving way. Paravlic et al.[29] found older patients recover quadriceps strength better than younger patients after TKA. This may be related to slower physiology and less demanding functionality in older adults, resulting in smaller postoperative quadriceps losses.[30] In summary, IS ratio and age advantages seem to mitigate the quadriceps weakness, commonly underlying giving way, through biomechanical and functional mechanisms, respectively.

This study has some limitations. As a single-center retrospective analysis with 1-year follow-up, there may be selection and recall biases. The small sample constrained the inclusion of other potential prognostic factors (e.g., comorbidities) in regression models. Follow-up duration was satisfactory for radiographic outcomes but longer assessments could better evaluate clinical results over time. Therefore, findings should be interpreted cautiously pending prospective validation in larger, multi-center cohorts, controlling for relevant covariates with extended follow-ups. Selection biases limit generalizability and important confounders may have been omitted. While radiographic impacts were reasonably captured, longer surveillance is needed to fully characterize patellar alignment effects on functional recovery patterns.

This study investigated the relationship between radiological indices of patellar height and patient outcomes following TKA. The results indicate that patellar height is a significant factor in predicting various clinical outcomes, patient satisfaction, and postoperative complications in TKA. These findings emphasize the importance of considering patellar height as a crucial predictive factor in TKA procedures. Surgeons should be mindful of the potential impact of patellar height on patient outcomes and adjust their surgical approaches accordingly to optimize results. Further research and validation studies are warranted to confirm these associations and refine our understanding of the role of patellar height in TKA.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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