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Original research

# Tibial baseplate position and posterior cruciate ligament status impact patient-reported outcomes in conforming dual-pivot bearing total knee arthroplasty

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*Background:* In an effort to optimize clinical outcomes and enhance stability, ultracongruent bearings have been increasingly used in primary total knee arthroplasty (TKA). The importance of the posterior cruciate ligament (PCL) and optimal sagittal tibial baseplate position in ultracongruent bearing TKA remains unknown. This study sought to determine whether these modifiable, surgical-technique-dependent variables meaningfully impact patient-reported outcome measures.
*Methods:* A total of 759 primary TKAs of the same dual-pivot design performed using a consistent surgical technique between January 2016 and April 2019 were retrospectively reviewed. PCL status was recorded, and anteroposterior (AP) tibial baseplate position and posterior tibial slope were measured by two independent blinded raters. Patient-reported outcomes related to pain, function, satisfaction, and activity level were analyzed in relationship to PCL status, posterior tibial slope, and AP tibial baseplate position, in addition to other pertinent covariates.
*Results:* Median age and body mass index of the cohort were 68.3 years and 33.4 kg/m$^2$, respectively, with 73% being female. In multivariate analysis, partial or full release of the PCL was predictive of a knee “always” feeling normal (odds ratio 1.42, $P = .041$). Furthermore, tibial baseplate position closer to the middle of the tibia was associated with greater improvements in pain with level walking, pain while climbing stairs, and Knee Injury and Osteoarthritis Outcome Score for Joint Replacement total scores ($P \leq .079$).
*Conclusion:* In congruent dual-pivot bearing TKA, partially or fully releasing the PCL and AP tibial baseplate position closer to the middle of the tibia may provide greater improvement in pain and function scores at minimum 1-year follow-up.


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## Introduction

Total knee arthroplasty (TKA) is the gold standard for treatment of symptomatic knee osteoarthritis, reliably reducing pain and restoring function in many patients [1]. Despite the clinical success of primary TKA [2], a sizable proportion of patients are dissatisfied postoperatively [3-6]. Innovators have sought to reduce this through modifications in surgical technique, fixation strategies, implant design, and bearing surface geometry.

One strategy to improve patient satisfaction and reduce the burden of symptomatic instability, a leading cause of revision TKA [7,8], has been the development of ultracongruent bearing surfaces [9]. Characterized by a more congruent articulating surface and higher anterior wall on the tibial insert to improve stability, in many cases, ultracongruent designs seek to replicate native kinematics [10-12]. Similar to a posterior-stabilized (PS) design, the articular geometry of the congruent bearings attempts to prevent anterior femoral translation [13] and offers the advantage of limiting bone sacrifice in the intercondylar notch [14,15]. Recently, there has been a migration to this bearing type with the American Joint Replacement Registry demonstrating nearly 10% of all TKAs performed in 2019 used an ultracongruent bearing [16]. However, these designs are relatively early in their evolution, and research is warranted to elucidate optimal surgical technique.

The role of the posterior cruciate ligament (PCL) in primary TKA performed using an ultracongruent bearing remains debated [17-21]. Some implant design manufacturers dictate whether the PCL is excised or retained; however, many ultracongruent bearings allow for PCL excision or retention based on tibiofemoral balance or surgeon preference. The options include retention, partial release, or complete excision. Opponents of PCL retention cite difficulty balancing the PCL, as well as the potential for creating kinematic conflict placing excess stress on periarticular soft tissues creating pain and potentially earlier bearing wear [22]. In contrast, proponents of PCL retention (CR) cite improvements in proprioception, improved knee stability, controlled femoral rollback, and a reduction in shear forces on the tibia.

In addition, the ideal anteroposterior (AP) position of the tibial baseplate in ultracongruent TKA, which may impact collateral ligament tension and kinematic patterns of knee motion, has yet to be evaluated. While implant malalignment is cited as the primary reason for revision in up to 7% of revised TKAs [23], and is associated with both decreased implant survival [24] and inferior patient-reported outcomes [25], this has largely been limited to evaluations in the coronal plane. Beyond the slope of the tibial component, optimal sagittal plane positioning remains unknown [26,27] and is likely of clinical significance because of the ultracongruent conformity in the sagittal plane of these particular bearings. Therefore, this study sought to investigate the interplay between PCL status and sagittal tibial baseplate positioning in patient-reported outcomes after primary TKA performed using an ultracongruent bearing.

## Material and methods

Seven hundred fifty-nine consecutive patients who underwent TKA using a single implant by one academic surgeon between January 2016 and April 2019 were retrospectively reviewed after obtaining institutional review board approval. All surgeries were performed in the same academic center, using an identical implant design (DJO EMPOWR 3D; DJO Surgical, Lewisville, TX) with a conforming polyethylene insert, and with the same perioperative and rehabilitation protocols. Fifty-seven cases were excluded: suboptimal radiograph quality or no radiographs present (7), simultaneous bilateral TKA (8), cementless design (16), early procedure on index knee within 1 year to reduce any influence on PROMS at minimum 1 year (7), medical complications unrelated to TKA (2), orthopedically complex case related to extensor mechanism reconstructions or Ehlers-Danlos syndrome (6), varus-valgus constrained implant (4), and no PROMS data available (7).

Regarding surgical technique, a medial parapatellar approach was used for all procedures. The patella was subluxed into the lateral gutter without patella eversion in all cases. Standard coronal plane tibial and femoral bone cuts were made with computer-aided navigation (Stryker Navigation, Kalamazoo, MI) to achieve a neutral mechanical alignment. The sagittal plane alignment, including femoral flexion and tibial slope, sought to reproduce the patient's native anatomy. A standard, posterior referenced, measured resection guide was used to size the femoral implant with rotation set parallel to the transepicondylar axis and perpendicular to Whiteside's line. After bony resections were performed, a gap-balanced technique was used by removing osteophytes and performing appropriate soft-tissue releases until a balanced medial and lateral gap was achieved in both flexion and extension. Balanced gaps were confirmed with a calibrated laminar spreader as previously described [28]. In cases of ligament excision, the PCL was first resected and then medial-lateral balance was achieved. In cases of PCL retention, after the collateral ligaments were balanced, trial implants were placed, and the tightness of the PCL was assessed; if excessive tightness was noted, the PCL was released as much as was required.

After the gaps were balanced, rotation and AP positioning of the tibial component was set with a trial tibial component that was allowed to freely translate, or "float," on the surface of the tibia until finding the most balanced "kinematic home" throughout a range of motion and in which the patella was ideally tracking. At the point of maximal flexion with the femoral and tibial trials in place, the rotation and AP depth of the tibial component was marked relative to the anterior tibial bone surface and tibial tubercle, and this position was determined by floating the tibial trial to find the position where the posterior femoral condyles settled into the deepest part of the tibial bearing conformity (the "dwell points"). This tibial component position of the trial was replicated exactly with the final cemented tibial component. Final implants were cemented with medium-viscosity polymethylmethacrylate bone cement mixed with low-dose antibiotics, and the components were securely cemented with manual hand pressurization (ie, finger packing) in a standardized manner during the working phase of the bone cement in all cases. The cement was allowed to cure with the knee held in extension, and visual confirmation of secured component fixation was obtained. Finally, the knee was vigorously irrigated again with a pulsatile lavage to remove any cement particles, and the final polyethylene insert was inserted and impacted into a locked position. Notably, between 2016 and 2017, the senior author transitioned to tourniquetless TKA and, in April 2018, stopped routine drain use in primary TKA. Variations in these two practices during the study period were recorded. Tranexamic acid was used in all patients.

The electronic medical record was used to compile study data: age, sex, body mass index (BMI) in $kg/m^2$, American Society of Anesthesiology Physical Status Classification, and intraoperative PCL disposition. The following potential confounders were recorded: the presence of lumbar spine pain, fibromyalgia, systemic lupus erythematosus, rheumatoid arthritis (RA), psoriatic arthritis (PA), depression, and preoperative narcotic use.

### *Radiographic measurements*

Sagittal tibial baseplate positioning including AP tibial baseplate position (relative to the middle of the tibial canal) and posterior tibial slope measurements were performed on 4-week postoperative lateral radiographs with a standardized measurement protocol by two independent blinded raters. Discrepancies >2 mm for tibial baseplate position and >4 degrees for tibial slope were resolved and averaged for consistency. Rater agreement was 100% within 2.0 mm and 71% within 1 mm of tibial baseplate position relative to the tibial canal. The mean difference between rater 1 and rater 2 was 0.72 mm. Rater agreement was 100% within 4 degrees for preoperative and postoperative tibial slope measurements. Furthermore, rater agreement was 73% within 2 degrees (preoperative) and 78% within 2 degrees (postoperative) for tibial slope measurements. The mean difference between rater 1 and rater 2 was 2.0 degrees for all tibial slope measurements.

*AP tibial baseplate position*

AP tibial baseplate positioning was measured on a lateral view radiograph in relation to the center of the tibial canal. This was carried out by bisecting the tibial baseplate and drawing a line from the most proximal anterior aspect of the tibia to the most anteroinferior cortical line seen on the radiograph (Fig. 1a). A pair of points 30 mm from the proximal part of this line was created, and a second pair of points 15 mm distal to the first pair of points was subsequently created. These pairs of points were bisected to form the tibial line, and the distance between the bisected tibial baseplate and the tibial line was measured (millimeters) to find the AP tibial baseplate position.

*Posterior tibial slope*

Posterior tibial slope was also measured on the lateral radiograph by drawing a line from the most proximal anterior aspect of the tibial baseplate to the most anteroinferior cortical line seen on the radiograph (Fig. 1b and c). A tibial line was generated by bisecting a pair of points 30 mm from the proximal part of this line and a second pair of points 15 mm from the first pair of points. Tibial slope was measured as the angle between the tibial line and a line parallel to the top of the tibial baseplate. Tibial slope was also measured on preoperative lateral radiographs to evaluate the influence of a change in tibial slope on postoperative outcomes.

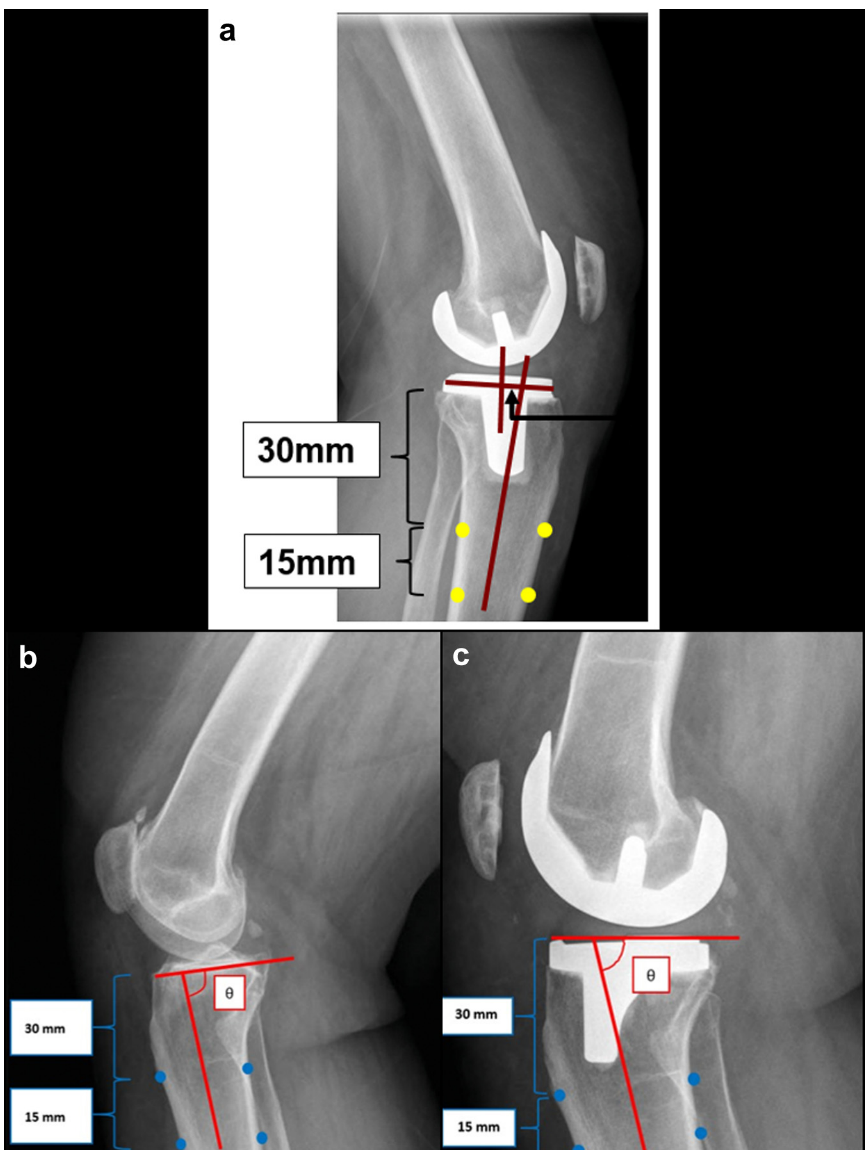


**Figure 1.** Radiographic measurements for (a) anteroposterior tibial baseplate position, (b) preoperative posterior tibial slope, and (c) postoperative posterior tibial slope.

**Table 1**
Demographics, covariates, and radiographic measurements.

| Demographics and PROM covariates | N | Mean ± SD/median [Q1, Q3]/percentage (%) | Minimum | Maximum |
|---|---|---|---|---|
| Age, y | 702 | 68.3 [63.1, 73.2] | 33.1 | 91.4 |
| BMI, kg/m$^2$ | 702 | 33.4 [28.5, 39.2] | 15.9 | 55.9 |
| Sex, % female | 702 | 73.4% | | |
| ASA-PS Class, % 1 or 2 | 701[a] | 35.0% | | |
| Lumbar spine disease | 694[b] | 14.8% | | |
| Self-reported preoperative narcotic use (prn or scheduled) | 702 | 11.8% | | |
| Fibromyalgia or SLE | 702 | 3.4% | | |
| RA or PA | 702 | 6.4% | | |
| Depression | 702 | 26.6% | | |
| Tourniquet use | 702 | 41.0% | | |
| Drain use | 702 | 62.5% | | |
| PCL disposition (3 groups) | 701[c] | 53.4% preserved<br>37.2% released<br>9.4% partial release | | |
| PCL disposition (released + partial) | 701[c] | 46.7% | | |
| PCL disposition (preserved + partial) | 701[c] | 62.8% | | |
| Radiographic measurements | | | | |
| Preoperative tibial slope, degrees | 702 | 8.5 [6.5, 11.0] | 0.0 | 19.5 |
| Postoperative tibial slope, degrees | 702 | 7.0 [5.5, 8.5] | 0.0 | 16.0 |
| Change in tibial slope, degrees | 702 | −1.5 [−4.0, 0.5] | −14.5 | 6.5 |
| AP tibial baseplate position, mm | 702 | 8.7 ± 1.6 | 3.3 | 14.6 |

ASA-PS, American Society of Anesthesiology Physical Status; SD, standard deviation; SLE, systemic lupus erythematosus.
[a] One case unknown ASA-PS classification.
[b] Eight cases with unknown location of spine disease specifically related to lumbar vs thoracic, etc.
[c] One case with unknown status of PCL after TKA.

*Patient-reported outcome measures*

Patient-reported outcome measures (PROMs) were collected preoperatively and at a minimum of 1 year postoperatively. PROMs included components of the modern Knee Society Score (KSS) related to pain and function [29-31] including pain with level walking, pain with stairs or inclines (both scored 0 = none to 10 = severe), and "does this knee feel normal to you?" The Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS, JR) [32] was also collected. The KOOS, JR survey measures overall knee health by evaluating stiffness, pain, function, and activities of daily living and is scored by summing the raw responses and then converting it to an interval score ranging from 0 to 100 where 0 represents total knee disability and 100 represents perfect knee health. Furthermore, the University of California Los Angeles (UCLA) Activity Level score [33] was collected. The UCLA activity score asks patients to choose their highest level of current activity, ranging from 0 (wholly inactive: dependent on others, cannot leave residence) to 10 (regularly participate in impact sports such as jogging, tennis, skiing, acrobatics, ballet, heavy labor, or backpacking). Finally, a global 5-point Likert scale satisfaction question was asked on the survey. Responses to the global satisfaction question "What is your current level of satisfaction with your knee replacement surgery?" (very satisfied, satisfied, neutral, dissatisfied, or very dissatisfied) were analyzed.

Minimal clinically important differences (MCIDs) were used to determine the clinical relevance of the change in score for each of the reported PROMs. For the KSS, an MCID of 0.61 was used [34], for the KOOS, JR an MCID of 6.0 was used [35], and for the UCLA activity level score, an MCID of 0.92 was used [36].

*Data analysis*

Statistical analyses were performed with Minitab 19 (State College, PA). Outliers were assessed with a Dixon's r22 ratio test based on the sample size of each analysis group. Normality of continuous variables was evaluated with an Anderson-Darling Normality test.

Variance between analysis groups was evaluated with Levene's and Bonett's methods for assumptions of using a t-test or nonparametric test equivalent. For normally distributed continuous variables with equal variance and independent groups, a Student's two-sample t-test (t) was used for analysis. Nonnormally distributed continuous variables of two groups were evaluated with a Mann-Whitney test (W) adjusted for ties. Normally distributed continuous variables of three or more groups were analyzed with

**Table 2**
PCL disposition group comparison of demographics and covariates.

| Variable | PCL preserved | PCL partial release | PCL full release | Test statistic | *P* |
|---|---|---|---|---|---|
| Age, y | 67.9 | 68.4 | 69.3 | H = 1.32 | .516 |
| BMI, kg/m$^2$ | 32.9 | 34.1 | 34.3 | H = 6.85 | *.033* |
| Sex, % female | 74.3% | 80.3% | 70.1% | $\chi^2 = 3.2$ | .201 |
| ASA-PS class, % 1 or 2 | 32.6% | 33.3% | 38.5% | $\chi^2 = 2.4$ | .304 |
| Lumbar spine disease | 16.7% | 10.8% | 13.2% | $\chi^2 = 2.4$ | .300 |
| Self-reported preoperative narcotic use | 12.0% | 12.1% | 11.5% | $\chi^2 = 0.0$ | .976 |
| Fibromyalgia or SLE | 4.3% | 0.0% | 3.1% | $\chi^2 = 3.3$ | .195 |
| RA or PA | 7.2% | 9.1% | 4.2% | $\chi^2 = 3.3$ | .188 |
| Depression | 28.9% | 25.8% | 23.8% | $\chi^2 = 2.1$ | .351 |

ASA-PS, American Society of Anesthesiology Physical Status; SLE, systemic lupus erythematosus.
*Italicized P-value* indicates statistical significance, but group differences were small which did not represent a clinically meaningful finding.

**Table 3**
Patient reported outcomes.

| Outcome | N | Median [Q1, Q3] | Minimum | Maximum |
|---|---|---|---|---|
| UCLA activity level | | | | |
| Preoperative | 678 | 4.0 [3.0, 5.0] | 1.0 | 10.0 |
| Minimum 1 y | 564 | 6.0 [4.0, 6.0] | 1.0 | 10.0 |
| Change | 540 | 1.0 [0.0, 2.0] | −4.0 | 8.0 |
| KSS pain with level walking | | | | |
| Preoperative | 667 | 6.0 [4.0, 7.0] | 0.0 | 10.0 |
| Minimum 1 y | 558 | 0.0 [0.0, 1.0] | 0.0 | 10.0 |
| Change | 524 | −5.0 [−7.0, −3.0] | −10.0 | 5.0 |
| KSS pain while climbing stairs | | | | |
| Preoperative | 667 | 8.0 [6.0, 9.0] | 0.0 | 10.0 |
| Minimum 1 y | 556 | 1.0 [0.0, 3.0] | 0.0 | 10.0 |
| Change | 522 | −6.0 [−8.0, −4.0] | −10.0 | 4.0 |
| KOOS, JR total score | | | | |
| Preoperative | 659 | 50.0 [42.3, 57.1] | 0.0 | 92.0 |
| Minimum 1 y | 562 | 84.6 [70.7, 92.0] | 24.9 | 100.0 |
| Change | 522 | 33.7 [20.9, 45.2] | −23.5 | 91.7 |
| | **N** | **Percentage (%)** | | |
| Global satisfaction | | | | |
| Minimum 1 y, "very satisfied or satisfied" | 562 | 85.8% | | |
| KSS "knee normal" score | | | | |
| Minimum 1 y, "always feels normal" | 557 | 51.9% | | |

an analysis of variance (F) and post-hoc Tukey tests, while nonnormal continuous outcome variables of three or more groups were analyzed with a Kruskal-Wallis test (H) adjusted for ties and individual post-hoc Mann-Whitney tests, if applicable. Pearson's chi-square ($\chi^2$) test was used to test independence among categorical variables, with Fisher's Exact test $P$ values reported for 2 × 2 contingency tables. Correlations between two continuous variables were evaluated with a Spearman correlation (rho) test to identify any monotonic relationships. Univariate tests for patient-reported outcomes in relationship to all variables listed in Table 1 with $P$ values ≤ .150 were entered into a multivariate model. Binary logistic regression was used for binary outcomes, and linear regression was used for continuous outcome multivariate models. Odds ratios and predicted outcome probabilities were generated from the multivariate models. Normally distributed continuous data are reported as mean ± standard deviation, and nonnormally distributed data are reported as median (interquartile range [IQR Q1, Q3]). A significance level of 0.05 was used for all statistical analyses.

A statistical power analysis was conducted using G*Power software v3.1.9.7. Statistical power (1-β) for the linear multivariate regression models was ≥0.859 using the appropriate sample sizes and number of predictors and a small effect size with an alpha level of 0.05 for each outcome.

## Results

Seven hundred two TKAs were included in the final data analysis. Median age was 68.3 years (IQR 63.1, 73.2), and median BMI was 33.4 kg/m$^2$ (IQR 28.5, 39.2). The cohort was predominantly female (73.4%). Median months of follow-up for patient-reported outcomes were 12.4 months (IQR 12.2, 13.7). Demographics, covariates, and radiographic measurements for the cohort are reported in Table 1. Of the cohort, 53.4% had a fully preserved PCL while 37.2% of cases underwent complete release of the PCL, and 9.4% of cases underwent partial release of the PCL. PCL disposition was unrelated to any of the recorded preoperative variables (Table 2; $P \geq .188$) except for BMI (H = 6.85, $P = .033$). While statistically significant, the confidence intervals between all three PCL groups showed significant overlap, and the maximum median BMI group difference of 1.4 kg/m$^2$ was not clinically meaningful.

The mean AP tibial baseplate position was 8.7 ± 1.6 mm posterior to the tibial canal. The mean tibial baseplate position was associated with a more posterior position in males than in females and patients with American Society of Anesthesiology Physical Status Classification of 1 or 2 compared to 3 or 4 in multivariate analysis ($P \leq .004$). However, the effect of these two variables on tibial baseplate position in the final multivariate model was small (≤0.6 mm difference). Important to note, mean tibial baseplate position was unrelated to PCL status in univariate or multivariate analysis ($P \geq .602$). Furthermore, tourniquet use and drain use were unrelated to PROMs in multivariate analysis. Patient-reported outcomes for the cohort are reported in Table 3.

### *UCLA activity level*

Overall, 56.9% of patients met the MCID (+0.92) for UCLA Activity Level by a minimum of 1 year of follow-up. Median UCLA Activity Level was 6.0 (IQR 4.0, 6.0) at minimum 1-year follow-up which corresponds to "regularly participating in moderate activities such as swimming and doing unlimited housework or shopping" (Table 3). Median improvement in UCLA Activity Level was 1.0 (IQR 0.0, 2.0). In multivariate analysis, only younger age and lack of depression were significant main effects of greater improvement in UCLA activity level scores ($P \leq .006$) with no interaction between the two main effects. PCL disposition and tibial implant position were unrelated to improvement in UCLA scores ($P \geq .187$).

### *Knee Society pain with level walking*

Overall, 92.6% of patients met the MCID (−0.61) for Knee Society pain with level walking by minimum 1-year follow-up. Median

**Table 4**
Multivariate model results for improvement in pain with level walking (Knee Society Score).

| Variable | Beta coefficient | Beta coefficient SE | T value | $P$ | R-sq |
|---|---|---|---|---|---|
| AP tibial baseplate position, mm | 0.13 | 0.074 | 1.76 | .079 | 0.59% |

SE, standard error.

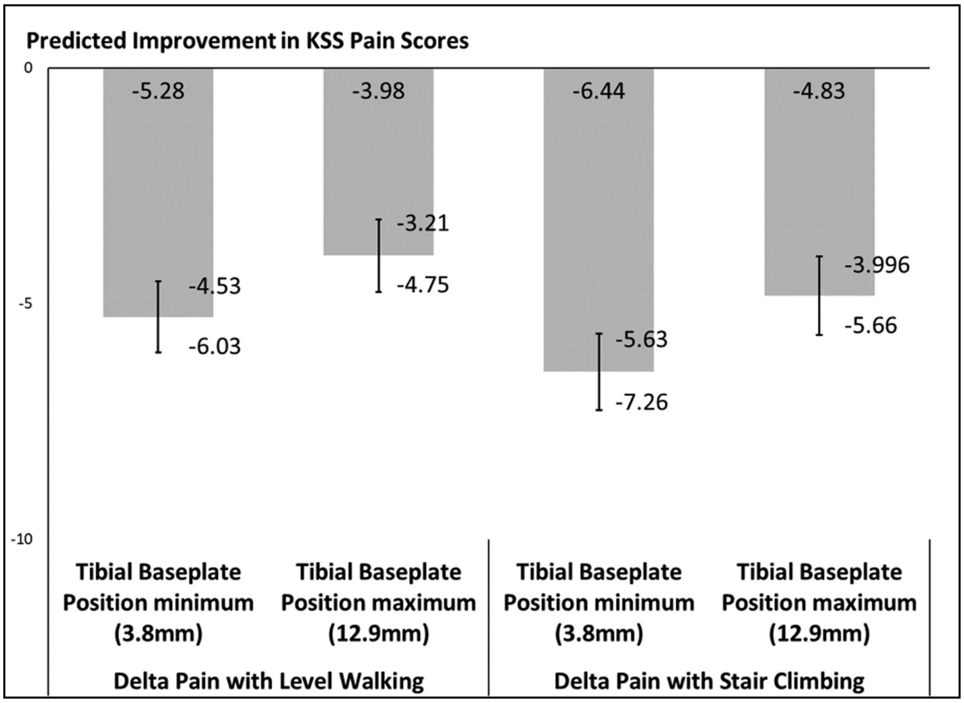


**Figure 2.** Predicted improvements in pain with level walking and pain while climbing stairs scores from their individual multivariate models. Tibial baseplate position closer to the middle of the tibial canal was predictive of a greater improvement in both scores which exceeded the MCID of −0.61 compared to a maximized tibial baseplate position.

pain with level walking was 0.0 (IQR 0.0, 1.0) at minimum 1-year follow-up (Table 3). Median improvement in pain with level walking was −5.0 (IQR −7.0, −3.0). In multivariate analysis, only a tibial baseplate position closer to the tibial canal was a significant main effect of greater improvement in pain with level walking scores (Table 4, $P = .079$). The final model predicted the maximum improvement in pain with level walking to be −5.28 when the tibial baseplate position was more centrally located anteroposteriorly compared to −3.98 improvement in pain with level walking when the tibial baseplate position was furthest from the central tibial canal (Fig. 2).

### *Knee Society pain while climbing stairs*

Overall, 94.8% of patients met the MCID (−0.61) for Knee Society pain while climbing stairs by minimum 1-year follow-up. Median pain while climbing stairs was 1.0 (IQR 0.0, 3.0) at minimum 1-year follow-up (Table 3). Median improvement in pain while climbing stairs was −6.0 (IQR −8.0, −4.0). In multivariate analysis, only tibial baseplate position closer to the tibial canal was a significant main effect of greater improvement in pain while climbing stairs scores (Table 5, $P = .043$). The final model predicted the maximum improvement in pain while climbing stairs to be −6.44 when tibial baseplate position was minimized compared to −4.83 improvement in pain while climbing stairs when tibial baseplate position was maximized and furthest from the tibial canal (Fig. 2).

### *KOOS, JR total score*

Overall, 83.0% of patients met the MCID (+6.0) for the KOOS, JR total score by minimum 1-year follow-up. Median KOOS, JR total score was 84.6 (IQR 70.7, 92.0) at minimum 1-year follow-up (Table 3). Median improvement in KOOS, JR total score was 33.7 (IQR 20.9, 45.2). In multivariate analysis, only tibial baseplate position closer to the tibial canal was a significant main effect of greater improvement in KOOS, JR total score (Table 6, $P = .019$). The final model predicted maximum improvement in KOOS, JR total score to be 38.74 when tibial baseplate position was more centrally located anteroposteriorly compared to 27.32 improvement in KOOS, JR total score when tibial baseplate position was furthest from the central tibial canal (Fig. 3).

### *Knee Society—does this knee feel normal to you?*

At minimum 1-year follow-up, 51.9% of patients reported their knee to “always” feel normal (Table 3). In multivariate analysis, knees were more likely to “always” feel normal with the presence of RA or PA (Table 7, OR 2.75, 95% CI 1.34 to 5.64, $P = .006$) and when the PCL was either fully released or partially released (Table 7, OR 1.42, 95% CI 1.01 to 2.00, $P = .041$). Presence of RA or PA and a PCL

**Table 5**
Multivariate model results for improvement in pain while climbing stairs (Knee Society Score).

| Variable | Beta coefficient | Beta coefficient SE | T value | *P* | R-sq |
|---|---|---|---|---|---|
| AP tibial baseplate position, mm | 0.16 | 0.08 | 2.02 | .043 | 0.78% |

SE, standard error.

**Table 6**
Multivariate model results for improvement in KOOS, JR total score.

| Variable | Beta coefficient | Beta coefficient SE | T value | *P* | R-sq |
|---|---|---|---|---|---|
| AP tibial baseplate position, mm | −1.14 | 0.49 | 2.35 | .019 | 1.06% |

SE, standard error.

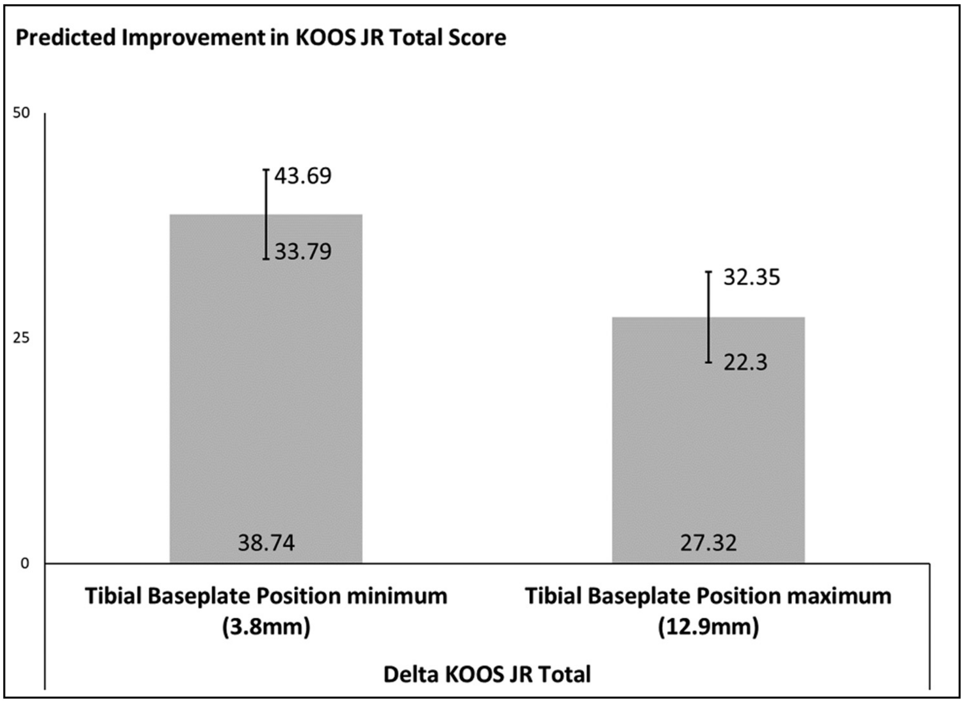


**Figure 3.** Predicted improvement in KOOS, JR total score from the multivariate model. Tibial baseplate position closer to the middle of the tibial canal was predictive of a greater improvement in KOOS, JR total score of +6.0 compared to a maximized tibial baseplate position.

full- or partial-release variables were main effects and did not have any significant interaction.

*Satisfaction*

At minimum 1-year follow-up, 85.8% of patients were "very satisfied or satisfied" after their knee replacement (Table 3). Univariate analysis revealed higher BMI, the lack of lumbar spine disease, and the presence of RA or PA to be associated with being "very satisfied or satisfied" after TKA ($P \leq .101$); however, no variables remained in the multivariate model with any statistical or clinical significance.

## Discussion

The ideal TKA reproducibly restores axial alignment, knee kinematics, and normal gait patterns [37]. In an effort to achieve these goals and reduce the burden of symptomatic instability, which is a leading cause of revision TKA [7,8], ultracongruent bearings have become increasingly popular. Characterized by a more congruent articulating surface that guides motion through implant design, ultracongruent bearings offer advantages including avoiding cam-post wear of traditional PS designs and limiting bone sacrifice in the intercondylar notch. However, these bearings are relatively early in their evolution, and research is warranted to elucidate optimal surgical techniques for their implantation. This study sought to better elucidate the role of the PCL and tibial sagittal plane positioning in TKA performed using a dual-pivot ultracongruent polyethylene bearing.

The results of this study found that AP tibial baseplate position closer to the middle of the tibia may allow greater improvement in pain and function scores at minimum 1-year follow-up. In addition, releasing the PCL increases the likelihood of the knee feeling normal postoperatively. While previous investigations have evaluated individual surgical variables in isolation, this is the first investigation to correlate PROMs with sagittal plane positioning and PCL disposition in TKA performed using an ultracongruent bearing.

Prior studies have evaluated the role of the PCL in highly conforming bearings. Stronach et al. demonstrated the PCL can be successfully retained with the use of a congruent bearing design, with no evident limitation in postoperative ROM in comparison to patients who undergo PCL release [38]. However, the authors of this study did not evaluate clinical outcomes between the two cohorts. In contrast, the results of the present study are similar to those of Roh et al., who found preservation of the PCL was not helpful for improving kinematics and clinical outcomes in highly conforming mobile bearing TKA [19]. Similarly, Peters et al. demonstrated comparable results between CR and ultracongruent bearings when the latter was used in the setting of PCL insufficiency [39]. Furthermore, Watanabe et al. performed a prospective randomized trial using the dual-pivot design with and without retention of the PCL and found most kinematic and clinical metrics were not affected by PCL status; however, the authors did observe more posterior femoral translation in knees with a retained PCL, but

**Table 7**
Multivariate model results for a knee feeling "always" normal vs "sometimes or never" (Knee Society Score).

| Variable | Beta coefficient | Beta coefficient SE | $\chi^2$ | $P$ | OR, 95% CI | R-sq | HF GOF $P$ |
|---|---|---|---|---|---|---|---|
| PCL disposition = partial or full release | 0.35 | 0.17 | 4.17 | .041 | 1.42, 1.01-2.00 | 1.53% | .862 |
| RA or PA = yes | 1.01 | 0.37 | 7.58 | .006 | 2.75, 1.34-5.64 | | |

CI, confidence interval; OR, odds ratio; HF GOF, Hosmer-Lemeshow goodness of fit; SE, standard error.

knees without the PCL had greater passive and kneeling maximum flexion [11,40].

While the status of the PCL remains a point of debate among orthopedic surgeons, with many arguing that PCL resection compromises joint stability and requires a PS knee design, many studies suggest that in ultracongruent bearing TKA, PCL status does not significantly affect stability or range of motion [11,12]. For example, Uvehammer et al. demonstrated that in cases of PCL insufficiency, there are no differences in tibial rotation, maximum femoral AP motion, and liftoff between an ultracongruent and PS bearing TKA using radiostereometry [41]. This is similar to the results of Laskin et al. in a prospective randomized trial of 176 patients with osteoarthritis using either a PS or ultracongruent bearing after PCL sacrifice, which demonstrated no significant difference in ROM, ascending or descending stairs, pain, KSS, or stability [10]. In contrast to the studies demonstrating no difference, our study indicates that patients may actually benefit from partial or complete release of the PCL, showing a higher percentage of patients stating their knee “always” feels normal, when compared to PCL preservation groups.

While the results of this study demonstrate clinically meaningful differences between groups, these are associations, and causation should not be concluded. In hypothesizing potential reasons for the differences observed between groups, it is possible that excessively posterior tibial baseplate positioning could result in engagement of the anterior slope of the tibial bearing earlier in flexion resulting in excessive collateral ligament tension, and in instances of PCL retention, this may also lead to kinematic conflict resulting in additional tension in the PCL and lower PROMs. In addition, the results of this study may be unique to this one particular congruent bearing type which was designed to replicate normal native ACL-intact knee kinematics through greater lateral conformity in early flexion to induce lateral-pivot motion and subsequent medial-pivot motion in greater flexion (termed “dual-pivot” motion) [11,12].

Interestingly, the potential clinical benefits seen with PCL release were observed regardless of the tibial baseplate component position, but the baseplate position may further stratify the observed clinical outcomes in ultracongruent bearings. Specifically, when the tibial baseplate was positioned closer to the middle of the tibia, the multivariate models predicted the maximum improvements in pain with level walking, pain with stair climbing, and KOOS, JR score improvements. Again, we hypothesize that posterior translation of the tibial component may induce kinematic conflict, particularly during deep flexion activities (eg, stair climbing) and that this could be the cause of a difference in clinical outcomes. Agreement on the ideal position of the tibial baseplate in TKA using ultracongruent bearings is yet to be established however. Mediolateral positioning [42], rotational alignment [43], and tibial plateau coverage [44] and their effects on kinematics and patient satisfaction have previously been investigated, but without a clear answer on the ideal position that maximizes clinical outcomes. The results of this study lead us toward an answer, with regard to AP positioning of the tibial component, but additional research is warranted to determine what other technique-dependent implant positioning variables impact PROMs and whether those variables are specific to the variety of conforming bearing geometries and types.

This study has several limitations including its retrospective design, which may introduce uncontrolled biases that a randomized controlled trial may overcome. In addition, the results of this study are limited to one particular ultracongruent bearing design and may not be generalizable to dissimilar implant designs. Similarly, the soft-tissue balancing protocol used for all knees in this study, while described, was not quantified and, thus, may be difficult to generalize. Although the results of this study suggest a certain position of the tibial baseplate on the AP can meaningfully impact PROMs, it should be noted that radiographic measurements of the AP tibial baseplate position can be skewed with rotational changes; however, we excluded cases with significant radiographic rotation to reduce erroneous measurements. Furthermore, the order of our surgical steps was such that the tibial baseplate was “floated” first and then the surgeon determined the ideal position, where the final implant was placed. Specifically, the tibial component was allowed to float in the deepest range of knee flexion so that the posterior femoral condyles settled in the “dwell points” or the deepest sulcus of the medial and lateral convexities of the bearing topography without any observable tibial tray anterior liftoff. If tibial liftoff was observed, a combination of posterior tibial translation, rotation, or PCL release was performed until this “kinematic home” of the posterior femoral condyle sitting in the tibial insert dwell points at maximum flexion was achieved. This aspect of our technique may be responsible for some implants sitting more posteriorly, and our technique has adapted based on this study to prioritize PCL release over posterior tibial translation when feasible. It was this “floating” technique that determined the position of the implant, and of all the tibias that were “floated,” we retrospectively determined which had the most significant improvement in PROMs. Thus, we cannot, necessarily, advocate a surgical technique that prioritizes tibial AP position over what a surgeon feels to be an appropriately balanced knee. Rather, when these two coincide, this may result in the most optimal outcome. Furthermore, the decision to release or resect the PCL was left to the surgeon’s interpretation of PCL integrity and tension intraoperatively, which is a potential source of selection bias. If the PCL was found to be too tight/scarred and causing excessive femoral rollback during flexion, then it was sacrificed to ensure a better flexion profile, but again this was not quantified.

In conclusion, the results of this study suggest that releasing the PCL in combination with positioning the tibial baseplate closer to the center of the tibial canal may improve patient-reported outcomes in primary TKA using ultracongruent bearings.

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