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## The Journal of Arthroplasty

journal homepage: [www.arthroplastyjournal.org](http://www.arthroplastyjournal.org)

Proceedings of The Knee Society 2024

## Radiographic and Clinical Comparisons of a Modern Symmetrical Versus Asymmetrical Implant Design in Primary Total Knee Arthroplasty

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## ARTICLE INFO

## Article history:

Received 18 November 2024

Received in revised form

6 February 2025

Accepted 8 February 2025

Available online xxx

## Keywords:

patellar tracking

patellar tilt

universal femur

total knee arthroplasty

symmetrical femur

<https://www.kneesociety.org/>

## ABSTRACT

**Background:** While asymmetrical, left/right specific, femoral, and tibial components are commonly used in modern total knee arthroplasty (TKA), the recent introduction of a modern symmetrical, left/right nonspecific, design may afford benefits as a result of reduced implant and instrumentation requirements. Given the symmetrical trochlear design of left/right nonspecific femoral components, some concerns over patient outcomes and patellar tracking may exist. The purpose of this study was to compare the clinical and radiographic outcomes in a symmetrical TKA design to a more commonly used asymmetrical femoral component. **Methods:** There were 225 patients (246 knees) who underwent TKA at an academic center with an implant featuring a symmetrical tibial and femoral component, which features a double 9° Q-angle trochlear design instead of left/right specific trochlea, and were compared to a matched historical cohort of 235 patients (236 knees) who had asymmetrical femoral components. All surgeries in both groups were performed using a similar posterior referenced, measured resection technique. Patient demographics, patient-reported outcomes (PROs), complications, knee range of motion, and radiographic analysis performed by an independent observer, including patellar tilt and displacement, were assessed. **Chi-square** and **t-tests** were used. There were no significant demographic differences between groups. **Results:** There were no differences in PROs, failures, or complications at one year ( $P > 0.05$ ). Radiographic patellar tracking was similar between groups with the exception of the symmetrical TKA demonstrating significantly less patellar tilt (0.5 versus 3.1°,  $P < 0.0001$ ). There was no significant difference in pre-operative or postoperative range of motion between the groups ( $P = 0.49$  and  $P = 0.25$ ). **Conclusions:** The symmetrical femoral design demonstrated similar PROs and outcomes to an asymmetrical design. Despite some concern that patellar tracking could be worse in a symmetrical implant, the modern symmetrical TKA design demonstrated less patellar tilt and overall appears to perform clinically similarly to an asymmetric anatomic design.

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In 2016, the United States spent 17.8% of its gross domestic product on health care, which was about twice that of other high-income countries [1]. According to the Centers for Medicare and

Medicaid, health care spending is growing 1.3% faster than the growth of the gross domestic product [2]. Although operating rooms generate much revenue for hospitals, they are also responsible for about 60% of total hospital costs [3]. Therefore, reducing costs in the operating room may have important implications for total hospital costs [4–6].

While an anatomic asymmetric, or left/right specific, femoral component is most widely utilized in contemporary total knee arthroplasty (TKA), the development of symmetrical, left/right nonspecific, universal TKA systems is also available. A modern symmetrical TKA system may afford particular benefits due to reduced implant and instrument inventory and reduced storage and space requirements [7,8]. With these added efficiencies along

Ethical Review Committee Statement: The University of Utah Institutional Review Board (Salt Lake City, UT, USA) approved this study.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to <https://doi.org/10.1016/j.arth.2025.02.021>.

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<https://doi.org/10.1016/j.arth.2025.02.021>

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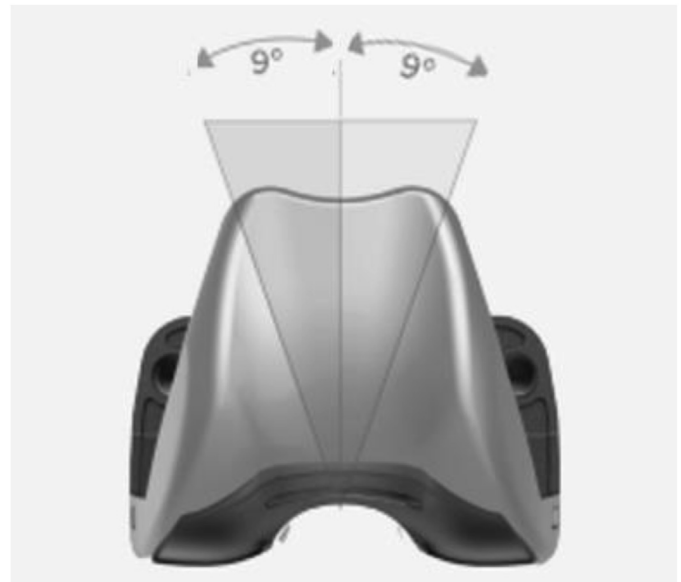
with the cost savings associated with such a universal TKA system, the value of TKA may be enhanced [9–13]. Although prior symmetrical femoral components demonstrated satisfactory long-term results, the use of an asymmetrical femoral component was thought to improve patellofemoral tracking in addition to increasing the surface area of the resected trochlea to improve fixation [14]. Compared to historical symmetric femoral component designs, reduced thickness of the anterior condyle and a lengthened trochlea are the primary improvements in this modern symmetrical femoral design [15].

However, there may exist concerns over the use of left/right nonspecific femoral components. While the use of a universal symmetrical, or left/right nonspecific, tibial tray is often used in TKA surgery, the use of a universal symmetrical femoral component is a departure from the contemporary standards of an anatomic, asymmetrical femoral component. To accept that the use of a modern universal TKA, with symmetrical tibial and femoral components, is suitable for use, it must demonstrate outcomes that are at least as good as existing anatomic asymmetrical implants. Given the left/right nonspecific anterior trochlear design, specific concerns could exist over patellar tracking with a symmetrical component. The purpose of this study was to compare clinical outcomes and a specific radiographic analysis of patellar tracking of a symmetrical TKA design to a control group with an asymmetrical femoral component.

## Methods

A retrospective review was performed on all patients who underwent TKA at a single academic center with the Total Joint Orthopedics Klassic Knee (Total Joint Orthopedics Inc., Salt Lake City, Utah) which features a symmetrical femoral component consisting of a double 9-degree trochlear Q-angle, Figure 1. All surgeries were performed by the senior author. The surgical technique remained consistent between the two groups. The surgeon performed a posterior referenced, measured resection technique, using an intramedullary guided distal femoral cut, and extramedullary tibial guide for tibial alignment. A preoperative long-standing radiograph was analyzed in all cases to plan for femoral and tibial varus/valgus alignment. The intraoperative use of anatomic landmarks and soft-tissue tension were used for final implant alignment and rotation. Femoral rotation was adjusted to be perpendicular to Whiteside's line using posterior referenced instrumentation. The surgeon utilized a mechanical alignment strategy, with an allowance of one to two degrees of femoral or tibial alignment adjustment during surgery to allow for enhanced soft-tissue balance. All surgeries were performed using a medial parapatellar approach. Selective patellar resurfacing was performed, with the rare nonresurfaced patella permitted for patients who had morbid obesity, young age, or pristine appearance of patellar cartilage. If patellar resurfacing was performed, a free hand cut was made parallel to the dorsal surface of the patella, matching the resurfacing combined thickness of bone and polyethylene to the precut caliper measurement. The only instance where an increased thickness was allowed was to account for cartilage or bone erosion. A symmetrical domed patellar implant was medialized. The lateral patellar facet was removed with a rongeur in both groups to remove residual bone left uncovered by the patellar component. In order to preserve patellar blood supply, lateral retinacular releases were not performed in any cases in either cohort.

A total of 225 patients (246 knees) received the symmetrical cruciate-retaining (CR) femoral implant system by the senior author. These patients were then compared to a matched historical cohort of 235 patients (236 knees) who received an asymmetrical CR femoral component (Vanguard Knee System, Zimmer Biomet,



**Figure 1.** Symmetrical femoral component with double 9-degree trochlear Q angle.

Warsaw, Indiana) performed using the same surgical technique as described above by the same surgeon. The symmetrical femoral design features a 9-degree double Q angle and maintains a neutral outside profile of the anterior flange. The asymmetrical femoral design provides a 6.5-degree valgus angulation with a 2-millimeter lateralized trochlear groove from 0 to 15 degrees of valgus. Notably, these two patient cohorts were collected of primary knees using the CR femoral components consecutively. Cases with major bone loss requiring augments and/or ligamentous laxity requiring advanced levels of constraint were not evaluated in this study. The senior author started to transition from an asymmetrical to a symmetrical TKA system at the beginning of October 2020, and as such, this study represents an interrupted time series retrospective review of the two different implants used as the primary of interest, with no major changes in the surgical technique. Patients from the asymmetrical cohort were reviewed from January 1, 2015, to October 1, 2020, and patients from the symmetrical cohort were reviewed from October 2, 2020, to August 1, 2023. All patients had at least a minimum follow-up of one year to be included in this retrospective review. In the symmetrical cohort, a total of nine patients did not have at least one-year follow-up, so they were not included in the cohort of 246 knees.

Clinical outcomes, including reoperations, infection, extensor mechanism complications, and manipulation under anesthesia (MUA), were recorded for both cohorts. Preoperative, two-week, and six-week knee range of motion (ROM) were collected for both patient groups. Patient-reported outcomes (PROs) consisted of Patient-Reported Outcomes Measurement Information System (PROMIS) Physical Function, PROMIS Physical Health, PROMIS Mental Health, PROMIS Pain, as well as Knee Injury and Osteoarthritis Outcome Score, Joint Replacement. An additional stratified analysis based on patellar resurfacing status was performed for both the symmetrical and asymmetrical TKA cohorts.

Radiographic analysis was performed by an independent observer following Knee Society guidelines [16]. Radiographs included weight-bearing anterior-posterior, lateral, and Merchant views. Patellar tilt, lateral patellar displacement, coronal distal femoral angle, and coronal proximal tibia angle were measured at six weeks postoperatively in accordance with Knee Society guidelines.

**Table 1**  
Demographics.

| Demographic  | Asymmetrical System (N = 236) | Symmetrical System (N = 246) | P-Value |
|--------------|-------------------------------|------------------------------|---------|
|              | Mean (Std), Range             | Mean (Std), Range            |         |
| Age in years | 68 (8.6), 45 to 88            | 68 (8.6), 40 to 95           | 0.41    |
| BMI          | 31.4 (6.0), 18 to 52          | 30.8 (5.8), 19 to 49         | 0.35    |
| CCI          | 2.6 (2.7)                     | 1.7 (2.2)                    | 0.0001  |
| ASA          | 2.5 (0.6)                     | 2.5 (0.5)                    | 0.68    |
| Follow-up    | 4.0 (2.5)                     | 1.0 (0.5)                    | <0.0001 |
|              | N (%)                         | N (%)                        | P-Value |
| Sex          |                               |                              |         |
| Women        | 144 (61.3)                    | 125 (57.6)                   | 0.43    |
| Men          | 91 (38.7)                     | 92 (42.4)                    |         |

BMI, body mass index; CCI, Charlson comorbidity index; ASA, American Society of Anesthesia Score.

Chi-square and *t*-tests were used to assess differences in demographics, PROs, clinical outcomes, and radiographic measurements as appropriate. All statistical analysis was performed using SAS (version 9.4; Cary, North Carolina). A *P*-value of  $\leq 0.05$  was considered statistically significant.

### Demographics

Patient demographics are summarized in Table 1. There were no significant differences in mean age, sex, body mass index, or American Society of Anesthesiologists Score between the two cohorts. The Charlson comorbidity index was significantly higher in the symmetrical TKA cohort (2.6 versus 1.7,  $P = 0.0001$ ), and mean follow-up was significantly shorter in the symmetrical TKA cohort given the interrupted time series design of the study (1.0 versus 4.0 years,  $P < 0.0001$ ).

## Results

### Clinical Outcomes

There were no significant differences in rates of MUA, patellar complications (fracture, polyethylene component loosening, and extensor mechanism disruption), reoperations, or infections between the symmetrical and asymmetric TKA cohorts (Table 2). There were no significant differences in overall rates of patellar resurfacing versus nonresurfacing in the symmetrical versus asymmetrical cohorts (90.2 versus 91.1%,  $P = 0.74$ ) (Table 2).

### Radiographic Outcomes

On average, the patients who underwent TKA with a symmetrical system had statistically significantly less lateral patellar tilt (0.5 versus 3.1°,  $P < 0.0001$ ) (Figure 2). There was no significant difference in lateral patellar displacement between the symmetrical group compared to the asymmetrical group (1.0 versus 1.5 mm,  $P = 0.052$ ) (Figure 3). Figure 4 shows an example of such patellar tracking between these two implant systems. In terms of final implant alignment, the symmetrical TKA group had a statistical, though very slight absolute difference in distal femoral angle (95.0 versus 94.5°,  $P = 0.0001$ ) and proximal tibia angle (88.8 versus 89.3°,  $P < 0.0001$ ). Preoperative knee ROMs were not significantly different between the two cohorts. The asymmetrical TKA group had a slightly greater ROM at postoperative week two (88.8 versus

**Table 2**  
Outcomes.

| Outcome                       | Asymmetrical System (N = 236) | Symmetrical System (N = 246) | P-Value |
|-------------------------------|-------------------------------|------------------------------|---------|
|                               | N (%)                         | N (%)                        |         |
| MUA                           | 10 (4.2)                      | 15 (6.1)                     | 0.36    |
| Reoperation                   | 7 (3.0)                       | 9 (3.7)                      | 0.67    |
| Patellar complication         | 1 (0.4)                       | 1 (0.4)                      | 0.98    |
| Infection                     | 4 (1.7)                       | 4 (1.7)                      | 0.95    |
| Patellar resurfacing          | 215 (91.1)                    | 222 (90.2)                   | 0.75    |
| Finding                       | Mean (std)                    | Mean (std)                   | P-Value |
| Patellar tilt                 | 3.1 (4.8)                     | 0.5 (2.5)                    | <0.0001 |
| Lateral patellar displacement | 1.5 (2.8)                     | 1.0 (2.3)                    | 0.0512  |
| Distal femoral angle (alpha)  | 94.5 (1.5)                    | 95.0 (1.1)                   | 0.0001  |
| Proximal tibial angle (beta)  | 89.3 (1.0)                    | 88.8 (1.1)                   | <0.0001 |
| Range of motion               |                               |                              |         |
| Preoperative                  | 118.1 (13.5)                  | 118.8 (10.0)                 | 0.49    |
| 2 weeks                       | 88.8 (10.0)                   | 85.0 (14.9)                  | 0.0012  |
| 6 weeks                       | 113.9 (13.2)                  | 112.5 (12.7)                 | 0.24    |

MUA, manipulation under anesthesia.

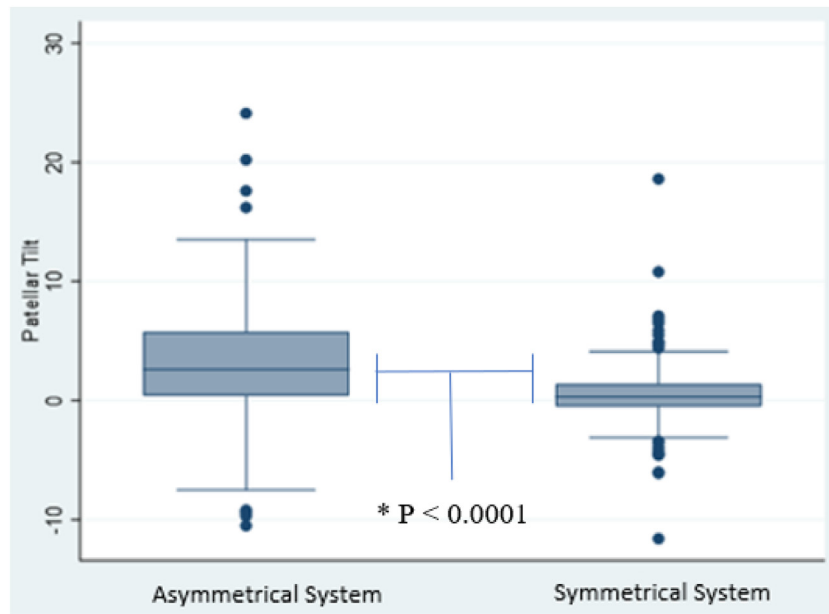
85.0°,  $P = 0.0012$ ), but this difference was no longer significant by postoperative week six.

### Stratification by Patellar Resurfacing

Selective patellar resurfacing was performed. There were no significant differences in overall rates of patellar resurfacing in the symmetrical versus asymmetrical cohorts (90.2 versus 91.1%,  $P = 0.75$ ) (Table 2). Outcomes were then stratified based on patellar resurfacing within each implant system used (Table 3). There were no significant differences in MUA, patellar complications (extensor mechanism injuries, fractures, and component loosening), reoperations, or infections when accounting for patellar resurfacing status within each TKA system cohort (Table 3). Within the asymmetrical TKA cohort, compared to resurfacing, those with unresurfaced patellae demonstrated significantly more lateral patellar tilt (5.8 versus 2.8°,  $P = 0.0098$ ) and lateral patellar displacement (4.7 versus 1.2 mm,  $P = 0.0004$ ). Similarly, within the symmetrical TKA cohort, compared to resurfaced patellae, those that were unresurfaced demonstrated significantly more lateral patellar tilt (2.9 versus 0.3°,  $P = 0.0073$ ) and lateral patellar displacement (3.4 versus 0.7 mm,  $P = 0.0049$ ). In the asymmetrical cohort, patients had better postoperative week two knee ROM (92.3 versus 88.4°,  $P = 0.039$ ) when patellae resurfaced. However, there were no significant differences preoperatively or at postoperative week six. For the symmetrical cohort, patients who had resurfaced patellae had significantly better knee ROM at postoperative week two (86.0 versus 75.8°,  $P = 0.032$ ) and postoperative week six (113.1 versus 106.8°,  $P = 0.020$ ) only.

### PROs

Patients in the symmetrical cohort started with slightly higher preoperative PROMIS physical function and Knee Injury and Osteoarthritis Outcome Score, Joint Replacement scores. However, there were no significant differences in any PROs at one year postoperatively between the two cohorts (Table 4). Figure 5 represents the PRO recovery curves for both cohorts. The PROMIS physical



**Figure 2.** Box plots of patellar tilt by implant system.

function and mental health showed no significant differences at any time point (Figure 5A and C). Figure 5B demonstrates a more significant reduction in pain at postoperative week two for the asymmetrical cohort, but they were not significantly different at any time point thereafter. Similarly, patients in the symmetrical TKA cohort had significantly better PROMIS physical health scores at postoperative week two, but these disappeared at postoperative week six and thereafter (Figure 5D).

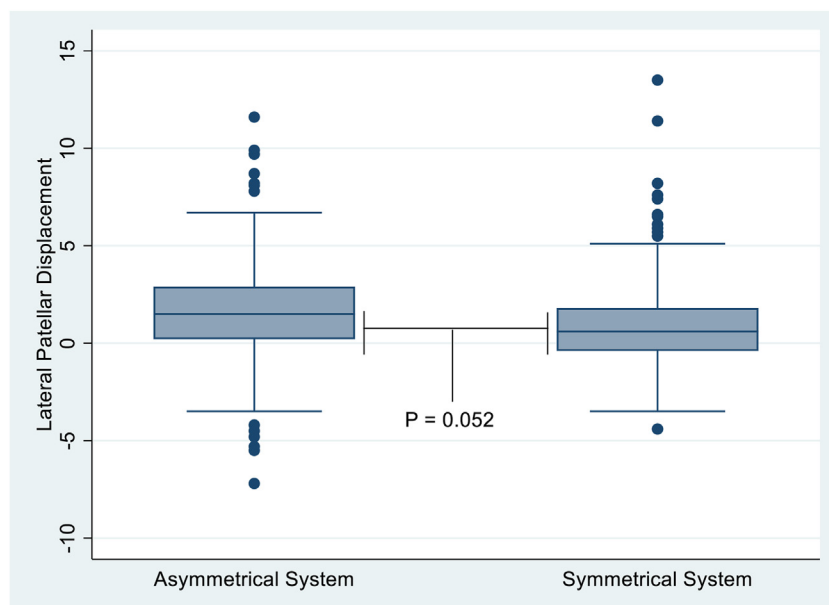
## Discussion

In this retrospective review, we found that a symmetrical TKA design demonstrated no significant differences in clinical outcomes or PROs compared to a historical cohort receiving an asymmetrical

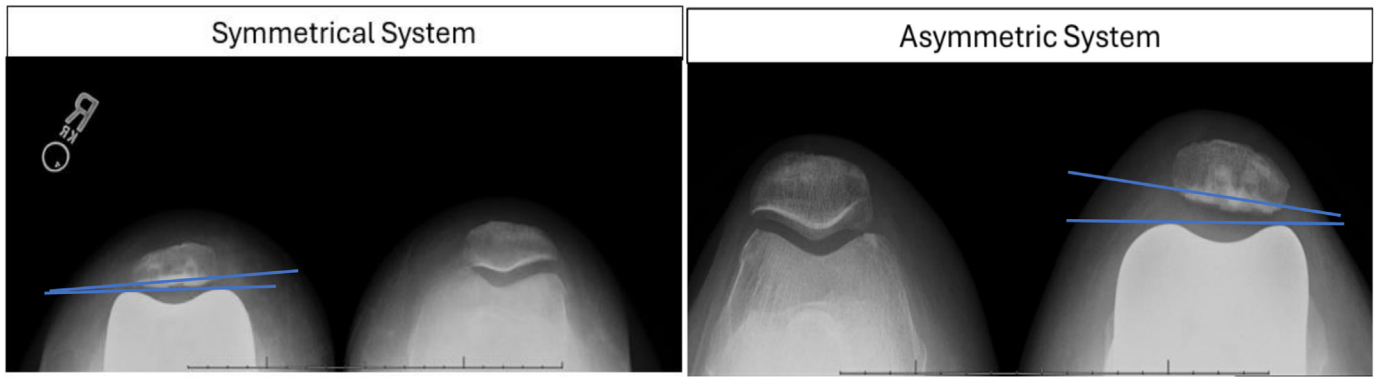
TKA implant. Of interest, the mean lateral patellar tilt was significantly less in the symmetrical cohort in comparison to the asymmetrical cohort, and this was accompanied by the symmetrical cohort having fewer outliers (outside of two SDs) in regard to lateral patellar tilt. As both implant cohorts had similar clinical outcomes and patellar tracking was not worse in the symmetrical cohort, this study offers further data regarding the use of a modern symmetrical TKA implant in contemporary TKA.

## Radiographic Outcomes

There may exist concerns that an asymmetrical anatomic femoral component may be optimal for patellar tracking and that an asymmetrical trochlear groove is needed in order to replicate



**Figure 3.** Box plots of lateral patellar displacement by implant system.



**Figure 4.** Examples of patellar tracking between symmetrical versus asymmetrical systems.

native patellar kinematics [17,18]. Specifically, both a raised lateral trochlear build-up and an anatomically oriented trochlear Q-angle are thought to prevent lateral patellar subluxation [17,19,20]. Based on our radiographic analysis, we do not believe a symmetrical femoral component leads to worse patellar tracking, and this study contributes to a growing body of literature in favor of a symmetrical femoral component in TKA design. Stoddard et al. performed a cadaveric investigation assessing patellar tracking using both symmetrical and asymmetrical TKA designs [21]. The authors measured patellar displacement and tilt at 0, 20, 30, 60, and 90 degrees of knee flexion while loading the quadriceps and iliotibial band. There were no significant differences in patellar displacement or tilt between the two systems at any tested degree of knee flexion. Worland et al. conducted a prospective randomized control trial in 101 patients undergoing TKA with either a universal symmetric versus asymmetric femoral component [22]. The authors found no significant difference between the two implants when assessing the need for lateral release intraoperatively or based on patellar displacement of postoperative radiographs. Similarly, Ashraf et al. reported on the prospective five-year outcomes of patients undergoing TKA with a symmetrical versus asymmetrical femoral component and found no significant differences in improvement of Bristol knee scores or rates of patellar subluxation on radiographs obtained at eight months, two and five years [23].

However, they did note a significantly greater improvement in knee ROM for those undergoing a TKA with a symmetrical femoral component (14 versus 4°,  $P < 0.05$ ). Based on these studies, we believe our retrospective review contributes to the growing body of literature that the use of a universal (symmetrical) femoral component does not pose an increased risk for patellar maltracking.

The lack of significant patellar tracking differences between these two types of femoral implants is likely multifactorial. As the trochlear groove is present in the anterior flange of the femoral component, the patella must engage this portion of the prosthesis for there to be a biomechanical benefit to trochlear prosthesis design. However, the mechanical constraints afforded by the anterior flange of the prosthesis likely do not serve a major function as the patella does not engage the most proximal aspects of the femoral component during the 0 to 20-degree flexion arc [24]. At this particular flexion arc, soft tissue is known to be the primary driver of patellar tracking [24,25]. Therefore, we hypothesize that the more proximal aspects of the anterior flange of an asymmetrical femoral component might be superfluous given the patella does not begin to engage the prosthetic trochlear groove until there is about 30 degrees of knee flexion [26]. It may very well be the case that surgical techniques, including implant alignment and femoral rotation, are the dominating factors in

**Table 3**  
Outcomes Stratified by Patellar Resurfacing.

| Outcome                       | Asymmetrical System            |                               |         | Symmetrical System             |                               |         |
|-------------------------------|--------------------------------|-------------------------------|---------|--------------------------------|-------------------------------|---------|
|                               | Unresurfaced Patellae (N = 21) | Resurfaced Patellae (N = 215) | P-Value | Unresurfaced Patellae (N = 24) | Resurfaced Patellae (N = 222) | P-Value |
|                               | N (%)                          | N (%)                         |         | N (%)                          | N (%)                         |         |
| MUA                           | 0                              | 10 (4.7)                      | 0.61    | 4 (16.7)                       | 11 (5.0)                      | 0.046   |
| Reoperation                   | 1 (4.8)                        | 6 (2.8)                       | 0.48    | 2 (8.3)                        | 7 (3.2)                       | 0.22    |
| Patellar complication         | 0                              | 1 (0.5)                       | 1.00    | 0                              | 1 (0.5)                       | 1.00    |
| Infection                     | 0                              | 4 (1.9)                       | 1.00    | 1 (4.2)                        | 3 (1.4)                       | 0.34    |
| Finding                       | Mean (std)                     | Mean (std)                    | P-Value | Mean (std)                     | Mean (std)                    | P-Value |
| Patellar tilt                 | 5.8 (7.0)                      | 2.8 (4.5)                     | 0.0098  | 2.9 (4.2)                      | 0.3 (2.1)                     | 0.0073  |
| Lateral patellar displacement | 4.7 (3.6)                      | 1.2 (2.5)                     | 0.0004  | 3.4 (4.1)                      | 0.7 (1.8)                     | 0.0049  |
| Distal femoral angle (alpha)  | 95.0 (1.5)                     | 94.5 (1.4)                    | 0.17    | 94.5 (1.4)                     | 95.1 (1.1)                    | 0.028   |
| Proximal tibial angle (beta)  | 88.9 (1.5)                     | 89.3 (1.0)                    | 0.31    | 89.0 (1.0)                     | 88.8 (1.1)                    | 0.463   |
| Range of motion               |                                |                               |         |                                |                               |         |
| Preoperative                  | 117.0 (15.1)                   | 118.2 (13.4)                  | 0.72    | 115.4 (14.2)                   | 119.2 (9.4)                   | 0.21    |
| 2 weeks                       | 92.3 (11.2)                    | 88.4 (9.8)                    | 0.039   | 75.8 (21.6)                    | 86.0 (13.7)                   | 0.032   |
| 6 weeks                       | 113.7 (11.2)                   | 113.9 (13.3)                  | 0.95    | 106.8 (18.7)                   | 113.1 (11.7)                  | 0.020   |

MUA, manipulation under anesthesia.

**Table 4**  
Patient-Reported Outcomes.

| PRO               | Asymmetrical<br>System<br>(N = 236) | Symmetrical<br>System<br>(N = 246) | P-Value |
|-------------------|-------------------------------------|------------------------------------|---------|
|                   | Mean (Std)                          | Mean (Std)                         |         |
| Preoperative PROs |                                     |                                    |         |
| Physical function | 38.3 (7.0)                          | 41.0 (7.2)                         | 0.0001  |
| Physical health   | 40.2 (6.5)                          | 41.4 (7.5)                         | 0.11    |
| Mental health     | 49.0 (8.2)                          | 50.5 (9.2)                         | 0.092   |
| Pain              | 58.1 (21.5)                         | 54.1 (23.7)                        | 0.074   |
| KOOS JR           | 48.1 (15.1)                         | 52.4 (13.5)                        | 0.0069  |
| One year PROs     |                                     |                                    |         |
| Physical function | 41.1 (7.8)                          | 43.5 (7.6)                         | 0.066   |
| Physical health   | 46.7 (7.6)                          | 48.2 (8.1)                         | 0.383   |
| Mental health     | 51.8 (8.3)                          | 53.3 (10.2)                        | 0.44    |
| Pain              | 27.4 (26.0)                         | 28.2 (24.6)                        | 0.87    |
| KOOS JR           | 78.4 (16.9)                         | 74.5 (13.9)                        | 0.26    |

PRO, patient-reported outcome; KOOS JR, Knee Injury and Osteoarthritis Outcome Score, Joint Replacement.

patellofemoral tracking as opposed to the reliance on the femoral components' trochlear design attempting to force or direct the patella. Although differences in prosthetic trochlear design may improve patellar tracking to a limited degree, they likely cannot overcome errors in surgical technique or component positioning [14]. It is also possible that the specific trochlear angle of the symmetric femoral component design we report on may be large enough to facilitate patellar tracking despite not being asymmetric/anatomic.

#### Differences Based on Resurfacing

The decision to resurface the patella remains a highly debated topic among surgeons [27]. Although multiple TKA designs were in existence at the time, it was not until the Insall-Burstein total condylar knee replacement (Zimmer, Warsaw, Indiana) was introduced in 1974 that a TKA prosthesis provided surgeons the decision to resurface the patella [28]. Rates of patellar resurfacing have an important geographic correlation, with the United States having an average resurfacing rate of 82% in contrast to Norway's 4% [29]. Given the large number of patients undergoing TKAs without patellar resurfacing, the influence of prosthesis design on patellar tracking should also be considered in this subset of patients. Although there has been investigation, on how femoral prosthesis design influences patellofemoral tracking and stresses in unresurfaced patellae, there is limited literature comparing symmetrical versus asymmetrical femoral prostheses in such regard [30]. Barink et al. performed a cadaveric study evaluating patellar tracking in specimens receiving TKAs with either a symmetrical or asymmetrical femoral component [31]. They found no significant difference in patellofemoral kinematics when comparing a symmetrical versus asymmetrical TKA system. Similarly, our study failed to demonstrate a significant disadvantage to using a symmetrical TKA system with regard to patellar tracking in patients who have unresurfaced patellae. Of interest, we did demonstrate slightly worse patellar tracking in both the symmetric and asymmetric groups with an unresurfaced patella compared to a resurfaced patella, suggesting again that femoral component design had little influence on the outcome. Ultimately, while the unresurfaced patella in our series showed slightly worse patellar tracking, both systems still showed similarly overall acceptable patellar tracking.

#### Clinical Outcomes

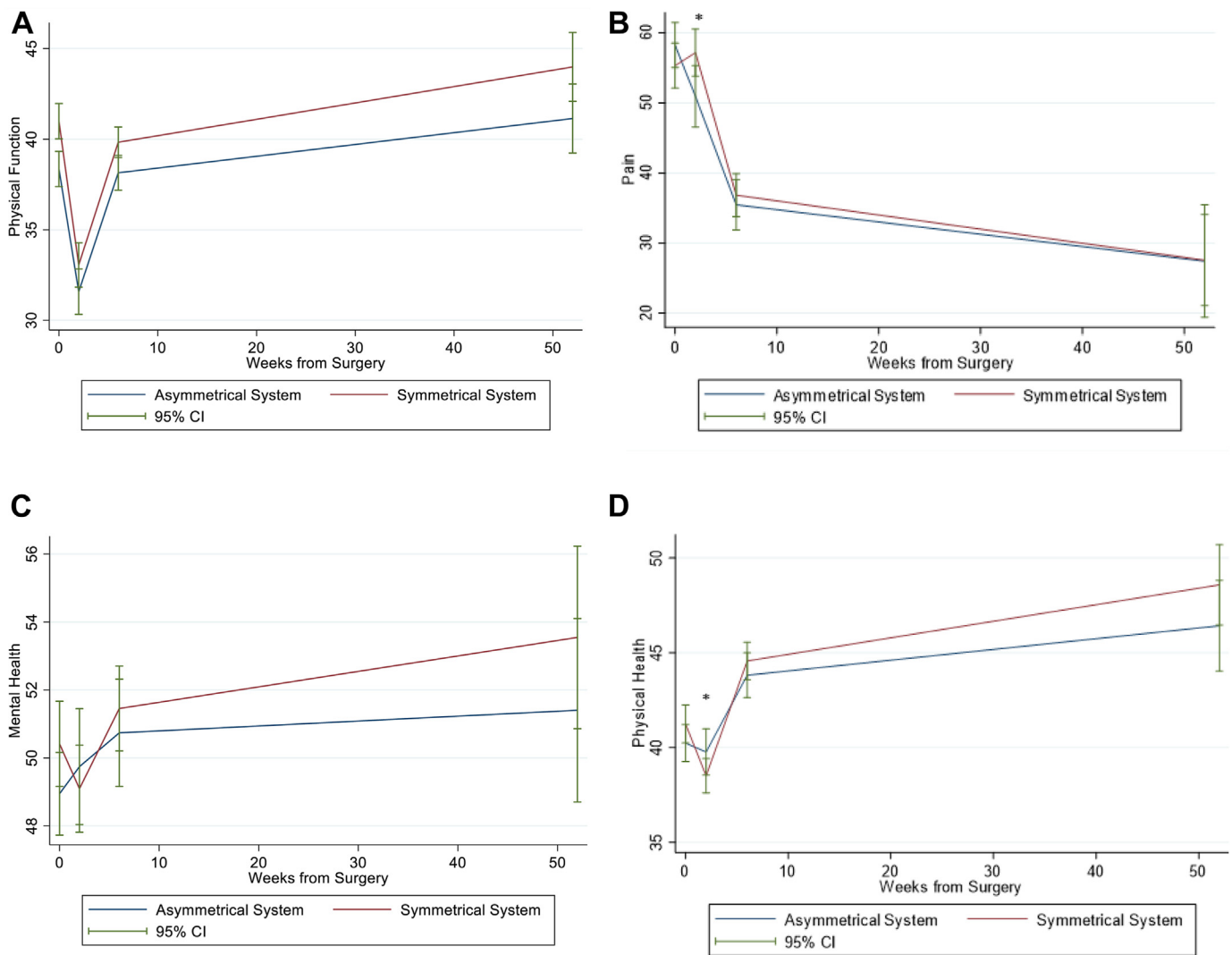
We found no significant differences in PROs, revisions, or complications at one year ( $P > 0.05$ ) for the symmetrical cohort versus the asymmetrical cohort. Previously, Law et al. published their early outcomes of this particular symmetrical TKA system with a minimum follow-up of two years and a mean follow-up of 3.1 years [32]. Of the 1,004 TKAs performed, three ultimately required revision. There was one patient who suffered bilateral periprosthetic joint infections, and one required patellar revision for aseptic loosening. The authors reported a Kaplan-Meier survival at 6.2 years of 98.4% for all-cause revision. Forrester et al. also published their six-year outcomes of this same prosthesis and retrospectively reviewed 131 patients (149 knees) [15]. The patella was left unresurfaced 24.8% of the time, and knee society scores all significantly improved postoperatively ( $P < 0.001$ ). A total of nine knees underwent reoperation within six years for the following reasons: two 2-stage revisions for infection, one aseptic revision for femoral loosening, two quadriceps tendon repairs, three polyethylene exchanges for laxity, and one posttraumatic patella fracture. There were no documented cases of patellar maltracking, and the authors concluded that their clinical results and survivorship were similar to those published using asymmetrical systems.

#### Post Hoc Analysis

We performed a *post hoc* analysis of the radiographic analysis of the patella position as this was the primary focus. We were adequately powered at 98.5%. For both PROs and complications, the incidence of complications was so low and the difference in PROs so little that we would need over 10,000 patients per group for adequate power. Even with adequate power and potential statistical significance, the differences would be unlikely to be clinically meaningful.

#### Potential Limitations

This retrospective review is not without potential limitations. The mean follow-up of the symmetrical TKA cohort is substantially shorter than the asymmetrical cohort given the senior author's relatively recent transition to this system. We are limited in drawing any long-term conclusions regarding these two systems beyond this short-term data. However, there is literature to support the longevity of this particular symmetrical implant with six-year outcomes data, as previously discussed [15]. In addition, patellar tracking was assessed with merchant view radiographs obtained at six weeks postoperatively, as is our clinic's standard. However, this provides a static view of patellar tracking at one position in knee ROM, and further conclusions about patellar tracking throughout a ROM cannot necessarily be extrapolated. Comparisons of outcomes between the resurfaced and unresurfaced patella should also be interpreted with caution given the inherent selection bias and obvious preference for patellar resurfacing, with fewer than 10% of patellae in either group being unresurfaced. While this study was adequately powered to detect statistical significance in the radiographic analysis, particularly patellar tilt, we recognize that the difference of 0.5 versus 3.1° may still be questionable as to whether this equates to clinical relevance. Also, patients who have major bone loss requiring augments and/or ligamentous laxity requiring advanced levels of constraint were not evaluated in this study, as the goal of the current investigation was to evaluate the results of the CR femur. As such, these patients were not eligible to receive



**Figure 5.** Patient-reported outcome recovery curves (A) physical function (B) pain (C) mental health (D) physical health. \*P value <0.05 between groups at that time point.

this implant, and this should be taken into consideration when evaluating this data.

## Conclusions

Patients receiving a symmetrical TKA design demonstrated similar PROs and outcomes to an asymmetrical TKA implant. Despite concerns that patellar tracking could be worse in a symmetrical implant, there were significantly fewer patellar mal-tracking outliers, particularly with regard to lateral patellar tilt, using this modern symmetrical universal TKA implant. Although it is questionable if the statistically significant improvements in radiographic parameters, such as patellar tilt, are clinically meaningful, our data at least further supports the finding that patellar tracking was not worse with the universal design. Given similar patient outcomes, similarly low rates of complications, and patellar tracking that appears to be clinically similar to that of an asymmetric anatomic design, this modern symmetrical total knee appears to be a reasonable consideration for use in contemporary TKA surgery.

## CRediT authorship contribution statement

**Joshua P. Rainey:** Writing – review & editing, Writing – original draft, Methodology, Data curation. **Brenna E. Blackburn:** Writing – review & editing, Methodology, Formal analysis. **Claire R. Kapron:** Writing – review & editing, Data curation. **Michael J. Archibeck:** Writing – review & editing, Methodology. **Lucas A. Anderson:** Writing – review & editing, Conceptualization. **Christopher E. Pelt:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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