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Robotic-Assisted Total Knee Arthroplasty Results in Shorter Navigation Working Time With Similar Clinical Outcomes Compared to Computer-Navigated Total Knee Arthroplasty

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A B S T R A C T

Background: Early clinical data are important in the appraisal of newly introduced robotic-assisted surgery (RAS) systems in total knee arthroplasty (TKA). However, there are few studies to date comparing 1-year clinical outcomes between RAS and computer-assisted navigation (CAS), the forerunner in reducing alignment outliers. The aim of this study was to determine if there was a difference between these two groups in early clinical outcomes, including functional outcome and patient-reported outcome measures (PROMs).

Methods: A total of 158 propensity score-matched patients who underwent primary TKA with either CAS or RAS were retrospectively analyzed. Perioperative outcomes (navigation time, length of stay, complications, readmissions, transfusions, and technical failure), as well as functional outcome measures (range of motion, sit to stand test, timed-up-and-go test, single-leg stance test, calf raises, and step count), and PROMs (Oxford Knee Score, Knee Injury and Osteoarthritis Outcome Score, 12-item Short Form Survey, Forgotten Joint Score-12, and satisfaction) were compared between those who underwent CAS and those who underwent RAS.

Results: Navigation time was shorter in the RAS group compared to the CAS group (mean difference, 15.4 minutes; $P < 0.001$). There were 2 complications reported in the CAS group (one patellar clunk, one periprosthetic joint infection), but none in the RAS group. There were no other readmissions, transfusions, or technical failures in either group. Postoperatively, there were no clinical differences in function between groups. Clinically meaningful improvement in PROMs was observed in both groups, with no differences.

Conclusions: The use of RAS resulted in shorter navigation time compared to CAS in TKA. No other differences were observed in early clinical outcomes between patients who underwent RAS and CAS.

Technology has been utilized in total knee arthroplasty (TKA) since the late 1990s in an effort to achieve precise and consistent implant positioning [1]. While computer-assisted navigation (CAS) is a proven method to reduce alignment outliers [2], the use of robotic-assisted surgery (RAS) in TKA has increased in the recent years and accounts for up to 23% of all TKAs performed [3,4]. With the aid of a robotic arm and advanced soft tissue balancing algorithms, RAS facilitates the preparation of bone surfaces to increase the precision and reliability of prosthetic alignment and gap

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balancing, aiming to achieve better clinical outcomes. There is also evidence that RAS reduces soft tissue trauma to the knee, resulting in less swelling, pain, and a faster recovery [5–7].

The biggest drawback to RAS today is the considerable costs associated with its usage. Additionally, numerous contemporary RAS systems have been introduced to the market in the recent years. Each system differs slightly in their specificities, algorithms, and execution arm. Therefore, the results of RAS are not generalizable across all systems. Each RAS system needs to be assessed for its own value [8]. Given the higher upfront costs of RAS compared to CAS, early clinical data play a paramount role in the appraisal of these modern robotic systems. Although RAS has been shown to be more accurate and efficient than CAS in TKA [9], it is unknown whether this translates to better clinical outcomes in the first year. Furthermore, published research compares RAS to conventional instrumentation, and many of these studies involve first-generation robots, which are no longer in use [10–15]. While RAS has shown superior patient-reported outcome measures (PROMs) compared to mechanical instrumentation in TKA [15], direct comparisons with CAS have not been reported.

The aim of this study was to determine if there is a difference in early clinical outcomes, especially functional outcome measures and PROMs, between patients who underwent TKA with CAS and those who underwent TKA with RAS. The patients in both groups were operated on by a single surgeon, receiving the same prosthesis and undergoing the same functional alignment target and balancing technique. Therefore, the only variable between the two patient groups was whether this was achieved using RAS or CAS. The study hypothesis was that patients who underwent TKA with RAS have better early clinical outcomes than those who underwent TKA with CAS, with no increase in complications.

Methods

Patient Cohort

This retrospective study received ethics approval from the Bellberry Human Research Ethics Committee (Sydney, Australia; No. 2012-03-710) before commencement. Patients who underwent primary TKA for unilateral symptomatic knee osteoarthritis with CAS or RAS at the authors' institution between January 6, 2020, and December 19, 2022 were reviewed for inclusion. The exclusion criteria were revision TKAs, previous history of infection, neuromuscular disorders, mental or neurological conditions that may interfere with the ability to provide self-reported data, and collateral ligament insufficiency requiring constrained prostheses. To minimize selection bias, propensity scores were determined using logistic regression analyses based on age, sex, body mass index (BMI), American Society of Anesthesiologists status, osteoarthritis grade as classified by the Ahlbäck classification, preoperative hip-knee-ankle (HKA) angle, and flexion deformity as covariates, forming a nearest neighbor one-to-one matched sample.

There were 346 primary TKAs performed during the study period, of which the first 245 TKAs were performed with CAS (Brainlab Knee3 Navigation, Munich, Germany) and the subsequent 101 TKAs were performed with RAS (Velys Robotic-Assisted Solution (DePuy Synthes, Warsaw, Indiana); an image-free, semiactive, operating table bedrail-mounted robotic system). Consecutive patients who underwent robotic-assisted TKA were matched with preceding patients who underwent navigated TKA, yielding a total of 158 propensity score-matched patients for analysis. The robotic group was the first cohort of patients who underwent RAS performed by the senior author, and all cases before that were performed with the assistance of computer navigation.

Surgical Technique

The surgical workflow was similar in every case, except for several aspects dependent on whether CAS or RAS was performed. Under spinal and/or general anesthesia, the knee was exposed utilizing a medial parapatellar approach without a tourniquet. Tibial arrays were placed outside the incision, while femoral arrays were placed within the incision via self-drilling and self-tapping pins. Anatomical landmarks were identified and acquired as per the prescribed protocol for each system. After removing accessible medial and lateral osteophytes and the anterior and posterior cruciate ligaments, initial limb alignment and the soft tissue envelope laxity were evaluated. The senior author's preferred technique was the tibia first, modified gap balancing technique aiming for functional alignment. Equal flexion and extension gaps were achieved through a combination of femoral component alignment and size adjustments within accepted boundaries (HKA 5° varus to 1° valgus, tibial coronal alignment 3° varus to 1° valgus, femoral coronal alignment 2° varus to 2° valgus). Soft tissue releases were infrequent but performed if necessary to satisfy the alignment boundaries and usually performed before final femoral planning. In the CAS group, bone cuts were made with a handheld saw once the cutting blocks were navigated and pinned to the desired location, while in the RAS group, bone cuts were made directly with the sawblade on the robotic arm. Once the box cut was performed, trial implants were inserted, and final limb alignment and ligament balance were recorded. The balance target was equal medial and lateral gaps in both flexion and extension, aiming for 0.5 to 1 mm extension laxity and 1 to 1.5 mm flexion laxity. Fully cemented mobile-bearing posterior stabilized prostheses (ATTUNE, DePuy Synthes, Warsaw, Indiana) were implanted in all cases with PALACOS (Heraeus, Hanau, Germany) bone cement, and patellae were resurfaced routinely. All patients followed a standardized postoperative protocol.

Clinical Outcomes

Patient charts and the authors' institutional database were reviewed for information on demography, BMI, American Society of Anesthesiologists status, preoperative clinical assessment, and clinical outcomes. The clinical outcomes of interest were navigation time, hospital length of stay, transfusion rate, readmission rate, surgery-related complications, technical failure, functional outcome measures, and PROMs. Navigation time was defined as the duration of time taken from the start of femoral head center acquisition to the end of assessment of final limb alignment with trial implants in place. This included bony landmark registration, assessment of initial limb alignment and soft tissue envelope, surgical planning, bone resection, and cut verification. Information was extracted from data logs retrieved from the units. Length of stay was defined as the number of days from admission to discharge from the hospital.

At 6 weeks preoperatively, patients were assessed by a physiotherapist, who delivered a prehabilitation program as well as education in preparation for surgery. After surgery, patients were started on a 6-week home exercise program to optimize recovery. Progress was frequently monitored via telemedicine by the physiotherapist-in-charge, with intervention instituted as and when needed. At the sixth week postsurgery mark, patients underwent another functional assessment. The assessments performed preoperatively and postoperatively were range of motion (°) measured with a goniometer, 30 seconds sit-to-stand test (number of full stands performed in 30 seconds), timed up and go test (number of seconds required to stand up from a standard seated position, walk a distance of 3 m, and sit down again), single

Table 1
Demography and Preoperative Clinical Details.

Variables	Overall	Navigation	Robotic-Assisted	P value
Sex				0.87[a]
Men	79 (50.0)	40 (50.6)	39 (49.4)	
Women	79 (50.0)	39 (49.4)	40 (50.6)	
Age (years)	68 ± 7.4	68 ± 7.4	69 ± 7.4	0.75[b]
ASA status				0.86[a]
1	19 (12.0)	10 (12.7)	9 (11.4)	
2	117 (74.1)	57 (72.2)	60 (75.9)	
3	22 (13.9)	12 (15.2)	10 (12.7)	
BMI	29.6 ± 5.1	29.5 ± 5.3	29.6 ± 4.9	0.90[b]
Ahlbäck OA grade				1.00[c]
4	150 (94.9)	75 (94.9)	75 (94.9)	
5	8 (5.1)	4 (5.1)	4 (5.1)	
Preoperative HKA (°)	−4.2 ± 6.5	−4.6 ± 5.9	−3.9 ± 7.1	0.51[b]
Flexion deformity (°)	5.3 ± 4.5	5.7 ± 4.6	4.9 ± 4.4	0.26[b]

Values are expressed as frequency (percentage) and mean ± SD. (−) indicates varus deformity.
ASA, American Society of Anesthesiologists; BMI, body mass index; OA, osteoarthritis; HKA, hip-knee-ankle angle; SD, standard deviation.
[a] *P* value determined by Pearson's *Chi*-square test.
[b] *P* value determined by independent samples *t*-test.
[c] *P* value determined by Fischer's exact test.

leg stance balance test (ability to stand on the surgical side, measured in seconds), calf raises (maximum number performed on the surgical side), and step count (day 1 to 42 after surgery using Garmin Vivofit 4 devices). These tests were performed to assess mobility, function, balance, and strength. Data from the functional assessments were routinely collected as part of the digital rehabilitation program supervised by the authors' institution patient-partner program [16].

Patient-reported knee-specific pain and function was measured using the Oxford Knee Score, Knee Injury and Osteoarthritis Outcome Score (KOOS), and the KOOS for Joint Replacement while health-related quality of life was assessed using the 12-item Short Form Survey (SF-12) physical (PCS) and mental (MCS) component summaries. The Forgotten Joint Score-12 was used as a measure of joint awareness. These PROMs were evaluated preoperatively and at 3, 6, and 12 months postoperatively. To measure patients' overall satisfaction with surgery, a four-point Likert scale was used, with response categories consisting of very satisfied (100 points), somewhat satisfied (75 points), somewhat dissatisfied (50 points), and very dissatisfied (25 points) [17].

Data Analyses

Sample size was calculated a priori using G*Power (Germany, version 3.1.9.6). Considering 5% marginal error, 80% power of study, and medium effect size, 51 subjects were needed in each group to detect a difference in the mean of outcome variables. Descriptive data were expressed as means ± standard deviations, while categorical data were expressed as frequency and percentage. The Kolmogorov-Smirnov and Shapiro-Wilk tests were conducted to test and confirm normality. To compare between groups, independent *t*-tests and Pearson's *Chi*-square tests were used. All statistical analyses were performed using *R* statistical software (version 4.2.3, R Foundation, Vienna, Austria) and a *P* value of < 0.05 was considered to be statistically significant.

Results

Patient demographics and preoperative clinical details are summarized in Table 1. Navigation time was significantly shorter in the RAS group compared to the CAS group with a mean difference of 15.4 minutes ($P < 0.001$, Table 2). There were two complications that were encountered in the CAS group: one case of patellar clunk requiring arthroscopic debridement and one case of acute prosthetic joint infection, which was treated with debridement, polyethylene exchange, and implant retention. There were no differences in complication rates as well as length of stay ($P = 0.43$ and 0.50, respectively). There were also no other readmissions, transfusions, technical failures, or aborted procedures in either group.

Preoperatively, patient function was similar in both groups, except for calf raises, where the mean number performed in the RAS group was significantly less than those in the CAS group ($P <$ 0.001, Table 3). This difference was also observed at 6 weeks after surgery ($P < 0.001$), but improvement in the ability to perform calf raises was similar between both RAS and CAS groups ($P = 0.22$). Although functional parameters such as postoperative knee extension, postoperative−preoperative differences in the sit-to-stand and timed up-and-go tests were significantly different between groups ($P = 0.009$, $P = 0.03$, and $P = 0.02$, respectively), these differences were small. An upward trend in the mean step count was observed in both groups as time passed following surgery (Figure 1). Both groups showed similar ability in performing single-leg stance on the surgical side preoperatively ($P = 0.14$) and postoperatively ($P = 0.58$) (Figure 2).

All patients reported improvement in knee pain and function, and this is reflected in the higher scores for Oxford Knee Score (Figure 3), KOOS for Joint Replacement, KOOS and its pain, symptoms, activities of daily living, and quality of life domains, as well as SF-12 PCS postoperatively (Table 4). There were no significant differences between the CAS and RAS groups for these PROMs except for SF-12 PCS at 3 and 6 months. In addition, joint awareness (Forgotten Joint Score-12) was similar between both groups at 12 months postoperatively ($P = 0.83$). Before surgery and at 3 and 12 months after surgery, patients in the CAS group had a higher SF-12 MCS score compared to the RAS group ($P = 0.005$, 0.04, and 0.01, respectively). The vast majority of patients were satisfied at 1 year after surgery, with 97.1 and 93.0% reporting "very satisfied" in the

Table 2
Comparison of Navigation Time, Length of Stay, and Complications Between Groups.

Variables	Overall	Navigation	Robotic-Assisted	P value	Mean Difference (95% CI)
Navigation time (minutes)	23.9 ± 7.9	37.3 ± 4.1	21.9 ± 6.1	***<0.001***[a]	15.4 (11.7 to 19.2)
Length of stay (days)	4.62 ± 1.67	4.73 ± 1.57	4.52 ± 1.77	0.43[a]	0.2 (−0.3 to 0.8)
Complications				0.50[b]	
Yes	2 (1.3)	2 (2.5)	0 (0.0)		
No	156 (98.7)	77 (97.5)	79 (100.0)		

Values are expressed as mean ± SD and frequency (percentage).
CI, confidence interval.
[a] *P* value determined by independent samples *t*-test.
[b] *P* value determined by Fischer's exact test.

Table 3
Preoperative and Postoperative Functional Assessment.

Variables	Overall	Navigation	Robotic-Assisted	*P* value	Mean Difference (95% CI)
Preoperative					
ROM (°)					
Extension	5.3 ± 4.5	5.7 ± 4.6	4.9 ± 4.4	0.26[a]	0.8 (−0.6 to 2.3)
Flexion	116.0 ± 18.5	114.67 ± 21.7	117.4 ± 14.3	0.37[a]	−2.7 (−8.7 to 3.3)
Sit to stand	9.5 ± 5.7	9.6 ± 5.4	9.4 ± 5.9	0.91[a]	−1.6 (−5.3 to 2.2)
Timed up and go (s)	8.6 ± 3.8	8.7 ± 3.4	8.6 ± 4.2	0.91[a]	0.1 (−1.2 to 1.3)
Calf raises	13.5 ± 5.0	15.5 ± 5.3	11.5 ± 3.7	***<0.001*[a]**	3.7 (2.2 to 5.4)
6-week assessment					
ROM (°)					
Extension	1.8 ± 2.0	1.4 ± 2.1	2.4 ± 1.7	***0.009*[a]**	−1.0 (−1.8 to −0.3)
Flexion	117.6 ± 9.2	118.5 ± 8.9	116.4 ± 9.4	0.28[a]	2.1 (−1.4 to 5.5)
Sit to stand	10.7 ± 5.4	11.2 ± 5.4	10.2 ± 5.5	0.39[a]	1.0 (−1.3 to 3.2)
Timed up and go (seconds)	7.4 ± 1.8	7.3 ± 1.8	7.4 ± 1.8	0.43[a]	−0.5 (−1.6 to 0.7)
Calf raises	16.7 ± 5.8	19.5 ± 5.6	13.4 ± 4.2	***<0.001*[b]**	6.1 (4.1 to 8.2)
Δ					
ROM (°)					
Extension	−2.5 ± 4.6	−3.1 ± 4.2	−1.9 ± 5.1	0.26[a]	−1.1 (−3.1 to 0.9)
Flexion	0.8 ± 21.8	4.1 ± 26.0	−2.9 ± 14.8	0.11[a]	7.0 (−1.8 to 15.8)
Sit to stand	0.0 ± 4.6	1.0 ± 4.0	−1.2 ± 5.0	***0.03*[a]**	2.2 (0.3 to 4.1)
Timed up and go (seconds)	−0.8 ± 1.8	−1.2 ± 1.8	−0.3 ± 1.7	***0.02*[a]**	−0.9 (−1.6 to −0.1)
Calf raises	3.0 ± 4.4	3.6 ± 4.6	2.4 ± 4.2	0.22[a]	1.2 (−0.7 to 3.1)

Values are expressed as mean ± SD and frequency (percentage).
P value < 0.05 considered to be statistically significant.
Δ: Postoperative−preoperative.
CI, confidence interval; ROM, range of motion.
[a] *P* value determined by independent samples *t*-test.

CAS and RAS groups, respectively (Figure 4). This difference was not statistically significant ($P = 0.21$).

Discussion

The most important finding of this study was that the use of RAS showed equivalent early functional and patient-reported outcomes as CAS, with the systems used in our study. Although RAS did not demonstrate superior clinical and functional outcomes over CAS as per our hypothesis, both groups of patients improved significantly and were highly satisfied. The PROMs and functional outcomes of both groups were at a high level and as good as or better than the PROMs reported with the same prosthesis in other studies [18–20]. The outcome measures may not have been sensitive enough to detect a difference between RAS and CAS due to ceiling effects of the PROMs [21]. The differences observed between those who underwent CAS and those who underwent RAS were very small and not clinically meaningful, such as in knee extension at 6 weeks postoperatively, and the postoperative−preoperative difference in sit-to-stand and timed up-and-go tests. Differences observed in other clinical parameters, such as calf raises and the SF-12 MCS scores, could be attributed to the difference in preoperative baseline values. Nevertheless, use of RAS did result in a significantly shorter navigation time compared to CAS. This was most likely because in the RAS group, navigating the cutting block into position, a time-consuming process, was not required. The robotic system positioned and maintained an oscillating saw for the surgeon to perform bony resections according to a predetermined plane. Additionally, we observed that the femoral, tibial, and instrument trackers were much less sensitive to soiling with blood, and rarely was the workflow interrupted with RAS to clean the trackers. This is due to the proprietary design of the retroreflective spherical Radix lens used in the optical reflectors, which enables it to continue tracking even when heavily contaminated.

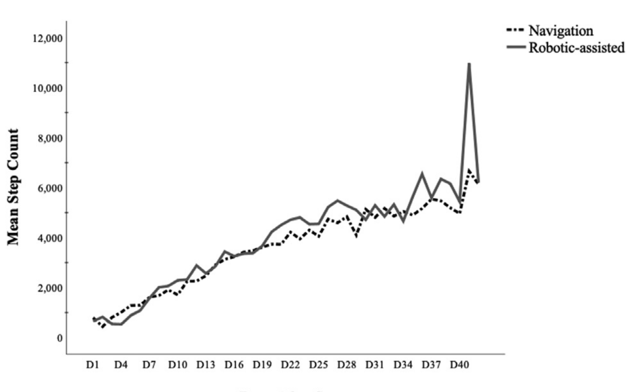

Fig. 1. Mean step count after surgery comparing between navigated and robotic-assisted total knee arthroplasty.

A balanced knee, as well as optimal component alignment and rotation, have all been implicated as factors determining implant survival and patient satisfaction after TKA [22–25]. The main advantage of modern computer navigation and robotic systems is the ability to perform real-time intraoperative assessments of alignment, gap balance, and implant positioning. These are achieved by means of digital mapping based on standard anatomical landmarks and kinematic analysis. Although CAS is a reliable method to reduce alignment outliers, errors can still occur during the process of making the bone cuts, leading to component malposition. This limitation had led to the development of RAS, which facilitates the preparation of bony surfaces with the aid of a robotic arm, aiming to increase accuracy and reduce outliers while achieving better clinical outcomes.

To date, most studies investigating RAS have made comparisons with mechanical alignment instruments. Published data have shown that both CAS and RAS are successful in improving alignment and patient outcomes when compared to conventional instrumentation [12,14,26–29]. However, this may not be a true

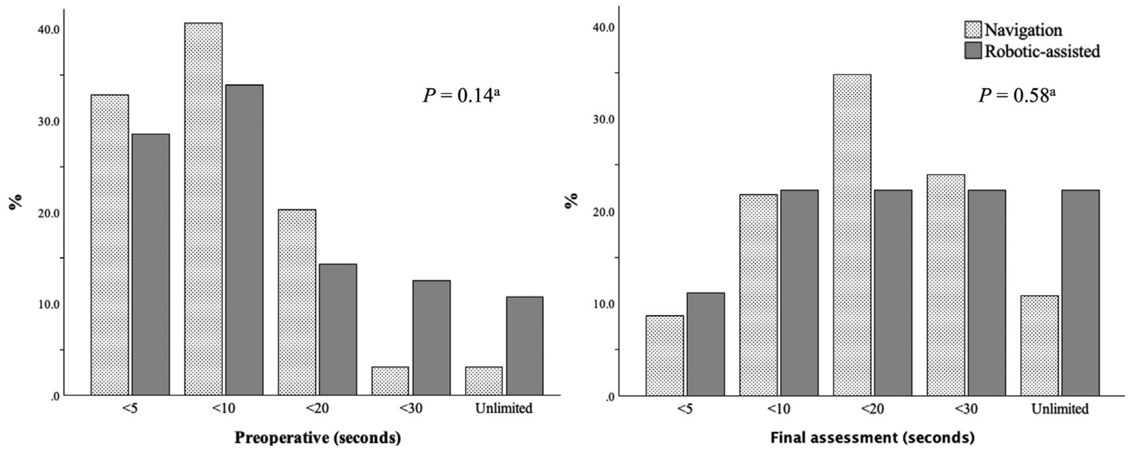

Fig. 2. Bar chart illustrating preoperative and postoperative assessment of single leg stance (seconds) on the surgical side. [a]P value determined by Fischer's exact test.

comparison, as mechanical alignment guides aim for neutral coronal alignment and fixed sagittal and rotational targets while CAS and RAS both provide information that permits alternative and functional alignment plans to be executed with precision. In addition, patient-specific alignment is accepted as a more contemporary strategy that improves patients' outcomes and PROMs.

There is little to no evidence at present as to whether RAS confers an advantage over CAS in TKA. A recent machine learning–augmented systematic review that investigated clinical outcomes associated with CAS and RAS concluded that both were associated with comparable positive outcomes, but there was a notable gap in the literature with regards to clinical studies designed for direct comparison between the two [30]. A search of the literature revealed only three comparisons of this nature. The first was a retrospective review by Clark et al. [9], which examined the efficiency and accuracy of RAS compared to CAS. The authors had found that the use of RAS was associated with shorter navigation time, decreased final malalignment, and shorter hospitalization length than when CAS was used. However, function and PROMs were not assessed. The second was an analysis by Lee et al. [13] comparing long-term clinical and radiological outcomes among robotic-assisted, navigated, and conventional TKA, which showed that there was no difference in these outcomes as well as survival and complication rates, except for the proportion of

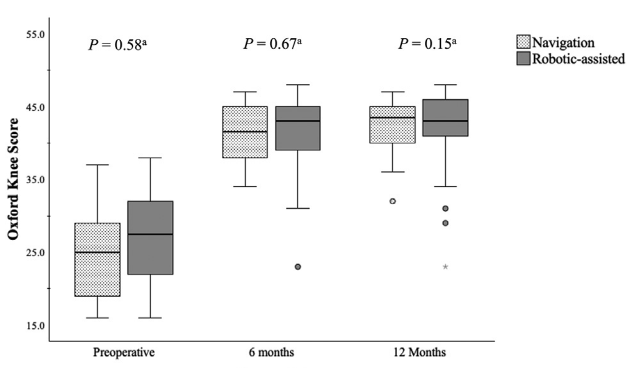

Fig. 3. Boxplot showing Oxford Knee Scores preoperatively and at 6 and 12 months after surgery in navigated versus robotic-assisted TKA. TKA, total knee arthroplasty. [a]P value determined by independent samples t-test.

outliers in postoperative HKA angle between the three groups. These two studies were performed using older navigation and first-generation robotic systems, which are inferior to current systems in optical tracking, gap balancing, soft tissue care, and versatility. In addition, the prostheses utilized were different between groups. The third study was an early outcome comparative study of a small cohort using similar RAS and CAS systems as the present study, which reported neutral surgical times and marginally better pain and knee function with RAS compared to CAS [31].

There are several potential limitations with the current study. This was a retrospective analysis with a relatively small sample size. However, propensity score-matching was performed to minimize selection bias, and an *a priori* power analysis was performed to ensure that this study was sufficiently powered to detect a statistically significant difference in the mean of outcome variables. Gap balance and surgical precision, including accuracy of bone cuts and implant alignment, were not assessed in this review, as they were not objectives of this investigation. Nevertheless, a previous cadaver study had demonstrated that the same robotic system used in this study can improve alignment accuracy and reduce outliers [32]. When evaluating operative time, only navigation times were compared, while other factors such as exposure, cementing, and closure were not considered. As all surgeries were performed by the same surgeon and patients were propensity-matched based on covariates such as BMI and degree of deformity, it is reasonable to presume that the time taken for those other steps would be uniform between groups. Furthermore, navigation times captured digitally by both systems were more reliable than skin-to-skin operative times recorded manually. Set-up time was also not included in this retrospective study as it was not routinely documented in the authors' institution, and thus data were not available for comparison. Although the robotic arm required additional draping and mounting time, there were considerably fewer trays to open and count. Other operating time parameters, such as wheel-in and wheel-out time, are dependent on various factors, such as operating room personnel efficiency and time required to anesthetize the patient, which can vary depending on who is on duty. Therefore, this parameter may not be a useful comparison. In addition, while not explored in this study, there are simpler and cheaper navigation system alternatives that may equal the clinical performance of the two systems compared here. Also, cost analysis, long-term clinical outcomes, and implant survivorship were not addressed in this study. Despite demonstrating comparable early clinical outcomes, a similar result long-term is unknown in modern robotic systems.

Table 4
Preoperative and Postoperative Patient-Reported Outcome Measures.

Variables	Overall	Navigation	Robotic-Assisted	*P* value	Mean Difference (95% CI)
Preoperative					
KOOS-JR	51.3 ± 10.0	51.6 ± 9.1	50.9 ± 10.9	0.65[a]	0.7 (−2.5 to 3.9)
KOOS	56.7 ± 11.0	56.9 ± 10.5	56.6 ± 11.5	0.87[a]	0.8 (−2.4 to 3.9)
Pain	48.1 ± 13.3	48.8 ± 13.6	47.4 ± 13.1	0.49[a]	1.5 (−2.8 to 5.7)
Symptoms	47.4 ± 18.7	48.1 ± 19.1	46.8 ± 18.5	0.67[a]	1.3 (−4.7 to 7.3)
Activities of Daily Living	56.8 ± 15.4	56.8 ± 14.7	56.7 ± 16.2	0.96[a]	0.1 (−4.8 to 5.0)
Quality of Life	26.6 ± 17.0	26.0 ± 17.2	27.2 ± 16.9	0.67[a]	−1.2 (−6.6 to 4.3)
SF-12					
PCS	30.8 ± 7.3	30.0 ± 7.6	31.6 ± 6.9	0.19[a]	−1.5 (−3.8 to 0.8)
MCS	57.5 ± 9.9	59.7 ± 8.4	55.2 ± 10.8	***0.005***[a]	4.5 (1.4 to 7.6)
Postoperative 3 mo					
KOOS-JR	72.2 ± 10.6	73.1 ± 9.6	71.6 ± 11.3	0.53[a]	1.5 (−3.1 to 6.0)
KOOS	74.7 ± 10.7	76.0 ± 10.7	74.0 ± 10.7	0.46[a]	2.0 (−3.3 to 7.2)
Pain	76.6 ± 14.1	78.4 ± 14.5	75.3 ± 13.7	0.32[a]	3.1 (−3.0 to 9.1)
Symptoms	71.4 ± 14.7	72.3 ± 17.7	70.8 ± 12.3	0.66[a]	1.5 (−5.3 to 8.2)
Activities of Daily Living	84.0 ± 11.8	85.9 ± 10.6	82.7 ± 12.6	0.19[a]	3.3 (−1.6 to 8.2)
Quality of Life	60.9 ± 20.4	62.7 ± 19.1	59.6 ± 21.3	0.48[a]	3.1 (−5.5 to 11.6)
SF-12					
PCS	39.8 ± 6.7	42.1 ± 5.4	38.1 ± 7.0	***0.003***[a]	4.0 (1.4 to 6.7)
MCS	56.1 ± 10.2	58.7 ± 8.3	54.3 ± 11.1	***0.04***[a]	4.4 (0.3 to 8.5)
Postoperative 6 months					
KOOS-JR	76.0 ± 13.0	76.3 ± 13.5	75.6 ± 12.5	0.76[a]	0.8 (−4.3 to 5.8)
KOOS	75.8 ± 14.6	77.0 ± 14.8	74.7 ± 14.5	0.46[a]	2.3 (−3.8 to 8.3)
Pain	82.8 ± 13.5	83.8 ± 12.9	81.5 ± 14.2	0.38[a]	2.3 (−2.9 to 7.5)
Symptoms	76.8 ± 13.5	78.0 ± 14.7	75.4 ± 11.8	0.31[a]	2.7 (−2.5 to 7.8)
Activities of Daily Living	87.7 ± 10.9	88.3 ± 11.1	87.0 ± 10.7	0.55[a]	1.3 (−2.9 to 5.5)
Quality of Life	67.6 ± 21.8	69.6 ± 21.4	65.2 ± 22.4	0.30[a]	4.4 (−3.9 to 12.8)
SF-12					
PCS	41.3 ± 7.3	42.8 ± 6.7	39.5 ± 7.6	***0.02***[a]	1.5 (0.0 to 6.1)
MCS	58.0 ± 9.3	59.3 ± 8.3	56.5 ± 10.1	0.12[a]	4.4 (0.3 to 8.5)
Postoperative 12 months					
KOOS-JR	82.6 ± 13.6	84.4 ± 13.0	80.1 ± 14.1	0.09[a]	4.3 (−0.6 to 9.2)
KOOS	81.5 ± 13.2	82.8 ± 11.7	79.9 ± 14.6	0.24[a]	2.9 (−2.1 to 7.8)
Pain	88.4 ± 12.8	89.9 ± 10.5	86.3 ± 15.3	0.13[a]	3.6 (−1.0 to 8.2)
Symptoms	84.0 ± 11.9	85.3 ± 11.4	82.2 ± 12.5	0.16[a]	3.0 (−1.3 to 7.3)
Activities of Daily Living	90.4 ± 10.6	91.5 ± 9.4	89.0 ± 11.9	0.20[a]	2.5 (−1.4 to 6.3)
Quality of Life	74.3 ± 21.1	75.1 ± 19.9	73.3 ± 22.8	0.65[a]	1.8 (−5.9 to 9.4)
SF-12					
PCS	41.8 ± 7.0	42.1 ± 6.8	41.3 ± 7.2	0.57[a]	0.7 (−1.8 to 3.3)
MCS	58.6 ± 7.9	60.2 ± 6.4	56.4 ± 9.2	***0.01***[a]	3.9 (1.1 to 6.7)
FJS-12	52.5 ± 28.7	54.1 ± 30.0	51.6 ± 28.2	0.83[a]	2.5 (−11.1 to 16.1)

Values are expressed as mean ± SD and frequency (percentage).
P value < 0.05 considered to be statistically significant.
CI, confidence interval; KOOS, Knee Injury and Osteoarthritis Outcome score; JR, joint replacement; SF-12, 12-Item Short Form Survey; PCS, physical component summary; MCS, mental component summary; FJS, Forgotten Joint Score-12.
[a] *P* value determined by independent samples *t*-test.

Understandably, long-term data do not exist yet, as this robotic system was only recently introduced. However, these are important parameters that need to be evaluated in the future.

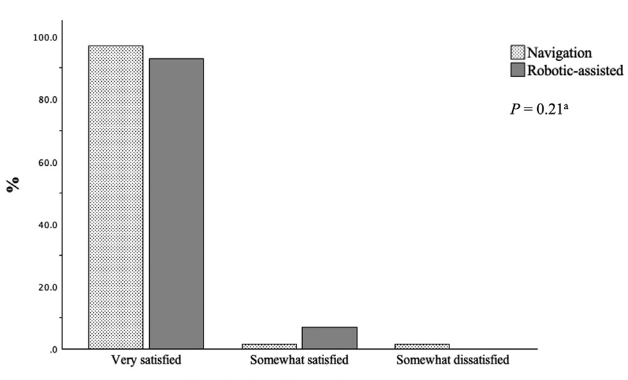

Fig. 4. Bar chart depicting patient satisfaction at 1 year after surgery in navigated versus robotic-assisted total knee arthroplasty. [a]*P* value determined by Fischer's exact test.

The strength of this study is that it is a single-surgeon series in which the same surgical workflow, alignment philosophy, implant design, and rehabilitation protocol were used in two systematically matched treatment groups, enabling a true comparison of the execution tool. In addition, to the best of the authors' knowledge, this is the first robust study in the literature to compare a modern robotic system with computer navigation. Furthermore, the findings from this review also suggest that for a high-volume arthroplasty surgeon, transitioning from CAS to this modern robotic system was seamless, and does in fact, allow a more efficient surgical workflow. Although comparable early clinical benefits were perceived by the study population in this analysis, RAS is still advantageous for both patient and surgeon.

Conclusions

The use of RAS resulted in shorter navigation time compared to CAS in TKA. Similar satisfactory improvements were observed in early clinical outcomes between patients who underwent RAS and CAS.

CRediT authorship contribution statement

Jade P.Y. Ho: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Ishaan Jagota:** Writing – review & editing, Software, Methodology, Investigation, Formal analysis, Data curation. **Joshua G. Twiggs:** Supervision, Resources, Project administration, Formal analysis, Data curation, Conceptualization. **David W.H. Liu:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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