

ROSA® Knee System

2026 Clinical Evidence

Summary

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Introduction

A report from the Agency for Healthcare Research and Quality has demonstrated that knee arthroplasty is one of the most frequent procedures in the operating room¹. The success of total knee arthroplasty (TKA) is well-established, and the most recent Australian and UK registry reports demonstrate 10- and 15-year cumulative percent revision (CPR) rates of 4.7% - 6.3% and 3.82% – 5.49%, respectively, for primary total knee arthroplasty (TKA) associated with osteoarthritis.^{2,3}

Despite its success, TKA continues to experience revisions related to aseptic failures, with loosening and instability the predominant reasons^{4,5}. Technological advances have sought to address these shortcomings; however, the value of such technologies remains controversial, stemming primarily from a lack of long-term outcomes and survivorship data.^{6,7} Kort et al. noted that while robotic-assisted TKA offers improved component positioning, evidence of improvements in clinical outcomes, patient satisfaction, and implant survivorship remains lacking.⁷ A recent umbrella review of 15 systematic reviews and meta-analyses similarly demonstrated advantages in surgical accuracy, precision, and alignment correction, yet conferred limited functional benefit over conventional TKA.⁸ Emerging large-scale database analyses offer encouragement: Guo and colleagues, analyzing over 17,000 cases from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database, reported that patients who underwent robotic-assisted TKA experienced better early post-operative functional status and fewer complications compared to conventional TKA, suggesting that robotic-assisted TKA leads to better joint function, mobility, and recovery.⁹ Nevertheless, large-scale randomized controlled trials with standardized protocols and more sensitive functional assessments are needed to determine whether alignment advantages translate

into meaningful long-term clinical and survivorship benefits.

A valuable source of real-world data in orthopedics has been the use of well-established registries.^{10,11} Graves noted the value of registries is their unique ability to provide comparative data.¹⁰ Additionally, data from registries have been shown to stipulate change in some orthopedic practices. Reviewing the 2025 Annual Report of the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), the data suggests that robotic knee arthroplasty is reducing the CPR rates of primary TKA at three to five years post-operatively.^{2,12} The registry reports CPR rates of robotically assisted TKA at 1.9% (95% CI, 1.8%, 2.0%) compared to 2.2% (95% CI, 2.1%, 2.3%) for non-technology-assisted at three-years follow-up. At five-years, the difference in CPR rates between robotic-assisted and non-technology-assisted were 2.3% (95% CI, 2.1%, 2.4%) versus 2.9% (95% CI, 2.8%, 3.0%), respectively (see AOANJRR 2025 Annual Report Table KT73). Although these differences were no longer significant after adjusting for covariates, there were differences in revisions between robotic and non-technology-assisted for aseptic causes of loosening and instability (see AOANJRR 2024 Annual Report Figure KT67).^{2,12}

The ROSA® Knee System is a semi-autonomous Robotic Arm that assists in the placement of the cutting jig along with providing ligament laxity assessments throughout the primary TKA workflow. It can be used with image-based or imageless modes.¹³ The primary purpose of this review was to identify and summarize the literature associated with the ROSA Knee System in relation to accuracy, efficiencies, and outcomes.

Accuracy

There has been a plethora of publications on the ROSA Knee System supporting improved accuracy and precision compared to conventional instrumentation (Tables 1-2).¹⁴⁻²⁵ In vivo studies^{19,21,23-28} have supported the initial findings of cadaveric studies^{17,29}, Winger et al.³⁰ demonstrated fewer outliers and improved accuracy over manual instrumentation in patients with severe pre-operative valgus deformities. Rossi et al.³¹

reported reliable and accurate radiographic outcomes in patients with either severe varus or valgus deformities. In addition to the comparative studies, several other publications support the system being accurate and precise (Tables 1-2)^{26,27,32-37} with no discernable learning curve regarding accuracy reported by Bolam et al.³⁸, Petrillo et al.³⁶, and Thongpulswad et al.³⁹

Table 1. The ROSA Knee System is more accurate and precise in achieving the planned coronal plane alignment (Hip-Knee-Ankle Angle) than conventional TKA.

	% Outside of target				Deviation from target, mean ± SD		
	Target	Robotic	Conventional	P value	Robotic	Conventional	P value
Schrednitzki ¹⁶	± 3°	0/71 (0%)	75/308 (24.3%)	<0.001	1.01° ± 0.08°	2.05° ± 0.11°	<0.001
Hasegawa ²⁶	± 3°	0/36 (0%)	NA	NA	0.6°	NA	NA
Shin ³³	± 3°	4/37 (11%)	NA	NA	NA	NA	NA
Parratte ¹⁵	± 5°	4 (10%)	8 (20%)	>0.05	NA	NA	NA
Vanlommel ¹⁸	± 3°	3/58 (5.2%)	19/79 (24.1%)	0.003	NA	NA	NA
Rossi ²⁷	± 3°	NA	NA	NA	1.2° ± 1.1°	NA	NA
Batailler ¹⁴	± 5°	2/40 (5%)	12/40 (30%)	0.003	NA	NA	NA
Seidenstein ¹⁷	± 3°	0/14 (0%)	5/20 (25%)	NA	0.8° ± 0.6°	2.0° ± 1.6°	0.004
Parratte ²⁹	± 3°	0/30 (0%)	NA	NA	-0.03° ± 0.87°	NA	NA
Mancino ⁴⁰	± 1°	41/86 (47.4%)	70/86 (81.4%)	<0.05	1.3° ± 1.3°	1.9° ± 1.2°	<0.001
Winger ³⁰	± 2°	44/103 (42.7%)	48/103 (46.6%)	>0.05	2.2° ± 0.39°	2.25° ± 0.35°	>0.05
Rajgopal ²¹	± 3°	0/135 (0%)	5/135 (3.7%)	0.024	NA	NA	NA
Nogalo ²²	± 3°	4/30 (13.3%)	14/67 (20.9%)	>0.05	NA	NA	NA
Azmi ⁴¹	<175°	4 (8.9%)	NA	NA	NA	NA	NA
Katsaras ²⁵	± 3°	18/91 (19.8%)	25/91 (27.5%)	0.22	1.55° [CI 0.99–2.11]	2.16° [CI 1.63–2.69]	0.006
Möller ²⁴	± 3°	7/39 (17.9%)	15/39 (38.5%)	0.047	2 ± 2°	3 ± 3.5°	0.067
Narkbunnam ⁴² (imageless)	± 3°	6/47 (87.2%)	NA	NA	2.0 ± 1.4°	NA	NA
Narkbunnam ⁴² (image-based)	± 3°	5/48 (89.6%)	NA	NA	1.7 ± 1.3°	NA	NA
Claudel ⁴³	NA	NA	NA	NA	2.1 ± 1.8°	NA	NA

* Katsaras et al. planned robotic HKAs to be within 5° of constitutional varus HKA, rather than neutral HKA, but defined outliers as ±3° of neutral, confounding the HKA outlier comparison.

An important aspect of all robotic systems is the ability to accurately register the landmarks and conduct a dynamic assessment. Charette et al. reported that the ROSA Knee System had excellent inter- and intra-rater reliability for both activities, and the reliability was consistent whether or not image-based planning was used⁴⁴. In this cadaveric study, they also reported no difference in the ability of a resident, an arthroplasty fellow, or a fellowship-trained arthroplasty surgeon to

accurately perform the registration of landmarks and evaluate the soft tissue laxity. Consistent with this, Narkbunnam et al.⁴² showed in a randomized controlled trial that imageless and image-based ROSA workflows achieved equivalent radiographic accuracy and similar short-term clinical outcomes, suggesting that workflow choice may be based on practical considerations rather than accuracy concerns. The ROSA Knee System also improves the accuracy of low-volume surgeons. Byrne

et al.¹⁹ recently reported fewer coronal tibial outliers and cases of notching compared to conventional instrumentation by a non-orthopedic trained, low-volume surgeon.

Four studies have directly compared the ROSA Knee System to other commercially available robotic-assisted TKA systems. Hasegawa et al.³⁵ reported no differences in mean absolute errors (planned vs. post-operative radiographically measured) between Navio™ (Smith & Nephew, Memphis, TN, USA) and the ROSA Knee System for coronal femoral and tibial angles nor sagittal femoral and tibial angles. Rajgor et al.⁴⁵ reported no differences between MAKO® total knee robotic arm-assisted surgery (Stryker, Kalamazoo, Michigan, USA) and the ROSA Knee System for restoration of joint line height, tibial slope, patella height, or posterior condylar offset. Similarly, Zhou et al.⁴⁶ demonstrated no differences in mean absolute error and percentage of outliers (>3°) between MAKO and the ROSA Knee System for coronal femoral and tibial angles nor sagittal femoral and tibial angles. Finally, Aflatooni et al.⁴⁷ reported no significant differences in the mean absolute difference of the sagittal femoral and tibial angles between the ROSA Knee System and MAKO.

ROSA Knee has been increasingly used to facilitate functional and personalized alignment strategies in TKA. The strongest direct evidence comes from studies of anatomic-functional and functional alignment, in which ROSA Knee-assisted workflows were shown to restore native or near-native alignment characteristics,

preserve joint line obliquity, optimize ligament balance, and maintain satisfactory patellar tracking.^{41,43,48-53} Azmi et al. reported that personalized robotic-assisted TKA using anatomic-functional implant positioning restored native knee alignment and reproduced physiological asymmetric flexion laxity.⁴¹ Claudel et al. similarly showed that robotic anatomic-functional alignment accurately resurfaced the distal femur, preserved joint line orientation in most cases, and restored functionally appropriate ligament tension.⁴³ Additional support for a functional alignment philosophy comes from Eu et al., who demonstrated feasibility in knees with extra-articular deformity⁵¹, and from Sangaletti et al., who reported that, compared with robotic mechanical alignment, robotic functional alignment better preserved native CPAK characteristics and produced smaller downstream changes in ankle alignment.⁵³ Beyond these direct radiographic studies, several papers support ROSA Knee as a practical platform for implementing personalized alignment by providing reliable intra-operative data and reproducible balancing tools.⁵⁴⁻⁵⁷ Kenanidis et al.⁵⁵ showed that ROSA Knee could characterize knee laxity patterns intra-operatively, Everaert et al.⁵⁴ demonstrated good-to-excellent reproducibility of soft-tissue and gap measurements across operators, and Qordja et al.⁵⁷ highlighted the importance of dynamic rather than purely static alignment assessment. Together, these findings suggest that ROSA Knee may provide benefits beyond component placement accuracy by supporting surgeons who adopt functional, personalized, or anatomic-functional alignment approaches.

Table 2. The ROSA Knee System is accurate and precise in achieving the planned tibial and femoral angles. Absolute Mean Errors from planned angles ± Standard Deviations (% > ± 3°), unless otherwise indicated.

	Comparison Type	Coronal Angles		Sagittal Angles	
		Femur	Tibia	Femur	Tibia
Hasegawa ²⁶	Post-Operative CT Scans	0.80° ± 0.67° (0%)	1.14° ± 0.77° (0%)	2.18° ± 1.19° (16%)	1.05° ± 0.96° (3%)
Hasegawa ²⁶	Post-Operative Radiographs	0.46° ± 0.70° (0%)	0.46° ± 0.57° (0%)	1.28° ± 0.81° (0%)	0.83° ± 0.56° (0%)
Shin ³³	Post-Operative Radiographs	0.88° ± 0.71° (0%)	1.24° ± 1.06° (8%)	1.93° ± 1.03° (17%)*	2.04° ± 1.55° (26%)*
Parratte ¹⁵	Post-Operative Radiographs	(2.5%)	(2.5%)	NA	(0%)
Vanlommel ¹⁸	Intra-operative Validation	0.32° ± 0.25°	0.46° ± 0.32°	0.40° ± 0.34°	0.89° ± 0.74°
Rossi ²⁷	Intra-operative Validation	0.5° ± 0.6°	0.7° ± 0.9°	0.8° ± 0.8°	0.5° ± 0.6°
Rossi ²⁷	Post-Operative Radiographs	0.6° ± 0.5°	0.3° ± 1.8°	0.1° ± 1.2°	0.03° ± 1.9°
Seidenstein ¹⁷	Intra-operative Validation	0.5° ± 0.4° (0%)	0.6° ± 0.4° (0%)	1.3° ± 1.0° (7.1%)	0.6° ± 0.4° (0%)
Parratte ^{29F}	Intra-operative Validation	0.03° ± 0.51° (0%)	-0.6° ± 0.69° (0%)	-0.95° ± 0.9° (3%)	0.2° ± 0.84° (0%)

Mancino ⁴⁰	Post-Operative Radiographs	1.3° ± 0.9°	0.8° ± 0.5°	0.9° ± 0.8°	0.9° ± 0.7°
Winninger ³⁰	Post-Operative Radiographs	NA	1.78° ± 0.26°	NA	NA
Byrne ¹⁹	Post-Operative Radiographs	NA	(10.1%)	NA	(0%, >5°)
Hasegawa ³⁵	Post-Operative Radiographs	0.47° ± 0.65°	0.59° ± 1.35°	1.11° ± 0.75°	0.90° ± 0.59°
Hax ²⁰	Post-Operative Radiographs	(0%)	(22%)	(2%)	(15%)
Nogalo ²²	Post-Operative Radiographs	(0%)	(0%)	NA	NA
Thongpulsawad ³⁹	Intra-Operative Validation	0.1° ± 0.6	0.2° ± 0.7°	0.4° ± 2.4°	0.2° ± 0.7°
Zaidi ⁴⁶	Post-Operative Radiographs	0.61° ± 0.97°	0.61° ± 1.26°	1.87° ± 1.11°	0.75° ± 1.34°
Zaidi ³⁷	Post-Operative Radiographs	1.62° ± 1.11°	1.44° ± 1.03°	1.39° ± 1.05°	0.99° ± 0.72°
Zhou ⁴⁶	Post-Operative Radiographs	1.8° ± 1.7° (25%)	1.3° ± 1.1° (5%)	NA	1.4° ± 0.9° (10%)
Aflatooni ⁴⁷	Post-Operative Radiographs	NA	NA	1.8 ± 1.5°	2.4 ± 1.5°
Eggermont ⁵⁸	Post-Operative Radiographs	NA	NA	NA	2.69 ± 2.13°
Narkbunnam ⁴² (imageless)	Post-Operative Radiographs	1.6 ± 1.2°	1.7 ± 1.5°	2.5 ± 1.6°	2.1 ± 1.4°
Narkbunnam ⁴² (image-based)	Post-Operative Radiographs	1.2 ± 1.2°	1.3 ± 1.5°	2.4 ± 1.7°	2.0 ± 1.4°
Petrillo ⁵⁹ †	Post-Operative Radiographs	0.53 ± 1.00°	0.31 ± 1.29°	NA	NA

*Percentages updated per author's response to [Letter to the Editor](#). † reported as actual mean ± Standard deviation

Efficiency

The adoption of robotics in arthroplasty is unique to each surgeon and practice. Some have reported that the decision to incorporate this system came down to their “desire to improve healthcare quality and outcomes and provide value in our practice”.⁶⁰ They report reviewing their data with hopes to support or refute this claim. In describing his personal journey through robotics, Lonner reported his decision to adopt the ROSA Knee System was due to the potential for this system to optimize surgical efficiencies, precision, and improve ergonomics.⁶¹

The surgical workflow has been described in several papers.^{13,29,32,62} Alessi et al. noted the diverse abilities of the system when performing primary TKA and reported that it can be used for either gap balancing or measured resection techniques.³² The robotic system is intended to work alongside the surgeon without excessively sacrificing autonomy.^{13,62} Batailler et al. also noted that, along with measured resection or gap balancing, surgical philosophy for alignment is left to surgeon preference.^{13,63}

Upon adoption of the system, Haffar et al. evaluated the ergonomic effects of the system compared to conventional instrumentation.⁶⁴ Specifically, they evaluated cardiorespiratory and ergonomic data of the operating surgeon in 20

consecutive robotic cases compared to 20 consecutive conventional cases. Ultimately, they reported less surgeon physiological stress, energy expenditure, and postural strain with the robotic system compared to conventional instrumentation.

The ROSA Knee System has also been reported to have a relatively rapid initial learning curve for operative times, with similar complication rates as conventional instrumentation.^{18,36,38,39,65} Polikandriotis and Cafferky described early cases following adoption taking as long as 30 minutes more than conventional.⁶⁰ However, they noted that after 10 robotic-assisted cases, surgical times were consistent with conventional cases, requiring approximately 45-60 minutes. When evaluating the learning curves specifically, multiple studies have reported initial learning curves ranging from 5-30 cases.^{18,36,38,39,66-68}

Of interest to the orthopedic surgeon and healthcare administrators is the ability to achieve time neutrality compared to conventional instrumentation when adopting new technologies. Bolem et al. reported no differences in operative times between robotic and conventional TKA.³⁸ In contrast, other studies have reported increased operative times with robotic-assisted TKA.^{14,18,63} However, Kenanidis et al. demonstrated an equilibrium in operative time between robotic-assisted TKA and conventional TKA occurs after

approximately 70 cases.⁶⁹ Niera et al.⁷⁰ reported no differences in operative times between robotic-assisted and conventional TKA in experienced surgeons during the proficiency phase of the learning curve. Recently, Ejnisman et al.⁷¹ reported robotic-assisted operative times were less than conventional TKA after 30 cases in high-volume surgeons. The reduction in operative time appears to be most driven by improved efficiency in surgical planning and joint balancing,³⁹ which is consistent with Braathen et al.,⁷² who found that the greatest time savings with ROSA Knee occurred in the planning portion of the procedure, whereas the technical execution steps changed comparatively little with experience.

In direct comparison with other robotic systems, the ROSA Knee System was found to have a significantly shorter operative time compared to MAKO total knee (94.8±23.0 vs. 112.7±12.8 min).⁴⁶ Chan et al.⁷³ also reported significantly shorter operative times with ROSA Knee compared to MAKO and Cori/Navio (102±28.1 vs. 112±31.5 vs 119±33.8 min, respectively). However, Kang et al.⁶⁷ reported significantly longer operative times with ROSA Knee, 5.6 min, compared to MAKO. A meta-analysis of these three studies found a weighted mean difference of approximately 6 to 7 minutes favoring ROSA Knee; however, the difference was not statistically significant because of high between study heterogeneity. Further studies are needed to determine if improved efficiency is associated with speed of adoption or related to individual surgeon and center workflows. Additionally, the evaluation of total operating room time between robotic and non-robotic cases is needed.

The ability to use plain radiographs for pre-operative planning, or no imaging at all, removes the patient, administrative, and potentially cost burden, of ordering more advanced imaging. Image-based cases are accomplished with the use of the X-Atlas[®] 2D to 3D Technology (Zimmer CAS, Montreal, Quebec, CA). Massé and Ghate described this process and evaluated the accuracy of this system, concluding that the imaging technology can accurately reconstruct a three-dimensional bone model from two-dimensional, pre-operative, orthogonal, long-leg radiographs.⁷⁴ Using this imaging technology, Klag et al. reported improved accuracy of implant

size prediction compared to pre-operative templating on two-dimensional films alone.⁷⁵ Similarly, Duchniewicz et al.⁷⁶ reported exact tibia and femoral component size matches in 83.6% and 70.9% of cases, respectively. Regarding patient safety, the use of plain film radiographs results in less radiation exposure to the patient compared to CT imaging used in other robotic systems.^{77,78} This amount is not negligible, as CT scans of the knee for pre-operative planning have been shown to provide similar radiation doses as approximately 48 chest X-rays.⁷⁹

Outcomes

By the end of 2025, the comparative outcomes evidence base for ROSA Knee has expanded to 17 studies versus conventional TKA. Although these studies are heterogeneous in design and measured endpoints, most (12 of 17) report encouraging results (Table 3). Parratte et al. demonstrated improvements in the Knee Society Knee and Function scores at six months in the robotic group,¹⁵ and Batailler et al. reported improved six-month Knee Society function compared to conventional TKA.¹⁴ At 12-month follow-up, Mancino et al. reported higher post-operative Knee Society Knee and Function Scores in robotic-assisted TKA compared to navigation-assisted TKA without differences in other PROMs evaluated.⁶³ Similarly, Winger et al.³⁰ reported greater three- and six-month National Institutes of Health Patient-Reported Outcomes Measurement Information System (PROMIS) scores in a high-volume surgeon performing robotic-assisted TKA compared to a separate high volume surgeon performing only conventional TKA.

Recently, Clapp et al.⁵⁰ reported that, after adjusting for confounders, robotic-assisted TKA required fewer soft tissue releases and was associated with greater early improvements in KOOS, JR scores and PROMIS pain reduction scores through one-year post-operative compared to conventional TKA. Similarly, El Othmani et al.⁸⁰ reported greater reductions in WOMAC pain at three-months and one-year post-operative, in addition to greater WOMAC function through one-year. When comparing robotic-assisted TKA with automatic femoral rotation planning to conventional TKA, Hohmann et al.⁸¹ reported greater Forgotten Joint Score (FJS) at

two-years post-operative and a significantly greater proportion of patients in the robotic cohort that achieved a PASS score (91.9% vs. 85.2%). Although FJS was not different between robotic-assisted and conventional TKA at five-years post-operative in Sangaletti et al.⁵³, an earlier report by Kenanidis et al.⁸² demonstrated the robotic-assisted TKA group had higher FJS and Oxford Knee scores, less pain, and more patients indicated they would undergo the procedure again at six-months post-operative. These findings provide additional evidence to support accelerated functional recovery with robotic-assisted TKA, as the ceiling effect for the PROMIS and FJS has been reported to be as low as 0.2%⁸³ and 3.9%,⁵³ respectively, compared to 18-22% for the KOOS, JR.⁸⁴

Range of motion (ROM) findings generally favor robotic-assisted TKA, although the magnitude and durability of this benefit appear to vary over time. Mancino et al.⁶³ reported a least-squares

mean difference of 12.39° (95% CI 7.77° to 17.01°; p < 0.0001) in favor of robotic-assisted TKA at one year post-operatively compared with navigated TKA, a difference that exceeds the minimal clinically important difference.⁸⁵ Fary et al.⁸⁶ likewise reported improved early ROM with robotic-assisted TKA compared with conventional instrumentation, including 5.1° greater flexion at one month and an odds ratio of 2.17 for achieving at least 90° of flexion by one month post-operatively. Eggermont et al.⁵⁸ also found greater flexion ROM at one year in robotic-assisted versus conventional TKA, although the difference was smaller, at approximately 3°. In contrast, Hohmann et al.⁸¹ reported no difference in ROM at two years post-operatively. Taken together, these findings suggest that ROM advantages with robotic-assisted TKA may be most pronounced in the early post-operative period and at short-term follow-up, with differences tending to diminish over time and potentially even out by two years.

Table 3. Improved PROMS in ROSA Knee System vs. controls, summarized using mean ± standard deviation unless otherwise indicated.

	Robotic	Conventional	P value
Kenanidis⁸²			
Forgotten Joint Score (6 months)	71.6 ± 8.3	61.9 ± 8.1	<0.001
Oxford Knee Score (3 months)	27.2 ± 3.0	25.9 ± 3.3	0.123
Oxford Knee Score (6 months)	37.8 ± 3.8	34.8 ± 4.0	0.006
Post-operative VAS (3 months)	3.0 ± 2.0	3.5 ± 3.0	0.175
Post-operative VAS* (6 months)	1 ± 2	2 ± 2	0.025
Would undergo operation again?†	30/30	26/30	0.038
Mancino⁶³			
Knee Society Knee Score (12 months)	84.5 ± 10.7	70.4 ± 14	<0.001
Knee Society Functional Score (12 months)	86.4 ± 12.9	70.5 ± 16.9	<0.001
Parratte¹⁵			
Knee Society Function score (6 months)	83.7 ± 15	73.3 ± 15	0.008
Improvement in Knee Society Knee score (6 months)	59.3 ± 11.9	49.3 ± 9.7	0.003
Improvement in Knee Society Function score (12 months)	48 ± 26	29.5 ± 20	0.004
Batailler¹⁴			
Knee Society Function score (6 months)	93.3 ± 7.6	80.7 ± 8.7	<0.001
Kahn⁸⁷			
KOOS JR (4-6 weeks)	63.1 ± 16.9	59.0 ± 15.7	0.035
KOOS JR (6 months)	73.6 ± 16.6	74.3 ± 14.8	0.754
KOOS JR (12 months)	77.8 ± 17.1	74.3 ± 17.9	0.014
Improvement in KOOS JR (4-6 weeks)	19.9 ± 18.7	14.0 ± 16.1	0.020
Improvement in KOOS JR (6 months)	28.7 ± 18.5	27.8 ± 17.6	0.650
Improvement in KOOS JR (12 months)	29.8 ± 19.7	28.2 ± 21.3	0.385
Fary⁸⁶			
Active Flexion ROM [§] (1 month)	106.3 (0.82)	101.2 (0.82)	<0.001
Active Flexion ROM [§] (3 months)	119.9 (0.95)	116.0 (0.82)	0.021

KOOS JR (3 months)	68.9 ± 12.6	70.5 ± 13.2	0.229
KOOS JR (6 months)	74.0 ± 14.1	74.6 ± 13.5	0.673
KOOS JR (12 months)	78.6 ± 13.6	79.5 ± 15.7	0.658
Wininger ^{€ 30}			
KOOS JR (3 months)	67.5 ± 2.5	64.5 ± 3.5	>0.05
KOOS JR (6 months)	67.5 ± 2.5	67.5 ± 2.0	>0.05
PROMIS Physical (3 months)	50 ± 1.8	46.75 ± 1.8	0.016
PROMIS Physical (6 months)	52.3 ± 1.7	47.75 ± 1.3	0.001
Zhang ⁸⁸			
Knee Society Knee Score (6 months, unmatched cohort)	80.9 ± 12.3	83.3 ± 13.8	0.122
Knee Society Knee Score (6 months, matched cohort)	80.9 ± 12.3	85.1 ± 13.7	0.059
Knee Society Function score (6 months, unmatched cohort)	76.3 ± 16.3	67.2 ± 22.9	0.026
Knee Society Function score (6 months, matched cohort)	76.3 ± 16.3	68.2 ± 22.4	0.083
Oxford Knee Score (6 months, unmatched cohort)	19.1 ± 6.7	21.0 ± 7.0	0.083
Oxford Knee Score (6 months, matched cohort)	19.1 ± 6.7	20.1 ± 6.73	0.602
SF36-Physical Component (6 months, unmatched cohort)	46.6 ± 9.09	44.8 ± 10.2	0.389
SF36-Physical Component (6 months, unmatched cohort)	46.6 ± 9.09	46.3 ± 10.1	0.900
Ratti ⁸⁹			
Utility Value (based off WOMAC, 1 year)	0.71 ± 0.11	0.78 ± 0.11	0.001
Utility Value (based off WOMAC, 2 year)	0.78 ± 0.22	0.78 ± 0.19	0.979
Rajgopal ²¹			
Knee Society Knee Score (3 months)	86.7	86.7	>0.05
Knee Society Knee Score (6 months)	89.9	89.9	>0.05
Knee Society Knee Score (12 months)	89.9	89.9	>0.05
Ejnisman ⁷¹			
KOOS-PS* (90 days)	61.4 (13.85)	63 (16.4)	0.282
EQ-5D* (90 day)	0.79 (0.12)	0.79 (0.31)	0.491
EQ-VAS* (90 day)	80 (15)	80 (20)	0.091
Clapp ⁵⁰			
Change in PROMIS Physical Function (2 weeks) ^φ	-0.32 (-1.06, 0.96)	Ref.	0.621
Change in PROMIS Physical Function (6 weeks) ^φ	-0.13 (-1.32, 1.06)	Ref.	0.828
Change in PROMIS Physical Function (1 year) ^φ	1.12 (-0.69, 2.92)	Ref.	0.225
Change in PROMIS Physical Health (2 weeks) ^φ	-0.44 (-1.77, 0.88)	Ref.	0.512
Change in PROMIS Physical Health (6 weeks) ^φ	0.76 (-0.48, 1.99)	Ref.	0.230
Change in PROMIS Physical Health (1 year) ^φ	1.26 (-0.89, 3.41)	Ref.	0.251
Change in KOOS JR (2 weeks) ^φ	2.06 (-1.02, 5.14)	Ref.	0.190
Change in KOOS JR (6 weeks) ^φ	3.05 (0.19, 5.91)	Ref.	0.036
Change in KOOS JR (1 year) ^φ	3.43 (-1.69, 8.55)	Ref.	0.190
Change in PROMIS Pain Interference (2 weeks) ^φ	-0.67 (-5.20, 3.84)	Ref.	0.770
Change in PROMIS Pain Interference (6 weeks) ^φ	-4.47 (-8.70, -0.25)	Ref.	0.038
Change in PROMIS Pain Interference (1 year) ^φ	-9.26 (-3.70, -16.51)	Ref.	0.012
Change in PROMIS Mental Health (2 weeks) ^φ	-0.55 (-1.95, 0.85)	Ref.	0.441
Change in PROMIS Mental Health (6 weeks) ^φ	1.28 (-0.02, 2.58)	Ref.	0.054
Change in PROMIS Mental Health (1 year) ^φ	0.84 (-1.44, 3.12)	Ref.	0.471
Eggermont ⁵⁸			
Flexion ROM (3 months)	106.0 ± 11.6	110.1 ± 13.7	0.645
Flexion ROM (6 months)	119.4 ± 9.9	116.5 ± 9.6	0.006
Flexion ROM (1 year)	121.9 ± 7.4	118.7 ± 8.2	0.002

Hohmann** 81			
Flexion ROM (2 years)	128 ± 8.6	127 ± 10.4	0.147
KOOS JR (2 years)	83.8 ± 15.0	80.6 ± 18.6	0.942
FJS (2 years)	71.0 ± 27.6	60.5 ± 30.4	0.016
Möller 24			
Change in Oxford Knee Score (1 year)	17.7 ± 6.7	18.0 ± 7.0	0.902
Change in EQ-5D-5L (1 year)*	0.21 (0.20)	0.25 (0.21)	0.089
El Othmani 80			
Knee Society Scores (3 months)	71.7	68.83	0.496
Knee Society Scores (1 year)	82.2	82.83	0.175
SF-12 P (3 months)	46.67	45.39	0.586
SF-12 P (1 year)	48.15	47.28	0.256
SF-12 M (3 months)	47.33	47.14	0.15
SF-12 M (1 year)	59.58	48.3	0.72
WOMAC-Pain (3 months)	83.9	74.68	0.024
WOMAC-Pain (1 year)	91.8	86.3	0.027
WOMAC-Stiff (3 months)	70.45	55.64	< 0.001
WOMAC-Stiff (1 year)	76.5	71.74	0.1
WOMAC-Function (3 months)	82.41	72.07	0.008
WOMAC-Function (1 year)	88.77	79.73	0.002
Sangaletti 53			
Knee Society Score (5 years)	90.2 ± 8.2	89.6 ± 8.5	0.56
FJS-12 (5 years)	83.5 ± 11.9	82.1 ± 12.3	0.40

*values given as median and (interquartile range)

† values presented as fractions with "yes" as numerator and total sample size for the cohort as the denominator.

§ values presented as mean and standard error

€ Values derived from Figure 2

φValues presented as adjusted mean difference and 95% CI

**ROSA Knee with automated femoral component rotation planning

Complication rates reported to date appear to be generally comparable between robotic-assisted and conventional TKA, with no consistent evidence of an increased risk associated with robotic assistance (Table 4.). Although Woelfle et al.⁹⁰ reported a lower aseptic revision rate with robotic-assisted TKA; that finding should be interpreted cautiously given the relatively short 18-month follow-up. Kenanidis et al. reported no complications in either group (Table 4); however, the sample size was likely too small to detect a real difference if any were actually present⁸². Both Mancino et al. and Parratte et al. reported minimal complications between robotic-assisted and their controls.^{15,63} In their learning curve analysis,

Vanlommel et al. also noted minimal complications between robotic-assisted and conventional.¹⁸ Hax et al.²⁰ reported no difference in complications between robotic-assisted and conventional TKA. Fary et al. reported fewer wound complications and a non-significant trend ($p=0.08$) for less stiffness in the robotic group⁸⁶. Rajgopal et al.²¹ observed 50% less blood loss with robotic-assisted TKA, and attributed this to the need to breach in the intramedullary canal with conventional TKA. In a study of nearly 4000 patients, Chan et al.⁷³ reported fewer cases of joint inflammation at 30- and 90-days post-operative.

Table 4. Complications present post-operatively.

	Robotic, n (%)	Control, n (%)	P value
Kenanidis ⁸²			
Complications and readmissions	0 (0%)	0 (0%)	NA
Mancino ⁶³			
Revision TKA	0 (0%)	2 (4.26%)	0.232
Infection	1 (2%)	2 (4.26%)	>0.99
Aseptic Loosening	0 (0%)	1 (2.13%)	0.485
Reoperations	1 (2%)	3 (6.38%)	0.191
DAIR*	1 (2%)	1 (2.13%)	>0.99
Wound Complication	2 (4%)	4 (8.7%)	0.426
Parratte ¹⁵			
DAIR*	1 (2.5%)	0 (0%)	NA
Traumatic Distal Femoral Fracture	0 (0%)	1 (2.5%)	NA
Vanlommel ¹⁸			
Arthrofibrosis	2 (2.2%)	1 (1.1%)	NA
Surgical site infection	1 (1.1%)	3 (3.3%)	NA
Deep vein thrombosis	1 (1.1%)	0 (0%)	NA
Periprosthetic joint infection	0 (0%)	1 (1.1%)	NA
Fary ⁸⁶			
Deep Knee Infection	2 (0.9%)	2 (0.9%)	NA
Stiffness	13 (6.0%)	23 (10.6%)	0.082
Pain	6 (2.8%)	13 (6.0%)	0.101
Wound Complications	6 (2.8%)	18 (8.3%)	0.023
Other Knee Related AE	15 (6.9%)	13 (6.0%)	0.696
Revision TKA	1 (0.5%)	4 (1.8%)	0.562
Manipulation Under Anesthesia	5 (2.3%)	10 (4.6%)	0.190
Woefle ⁹⁰			
Aseptic Loosening (tibial implant)	0 (0%)	4 (6.6%)	0.038
Hax ²⁰			
Infection	1 (1.8%)	0 (0%)	0.999
Vascular, neural, or soft tissue	0 (0%)	1 (1.8%)	0.999
Stiffness	3 (5.5%)	3 (5.5%)	1.000
Rajgopal ²¹			
Blood loss (ml)	206.7 ± 80.9	413.9 ± 128.4	<0.001
Chan ⁷³			
Emergency Department Visits (30 day)	17/220 (7.7%)	22/3715 (5.6%)	0.179
Emergency Department Visits (90 day)	36/220 (16.4%)	490/3715 (13.1%)	0.248
Joint Inflammation (30 day)	0/220 (0%)	38/3715 (1.0%)	<0.001
Joint Inflammation (90 day)	2/220 (0.9%)	68/3715 (1.8%)	<0.001
Reoperation (90 day)	1/220 (0.5%)	23/3715 (0.6%)	0.761
Clapp ⁵⁰			
Manipulation Under Anesthesia	22/398 (5.5%)	46/1216 (3.8%)	0.211
Gordon ⁶⁵			
Revision (6 week)	1/90 (1.1%)	0/30 (0%)	NA
Manipulation Under Anesthesia	3/90 (3.3%)	3/30 (10%)	NA
Coagulopathies	1/90 (1.1%)	0/30 (0%)	NA
Katsaras ²⁵			
Complications (90 day)	1 (1.1%)	1 (1.1%)	NA
Sangaletti ⁵³			
Periprosthetic joint infection	1/150 (0.6%)	0/150 (0%)	NA

*DAIR: debridement antibiotics and implant retention

Conclusion

Multiple studies support the ability of the ROSA Knee System to assist the surgeon accurately and reliably in placing the cut guide and achieving the planned cut angles and resections.^{14-17,21,26-29,33,37,39,40,46} The system has been shown to be easily incorporated into the surgical workflow, with a rapid initial learning curve.^{18,32,36,38,39,60,71} The flexibility of the system allows for a variety of surgical techniques,^{13,31,32,62,91-95} and has been shown to reduce surgeon stress compared to conventional instrumentation.⁶⁴ Additionally, patient and administrative burdens of obtaining advanced imaging are unnecessary, and radiation exposure is minimized.^{61,77,78} Early studies have demonstrated improved outcomes, including PROMs, ROM, pain and satisfaction, with minimal complications during the immediate (4-12 weeks) and early (6 - 12 months) post-operative period.^{14,15,18,21,30,63,82,86,88,90} In addition to the current potential values seen in these studies, there is also added value in the data provided by this robotic system. Lonner et al. demonstrated the ability to connect the intra-operative data provided by the ROSA Knee System with post-operative step counts and PROMs data in a commercial system.⁹⁶ They reported associations with the degree of intra-operative laxity

decisions and patient recovery outcomes. This information may be used to guide future care; however, the authors recommend more robust investigations be performed prior to making surgical decisions based on the current data.

This review summarizes the value of the ROSA Knee System and its ability to:

- Improve component positioning
- Improve early patient outcomes
- Decrease radiation exposure

In addition, the intra-operative data collected has the potential to change practice as more data is evaluated and used to better understand the intricacies of intra-operative decisions. The long-term outcomes and survivorship of TKA using the ROSA Knee System are yet to be determined, but the addition of this technology to assist in TKA procedures has been shown to have both patient and surgeon benefits.

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