■ KNEE

Mid-term survivorship and patient-reported outcomes of robotic-arm assisted partial knee arthroplasty

A SINGLE-SURGEON STUDY OF 1,018 KNEES

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Aims

Limited evidence is available on mid-term outcomes of robotic-arm assisted (RA) partial knee arthroplasty (PKA). Therefore, the purpose of this study was to evaluate mid-term survivorship, modes of failure, and patient-reported outcomes of RA PKA.

Methods

A retrospective review of patients who underwent RA PKA between June 2007 and August 2016 was performed. Patients received a fixed-bearing medial or lateral unicompartmental knee arthroplasty (UKA), patellofemoral arthroplasty (PFA), or bicompartmental knee arthroplasty (BiKA; PFA plus medial UKA). All patients completed a questionnaire regarding revision surgery, reoperations, and level of satisfaction. Knee Injury and Osteoarthritis Outcome Scores (KOOS) were assessed using the KOOS for Joint Replacement Junior survey.

Results

Mean follow-up was 4.7 years (2.0 to 10.8). Five-year survivorship of medial UKA (n = 802), lateral UKA (n = 171), and PFA/BiKA (n = 35/10) was 97.8%, 97.7%, and 93.3%, respectively. Component loosening and progression of osteoarthritis (OA) were the most common reasons for revision. Mean KOOS scores after medial UKA, lateral UKA, and PFA/BiKA were 84.3 (SD 15.9), 85.6 (SD 14.3), and 78.2 (SD 14.2), respectively. The vast majority of the patients reported high satisfaction levels after RA PKA. Subgroup analyses suggested tibial component design, body mass index (BMI), and age affects RA PKA outcomes. Five-year survivorship was 98.4% (95% confidence interval (CI) 97.2 to 99.5) for onlay medial UKA (n = 742) and 99.1% (95% CI 97.9 to 100) for onlay medial UKA in patients with a BMI < 30 kg/m^2 (n = 479).

Conclusion

This large single-surgeon study showed high mid-term survivorship, satisfaction levels, and functional outcomes in RA UKA using metal-backed tibial onlay components. In addition, favourable results were reported in RA PFA and BiKA.

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Introduction

In the setting of partial knee arthroplasty (PKA), either unicompartmental knee arthroplasty (UKA) or patellofemoral arthroplasty (PFA), innovative designs, improved surgical techniques, and precise patient selection have led to promising results.[1] Compared to total knee arthroplasty (TKA), PKA patients tend to recover faster and report a larger range of movement postoperatively, which can potentially lead to better patient-reported outcomes after surgery.[2-4] Historically poor outcomes for PKA and the technically demanding nature of the procedure have discouraged some surgeons from undertaking these operations. Recently, arthroplasty registries have reported that PKA accounts for 3% to 10% of all primary knee arthroplasties.[5,6] However, retrospective studies have shown that up to 40% of the patients undergoing TKA may be eligible for UKA based on radiological assessment.[7]

Over the last decade, many studies have focused on identifying causes of PKA failure. It was noted that lower leg malalignment, implant malpositioning, and instability were associated with an

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increased risk of revision.[8-11] To overcome these technical difficulties, robotic-arm assisted (RA) surgery has been introduced. This tool allows the surgeon to modify implant position and component size to fit a patient's knee before any bone resection is made. Intraoperatively, a surgeon-controlled robotic arm is used to resect bone within predefined boundaries. While there are no reports on the accuracy of RA PFA, several studies have shown more accurate implant positioning, soft-tissue balancing, joint line preservation, and lower leg alignment after RA UKA compared with conventional UKA.[12-17] Moreover, some studies have suggested that there is little to no effect on the accuracy of component position or lower limb alignment during the learning curve, even in less experienced surgeons.[18,19] However, uncertainty remains whether RA PKA leads to improved clinical outcomes, which is necessary to justify the higher costs associated with RA surgery.[20]

Several studies have reported promising clinical outcomes at different early follow-up intervals, including enhanced postoperative functional rehabilitation and improved early functional outcomes in highly active patients compared to conventional techniques.[21-24] Moreover, high implant survival has been shown after RA PKA at early follow-up.[17,25,26] However, the literature is lacking studies assessing mid-term outcomes after RA PKA, especially following lateral UKA and PFA. One large multicentre study showed RA medial UKA survivorship of 97% at five-year follow-up with an excellent rate of satisfaction (91%).[27] Another study found that normal gait was better restored after RA medial UKA compared with conventional UKA at five-year follow-up.[28] To the best of our knowledge, there are no existing studies to inform surgeons what to expect of RA surgery in different PKA types at mid-term follow-up.

The purpose of this single-surgeon study was to evaluate five-year survivorship, modes of failure, and patient-reported outcomes of RA medial UKA, lateral UKA, and PFA. Our hypothesis is that patients can benefit from the use of RA during PKA, as demonstrated by high survivorship and good functional outcomes.

Methods

Study design. Approval from the Institutional Review Board of Hospital for Special Surgery was obtained (IRB# 2013-056), and all patients were consented before data collection. A consecutive series of patients who underwent RA PKA between June 2007 and August 2016 were contacted for this study. All operations were carried out by one non-designer surgeon with extensive experience with RA PKA (ADP). Patients received either a cemented medial UKA, lateral UKA, PFA, or a combination in the event of bicompartmental osteoarthritis (OA) (PFA plus medial UKA) (RESTORIS MCK System, Mako Surgical Corp. (Stryker), Fort Lauderdale, Florida, USA). Two different fixed-bearing tibial components were used for medial UKA in this series due to a change in design: all-polyethylene tibial inlay components were no longer implanted after April 2010, while metal-backed tibial onlay components were used beginning in August 2008. Patients who underwent a PFA received a metal trochlear component with polyethylene patellar component.

Robotic-arm assistance. PKAs were implanted using the Robotic-Arm System (Mako Surgical Corp. (Stryker), Fort Lauderdale, Florida, USA), a third-generation RA instrument.[27] This image-based system uses CT imaging to prepare a plan using surgical variables; component size, component position, bone resection, and lower leg alignment. All these variables are checked preoperatively and if needed, intraoperative adjustments can be performed based on patient-specific anatomy and kinematics. During the procedure, the surgeon receives real-time feedback (visual, auditory, and/or haptic) on implant position, ligament tension throughout the arc of movement, and boundaries for bone resection to ensure a high degree of accuracy.[12,14-16]

Surgical inclusion criteria for medial or lateral UKA were symptomatic preferential unicompartmental OA, a passively correctable coronal plane deformity and a fixed flexion deformity of < 15°. Surgical exclusion criteria were signs of radiological inflammatory arthritis, the presence of Kellgren-Lawrence[29] (KL) grade 3 to 4 in the contralateral tibiofemoral compartment or PF joint-related symptoms (anterior knee pain with prolonged sitting with the knee flexed or pain specific to stair-climbing rather than descending stairs). Degenerative changes of the PF joint were not considered to be a contra-indication, unless there was bone loss or grooving of the lateral or medial PF facet in the case of medial or lateral UKA, respectively.

Criteria for PFA included isolated radiographic PF arthrosis with pain after prolonged knee flexion and significant difficulty with stair climbing refractory to over three months of physiotherapy without significant coronal plane deformity (> 5°, valgus and varus), PF instability, and PF malalignment. Surgical criteria for bicompartmental knee arthroplasty (BiKA; PFA plus medial UKA) included the aforementioned criteria for PFA, as well as grade 3 to 4 medial compartment KL scores and/or the identification of high grade or full-thickness medial compartment chondral wear on MRI.

A total of 1,062 patients (1,260 knees) underwent RA PKA. A total of 24 patients (2.3%) died, for whom relatives confirmed by telephone that no revision was performed. Additionally, 24 patients (2.3%) declined study participation, 78 patients (7.3%) had disconnected telephone numbers and 106 patients (10.0%) did not answer on multiple attempts. Overall, 854 patients (1018 knees) were included. Of these, 802 knees (78.8%) received medial UKA, including 60 with tibial inlay components (7.5%), and 742 with tibial onlay components (92.5%). In the lateral UKA group, tibial onlay components were used exclusively (171 knees, 16.8%). Furthermore, 35 PFAs and ten BiKAs were included (4.4%). Of the ten BiKAs, three patients received tibial inlay components, and seven tibial onlay components.

Data collection. All patients received a questionnaire at a minimum of two-year follow-up. The questionnaire assessed demographic data, reoperations (including revisions), as well as patients' satisfaction with their current knee function using a five-level Likert scale (very satisfied, satisfied, neutral, dissatisfied, very dissatisfied), and whether or not patients would choose to undergo the surgery again. Knee Injury and Osteoarthritis Outcome Scores (KOOS) were assessed using the validated KOOS for Joint Replacement Junior (KOOS JR) survey.[30] Patients were contacted three times by letter. If unresponsive, they were contacted by telephone; after five unsuccessful attempts, they were considered lost to follow-up.

Table I. Characteristics by robotic-arm assisted partial knee arthroplasty group.

Variable	Medial UKA (n = 802)	Lateral UKA (n = 171)	PFA/BiKA (n = 35/10)
Mean follow-up, yrs (SD)	4.9 (2.0)	4.3 (1.7)	4.7 (2.5)
Mean age, yrs (SD)	63.5 (9.5)	64.4 (11.0)	58.2 (11.6)
Male sex, n (%)	426 (53.1)	69 (40.4)	8 (17.8)
Mean BMI, kg/m^2 (SD)*	28.7 (5.3)	26.9 (4.8)	27.0 (4.9)
Inlay/onlay, n (%)	60/742 (7.5/92.5)	0/171 (0/100)	3/7† (30.0/70.0)
Revisions, n (%)	16 (2.0)	3 (1.8)	4 PFA (11.4); 1 BiKA (10.0)
Mean time to revision, yrs (range)	4.3 (0.8 to 8.7)	1.6 (0.2 to 3.8)	3.9 (0.3 to 9.6)
Preoperative KL grade, n (%)‡			
Missing	20 (2.5)	1 (0.6)	8 (17.8)
Grade 1 to 2	30 (3.7)	19 (11.1)	4 (8.9)
Grade 3 to 4	752 (93.7)	151 (88.3)	33 (73.3)
Mean mechanical axis, ° (SD)			
Preoperative	Varus: 7.2 (3.5)	Valgus: 5.2 (4.7)	Varus: 3.7 (3.6)
Postoperative	Varus: 2.9 (2.3)	Valgus: 2.3 (2.6)	Varus: 1.1 (2.8)
Correction	Varus: 4.4 (2.8)	Valgus: 3.0 (3.6)	Varus: 2.6 (1.6)

*28 patients were morbid obese and BMI was missing in 18 patients.
†Tibial component design used in BiKA.
‡KL grade of the operated side; some radiological evaluations could not be completed since they were missing.
BiKA, bicompartmental knee arthroplasty; BMI, body mass index; KL, Kellgren-Lawrence; PFA, patellofemoral arthroplasty; UKA, unicompartmental knee arthroplasty.

Radiological assessment. For all patients, KL grade of each individual knee compartment (medial, lateral, patellofemoral) was determined using preoperative anteroposterior, flexed posteroanterior, lateral, and Merchant radiographs.[29] Furthermore, pre- and postoperative hip-knee-ankle standing radiographs were used to determine the mechanical axis angle of the lower limb.[31] Radiological assessment was performed by one trained independent observer (NL).

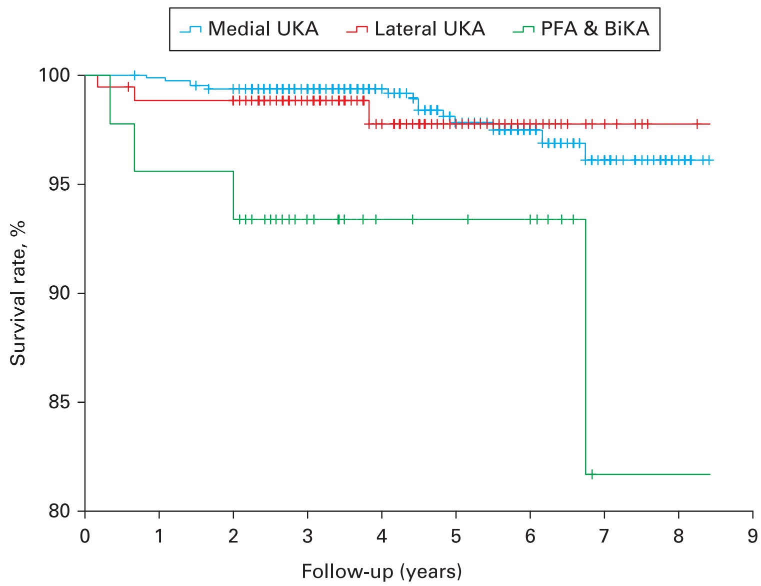
Statistical analysis. All statistical analyses were performed using SPSS version 25 (SPSS, Armonk, New York, USA). Descriptive analyses are reported as means, SDs, and ranges for continuous variables, and frequencies and percentages for discrete variables. Overall survivorship was determined using the Kaplan-Meier method. Body mass index (BMI) was stratified into nonobese (< 30 kg/m^2) and obese (≥ 30 kg/m^2) and age into younger than 60 years and 60 years or older for subgroup analysis. Differences between subgroups were assessed using independent-samples *t*-tests for continuous variables, Fisher's exact tests for discrete variables, and log-rank tests for survival data. No subgroup analysis was performed for PFA/BiKA group, as the number of patients included was less than 50 patients. Moreover, analysis was not performed when subgroups contained fewer than 20 patients, as no meaningful clinical statistical difference could be expected. p-values < 0.05 were considered statistically significant.

Results

Demographics and radiological characteristics by RA PKA group are reported in Table I.

Survival. Five-year survivorship of medial UKA was 97.8% (95% confidence interval (CI) 96.4 to 99.2), lateral UKA 97.7% (95% CI 94.9 to 100), and PFA/BiKA 93.3% (95% CI 86.0 to 100) (Figure 1). Subgroup analysis of all medial UKA revealed differences in survival related to tibial implant type and BMI; however, no differences were observed for sex and age. Specifically, five-year survivorship of tibial onlay and inlay components in medial UKA was 98.4% (95% CI 97.2 to 99.5) and 93.3% (95% CI 86.9 to 99.7), respectively, resulting in a significant difference (p = 0.036, log-rank test). Although, when evaluating the onlay medial UKA group, patients with a BMI < 30kg/m^2 showed a five-year survivorship of 99.1% (95% CI 97.9 to 100) compared with 97.4% (95% CI 94.6 to 100) in patients with a BMI ≥ 30kg/m^2 (p = 0.088, log-rank test) (Figures 2 and 3). The subgroups of lateral UKA contained less than 20 patients at risk at five-year follow-up, and were therefore considered too small to allow analysis.

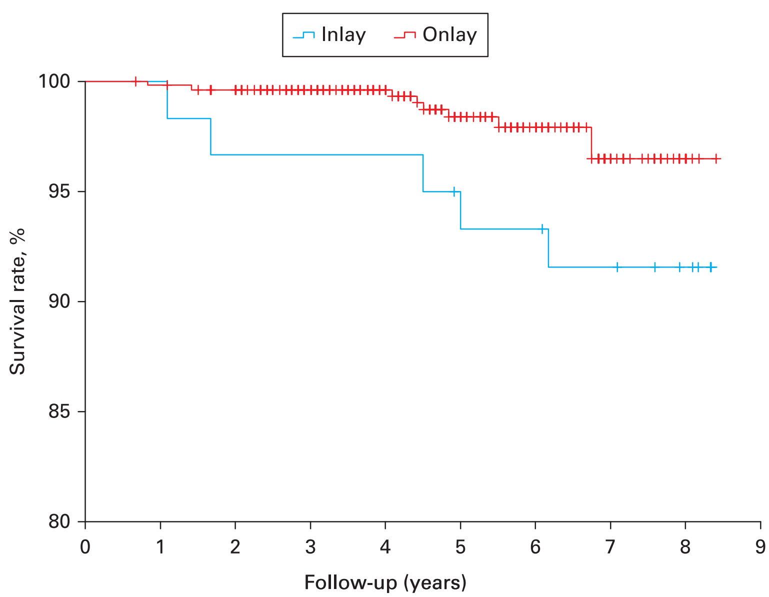
Revisions and reoperations. In all, 23 patients (24 knees) underwent revision (details given in Table II). All other subsequent operations after PKA were classified as reoperations including simple insert exchange. A total of 30 patients (30 knees) underwent reoperation. One lateral and two medial UKA patients were successfully treated with irrigation, debridement, and insert exchange due to early infection at one month after surgery. One medial UKA patient underwent insert exchange at 5.6 years due to polyethylene wear. All four patients who underwent insert exchange were satisfied and reported good to excellent mean KOOS scores after reoperation (84.6 to 100) at a mean of 2.5 years (1.0 to 4.0). Furthermore, 24 patients (22 medial UKA, one lateral UKA, and two PFA) underwent arthroscopic procedures at a mean of 2.3 years (0.1 to 5.7). One patient underwent manipulation under anaesthesia at 0.2 years and one cryolysis of the infrapatellar branch of the saphenous nerve at 0.5 years. Arthroscopy was primarily performed due to pain and/or swelling. The arthroscopic findings were meniscal tears in the contralateral compartment, chondromalacia of the PF joint, a loose body, scar tissue, synovitis, or a combination of these reasons. Four patients that underwent arthroscopy had a tibial plateau insufficiency fracture and underwent subchondroplasty during the same procedure. All four patients received a tibial inlay component at index surgery.



Number at risk					
Medial UKA	802	792	460	184	59
Lateral UKA	171	167	78	28	2
PFA & BiKA	45	42	16	13	6

Fig. 1

Kaplan-Meier survival curve for robotic-arm assisted medial unicompartmental knee arthroplasty (UKA) (802 knees), lateral UKA (171 knees), and patellofemoral arthroplasty (PFA)/bicompartmental knee arthroplasty (BiKA) (35/10 knees).



Number at risk					
Inlay	60	58	58	55	48
Onlay	742	734	403	129	14

Fig. 2

Kaplan-Meier curve of robotic-arm assisted medial unicompartmental knee arthroplasty, survivorship divided by type of tibial component design. Five-year survivorship of knees with a metal-backed tibial onlay component was 98.4% (95% confidence interval (CI) 97.2 to 99.5) and for all-polyethylene tibial inlay component 93.3% (95% CI 86.9 to 99.7; p = 0.036, log-rank test).

Patient-reported outcomes. At mid-term follow-up, good to excellent KOOS scores were reported for medial UKA, lateral UKA, and PFA/BiKA (Table III). Subgroup analysis suggested that lower BMI (< 30kg/m^2), higher age (≥ 60 yrs), and tibial onlay components were associated with higher post-operative KOOS scores in medial UKA patients (p < 0.001,

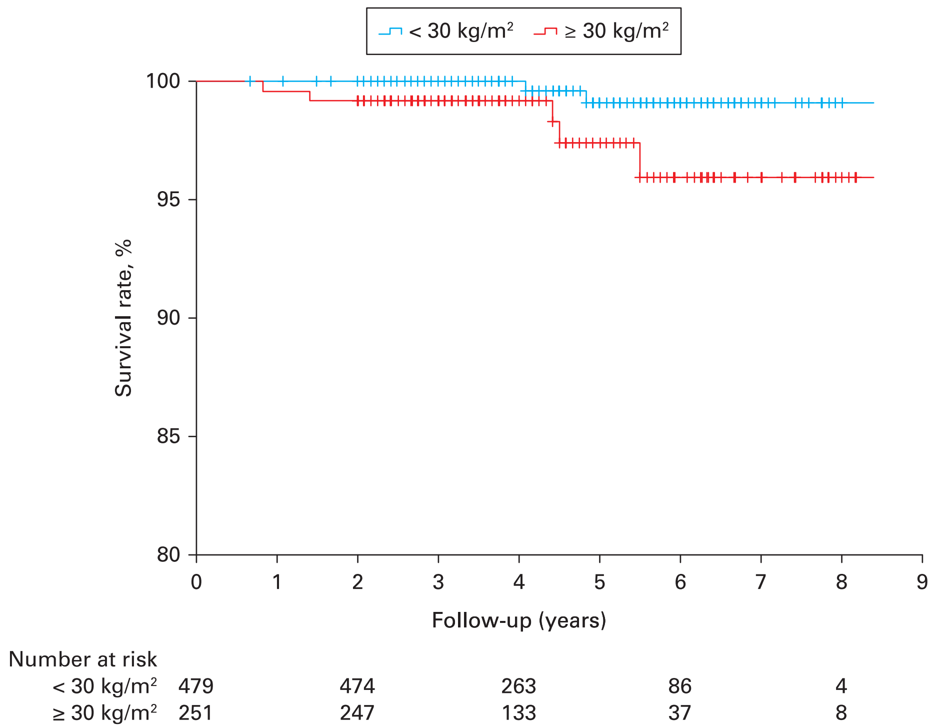


Fig. 3

Kaplan-Meier curve of robotic-arm assisted medial unicompartmental knee arthroplasty with onlay tibial components divided by body mass index (BMI) subgroup. Five-year survivorship of nonobese patients (< 30 kg/m^2) was 99.1% (95% confidence interval (CI) 97.9 to 100) and for obese patients (≥ 30 kg/m^2) was 97.4% (95% CI 94.6 to 100) (p = 0.088, log-rank test).

p = 0.009, p = 0.022, respectively; all independent-samples *t*-test). No significant difference in age, BMI, and sex subgroups were observed after lateral UKA (Table III).

With regard to satisfaction rates, 684 (90.7%) of medial UKA patients, 150 (92.6%) of lateral UKA patients, and 30 (78.9%) of PFA/BiKA patients were either very satisfied or satisfied with their knee function. In addition, of the majority of patients in all the groups would choose to undergo the surgery again (Table IV). Subgroup analysis showed that patients with onlay medial UKA would choose to undergo surgery again statistically more often than patients with inlay medial UKA (650/707 (91.9%) vs 38/47 (80.8%); p = 0.016, Fisher's exact test). Age, sex, and BMI did not affect patients' satisfaction following medial UKA.

Discussion

In this large retrospective study, high five-year survivorship was demonstrated in RA medial UKA (97.8% (95% CI 96.4 to 99.2)), lateral UKA (97.6% (95% CI 94.9 to 100)), and PFA/BiKA (93.3% (95% CI 86.0 to 100)). Specifically, excellent survivorship (98.4% (95% CI 97.2 to 99.5)) was reported when using metal-backed tibial onlay components in RA medial UKA. Furthermore, differences in survivorship were found between all medial UKA patients with a BMI < 30 kg/m^2 and ≥ 30 kg/m^2, although both reported a mid-term survivorship exceeding 97% at mid-term follow-up when using metal-backed tibial onlay components. The most common modes of failure were aseptic loosening and progression of OA. Good to excellent KOOS scores and high satisfaction levels were reported after different types of RA PKA.

The excellent survivorship of RA medial UKA in the current study was confirmed in an earlier multicentre study by Kleeblad et al,[27] reporting a survival rate of 97.0% (95% CI 95.2 to 98.8) at five-year follow-up (432 knees). To the best of our knowledge, no studies have reported mid-term survival of lateral UKA using robotic assistance. With regard to conventional techniques, recent large studies have reported five-year survival rates of 97.2% (95% CI 96.2 to 99.2) (460 knees) and 97.7% (95% CI 96.7 to 98.6) (1,000 knees) following commonly used medial UKA designs.[32,33] Recent lateral UKA studies have reported survival rates of 95.5% (95% CI 86.7 to 98.5) (101 knees) and 85.0% (95% CI 77.9 to 89.9) (344 knees) at five-year follow-up.[34,35] These survival results of conventional UKA performed by experienced surgeons appear to be lower than our results, especially when compared with our tibial onlay component findings. However, this comparison must be interpreted with caution, as variation of cohort demographics (age, BMI, and sex), follow-up period, and implant design between different studies may explain the difference in results. Overall, our results suggest that in experienced surgeons' hands, RA surgery can achieve at least similar results as conventional techniques in UKA.

A possible explanation for the high mid-term survival rate after RA UKA may be that robotic surgery produces more reliable lower limb alignment, improved component positioning, and accurate restoration of ligament balance throughout the range of movement.[12,14-17] Furthermore, due to the surgeon's experience, careful patient selection was performed. These factors have been associated with good outcomes; however, it is

Table II. Summary of revised robotic-arm assisted partial knee arthroplasty cases.

Patient	PKA type, tibial design	Sex	Age, yrs	BMI, kg/m^2	Time to revision, yrs	Reason for revision	Revised to:
1	Medial UKA, inlay	Female	66.2	23.6	1.1	Pain	Tibial onlay component and insert exchange
2	Medial UKA, inlay	Female	71.5	36.2	1.7	Tibial loosening	TKA
3	Medial UKA, inlay	Male	46.3	35.4	4.5	Progression lateral OA	TKA
4	Medial UKA, inlay	Female	71.0	34.4	5.0	Tibial loosening	Tibial onlay component and insert exchange
5	Medial UKA, inlay	Male	58.9	32.0	6.2	Progression lateral OA	TKA
6	Medial UKA, inlay	Male	43.2	23.1	8.5	N/A	TKA
7	Medial UKA, onlay	Female	52.0	33.7	0.8	Tibial loosening	TKA
8	Medial UKA, onlay	Male	51.2	33.2	1.4	Pain	TKA
9	Medial UKA, onlay	Female	65.1	N/A	1.4	Tibial loosening	TKA
10	Medial UKA, onlay	Female	71.5	28.7	4.1	Aseptic loosening	TKA
11	Medial UKA, onlay	Male	49.6	39.0	4.4	Femoral loosening	Femoral component and insert exchange
12	Medial UKA, onlay	Female	61.8	31.7	4.5	Progression lateral OA	TKA
13	Medial UKA, onlay	Male	57.1	24.4	4.8	Progression lateral OA	TKA
14	Medial UKA, onlay	Female	59.6	33.5	5.5	Pain	TKA
15	Medial UKA, onlay	Female	66.8	N/A	6.8	Progression lateral OA	TKA
16	Medial UKA, onlay	Female	80.8	29.0	8.7	Progression lateral OA	TKA
17	Lateral UKA, onlay	Male	65.6	29.5	0.2	Infection	TKA
18	Lateral UKA, onlay	Female	52.7	34.0	0.7	Aseptic loosening	TKA
19	Lateral UKA, onlay	Female	77.7	25.0	3.8	Pain	TKA
20	Both knees: PFA, N/A	Female	63.2	29.2	Left: 0.3; Right: 0.7	Rapid progression OA	Both knees TKA
21	PFA, N/A	Female	45.9	23.1	2.0	N/A	TKA
22	PFA, N/A	Female	68.6	N/A	6.8	Progression medial OA	TKA
23	Bicompartmental, inlay	Female	46.3	25.0	9.6	Inlay collapse	TKA

BMI, body mass index; N/A, not available; OA, osteoarthritis; PFA, patellofemoral arthroplasty; PKA, partial knee arthroplasty; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.

Table III. Total and subgroup KOOS by robotic-arm assisted partial knee arthroplasty group.

Variable	Medial UKA		Lateral UKA		PFA/bicompartmental	
	n	Mean KOOS score (SD)	n	Mean KOOS score (SD)	n	Mean KOOS score (SD)
Total	713	84.3 (15.9)	152	85.6 (14.3)	36	78.2 (14.2)
Age, yrs						
≥ 60	446	85.5 (15.6)	96	84.6 (15.4)	14	82.7 (13.8)
< 60	267	82.3 (16.3)	56	87.2 (12.1)	22	75.4 (13.9)
p-value*		0.009†		0.277		N/A
BMI, kg/m^2						
≥ 30	227	80.7 (16.9)	28	81.3 (17.3)	7	77.3 (14.4)
< 30	481	85.9 (15.2)	124	86.6 (13.4)	29	82.0 (13.6)
p-value*		< 0.001†		0.076		N/A
Sex						
Male	375	85.3 (15.6)	62	85.0 (15.5)	8	86.4 (11.9)
Female	338	83.1 (16.2)	90	86.1 (13.4)	28	75.9 (14.1)
p-value*		0.053		0.675		N/A
Tibial implant						
Inlay	39	78.6 (18.7)	0	N/A	1	68.3
Onlay	674	84.6 (15.7)	152	85.6 (14.3)	7	80.5 (10.4)
p-value*		0.022†		N/A		N/A

*Independent-samples *t*-test.

†Statistically significant.

BMI, body mass index; KOOS, Knee Injury and Osteoarthritis Outcome Score; N/A, not available as no meaningful clinical statistical difference could be expected; PFA, patellofemoral arthroplasty; UKA, unicompartmental knee arthroplasty.

difficult to be certain which factor is most important based on current literature.[33] Therefore, randomized and registry-based comparative studies are necessary to show the clinical efficacy of RA UKA. Additionally, these studies may help justify the additional costs of RA surgery, as improved outcomes may lead to reduced healthcare expenditure. Based on current

Table IV. Patient satisfaction rates by robotic-arm assisted partial knee arthroplasty group

Variable	Medial UKA	Lateral UKA	PFA/bicompartmental
Total, n*	754	162	38
Satisfaction, n (%)			
Very satisfied	546 (*72.4*)	118 (*72.8*)	23 (*60.5*)
Satisfied	138 (*18.3*)	32 (*19.8*)	7 (*18.4*)
Neutral	32 (*4.2*)	6 (*3.7*)	4 (*10.5*)
Dissatisfied	28 (*3.7*)	3 (*1.9*)	2 (*5.3*)
Very dissatisfied	10 (*1.3*)	3 (*1.9*)	2 (*5.3*)
Undergo surgery again, n (%)			
Yes	688 (*91.2*)	150 (*92.6*)	34 (*89.5*)
No	66 (*8.8*)	12 (*7.4*)	4 (*10.5*)

*Patients who were revised or deceased were not included in this analysis. All included patients had a minimum two-year follow-up with an overall mean of 4.6 years (SD 2.0).
PFA, patellofemoral knee arthroplasty; UKA, unicompartmental knee arthroplasty.

cost-analyses in the literature comparing RA and conventional UKA, high-case volumes and improvement in outcomes are required to be cost-effective.[20,36]

Despite the use of robotic assistance, component loosening remains one of the primary causes of failure of UKA. It has been suggested that higher loads are concentrated on a smaller surface area compared to TKA. This may challenge the fixation at the bone-component interface of UKA, especially for medial UKA, as 65% to 75% of the load passes through the medial compartment in a neutrally aligned knee.[37] In alignment with our findings, previous literature has noted that excessive varus alignment, the use of all polyethylene tibia components, and high BMI are associated with increased risk for aseptic loosening.[38]

To lower the risk of fixation failure, the Oxford group has introduced a cementless implant and reported lower incidence of aseptic loosening compared to our findings.[39] These findings probably cannot be extrapolated to fixed-bearing UKA since bone-implant interfacial loads differ between bearing designs. However, recent studies have shown good mid- to long-term survival rates using a hydroxyapatite-coated cementless fixed-bearing design with an overall small number of revisions due to aseptic loosening.[40-42] To summarize, the accuracy and reliability of implant positioning while using RA surgery coupled with cementless UKA designs may decrease aseptic loosening and thereby improve UKA survivorship.

Another mode of failure observed in our study was progression of OA in the lateral compartment after RA medial UKA (six patients). Pre-existing mild degenerative changes in the lateral compartment were reported in three patients. However, this has not been associated with increased probability of revision for progression of OA.[43] In addition, no overcorrection of the mechanical axis angle of the lower limb was observed in any of the revised patients. Based on our available data, we were unable to identify specific causes for revisions due to progression of OA in the lateral compartment.

Although the current study reported good to excellent outcomes after PKA, our findings suggest that BMI, age, and tibial implant can influence the results of medial UKA. The current literature seems to be contradictory concerning the association between BMI and revision rates in UKA. A large registry-based study by Kandil et al[44] determined that obese patients had a significantly higher risk of revision than nonobese patients. However, Plate et al[45] performed a study including 746 medial UKAs and reported no differences in revision rates between BMI subgroups. Similarly, Murray et al[46] found no influence of BMI on implant survival in 2438 medial UKAs, although increasing BMI was significantly related to lower postoperative functional outcome scores. Based on our data as well as current literature, UKA may be an acceptable option in patients with elevated BMI, although survivorship and functional scores may be slightly inferior in obese patients after UKA.

Furthermore, significantly higher KOOS scores were found in medial UKA patients aged over 60 years, which is consistent with the study by Liddle et al.[47] The authors reported higher Oxford Knee Scores[48] and satisfaction rates with increasing age, analyzing 25,982 cases from three national databases. They observed worse preoperative scores in younger patients and less improvement with surgery, which could be due to a higher threshold for offering arthroplasty to younger patients. Another possible explanation could be the higher functional demands of younger patients. Patients with higher expectations are more likely to be dissatisfied after knee arthroplasty, which could influence patient-reported outcome scores.[49]

A small number of patients with RA PFA and BiKA was assessed in our series. Similar survivorship was reported in recent cohort studies using conventional techniques. Three large studies reported a five-year survival rate of 89.0% (95% CI not reported; 103 PFAs), 95.8% (95% CI 91.8 to 99.8; 109 PFAs), and 92% (95% CI not reported; 55 BiKAs).[50-52] Most studies noted that progression of OA was the main reason of revision in PFA implants; however, authors still argue that when using conventional techniques, malalignment is an important mode of failure as well.[50,51] RA surgery has shown to improve accuracy of implant positioning in UKA and therefore may likely improve positioning in PFA as well. This could have contributed to the favourable outcomes in our study following RA PFA and BiKA; however, additional studies are needed to compare radiological and functional outcomes between conventional and RA methods.

The strength of this study includes the large number of patients and the single-surgeon research design, resulting in less variation in surgical indications, surgical technique, and rehabilitation. The main limitation, resulting from the retrospective nature, was that 17.3% patients could not be contacted and 2.3% declined participation, leading to potential selection bias. Furthermore, both inlay and onlay designs for medial UKA were included in this study. However, through experience, it has been found that the tibial inlay design is inferior to the onlay design. These observations are now supported by our current mid-term data. Finally, all RA PKA were performed by a high-volume surgeon and results may therefore not be generalizable.[53] Some authors suggest that RA PKA can reduce the risk of technical error in less experienced surgeons.[18] This may encourage these surgeons to undertake PKA more often. However, not only a reliable and precise surgical technique is required, but proper indications for PKA need to be considered. We believe when using appropriate indications using RA surgery consistently good outcomes can be expected.

This study showed that excellent mid-term survivorship, satisfaction levels, and functional outcomes can be achieved with RA medial and lateral UKA using metal-backed tibial onlay component, especially in nonobese patients aged over 60 years. In addition, RA surgery can safely be used for PFA and BiKA. The promising findings within this study may partially result from a more controlled approach for PKA compared with conventional techniques. However, fixation failure of cemented components remains of concern. Further work is required to determine if RA PKA will report equivalent or better mid- to long-term survivorship and functional outcomes than conventional PKA.

Take home message

- Good to excellent mid-term survivorship and patient-reported outcomes can be achieved with robotic-arm assisted medial and lateral unicompartmental knee arthroplasty, using metal-backed tibial onlay components.
- In addition, robotic-arm assisted surgery can be safely used for patellofemoral arthroplasty and bicompartmental knee arthroplasty.

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