Ten-Year Survivorship and Patient Satisfaction Following Robotic-Arm-Assisted Medial Unicompartmental Knee Arthroplasty

A Prospective Multicenter Study

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Background: Robotic-arm-assisted unicompartmental knee arthroplasty (UKA) has been shown to result in high short- and mid-term survivorship. However, it is not known whether these outcomes are maintained at long-term follow-up. This study aimed to evaluate long-term implant survivorship, modes of failure, and patient satisfaction following robotic-arm-assisted medial UKA.

Methods: A prospective multicenter study of 474 consecutive patients (531 knees) undergoing robotic-arm-assisted medial UKA was conducted. A cemented, fixed-bearing system with a metal-backed onlay tibial implant was used in all cases. Patients were contacted at 10-year follow-up to determine implant survivorship and satisfaction. Survival was analyzed using Kaplan-Meier models.

Results: Data were analyzed for 366 patients (411 knees) with a mean follow-up of 10.2 ± 0.4 years. A total of 29 revisions were reported, corresponding to a 10-year survivorship of 91.7% (95% confidence interval, 88.8% to 94.6%). Of all revisions, 26 UKAs were revised to total knee arthroplasty. Unexplained pain and aseptic loosening were the most commonly reported modes of failure, accounting for 38% and 35% of revisions, respectively. Of patients without revision, 91% were either satisfied or very satisfied with their overall knee function.

Conclusions: This prospective multicenter study found high 10-year survivorship and patient satisfaction following robotic-arm-assisted medial UKA. Pain and fixation failure remained common causes for revision following cemented fixed-bearing medial UKA, despite the use of a robotic-arm-assisted technique. Prospective comparative studies are needed to assess the clinical value of robotic assistance over conventional techniques in UKA.

Level of Evidence: Prognostic Level II. See Instructions for Authors for a complete description of levels of evidence.

Unicompartmental knee arthroplasty (UKA) is a surgical treatment for medial osteoarthritis, with the potential to result in faster recovery, lower perioperative complication rates, improved kinematics, and better functional outcomes compared with total knee arthroplasty (TKA)[1-4]. However, the technically challenging nature of UKA has likely contributed to inconsistent long-term implant survival after this procedure, as commonly reported in arthroplasty registries[5,6]. Moreover, a recent registry study demonstrated a twofold higher lifetime revision risk for UKA compared with TKA[7]. Furthermore, clinical outcomes following conversion of UKA to TKA are often inferior to those of primary TKA[8], which emphasizes the importance of a successful primary UKA.

Failure of UKA can frequently be attributed to technical errors, including component malpositioning and lower-limb malalignment, which may result in instability[4,9]. The need to reliably control these surgical factors has led to a growing interest in robotic-arm-assisted technologies. Robotic-arm-assisted systems offer virtual preoperative implant planning and precise control over intraoperative variables through the use of a surgeon-controlled robotic arm[10]. The precision of robotic-arm-assisted UKA has been well documented[11-14] and is theorized to translate into more natural knee kinematics and improved functional outcomes and survivorship compared with traditional techniques.

Although the literature on robotic-arm-assisted UKA is gradually expanding, studies reporting long-term outcomes following this technique are currently lacking. In a recent multicenter study, our group reported 97% survivorship at 5.5-year follow-up after robotic-arm-assisted medial UKA[15]. However, to our knowledge, no published studies have reported longer than

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5.9 years of follow-up after such procedures[16]. Given the increased use of robotic systems in knee arthroplasty and the favorable early outcomes[6,17], the current challenge lies in demonstrating whether these results can be maintained at longer-term follow-up.

The objective of this study was to evaluate long-term survivorship, failure modes, and patient satisfaction following robotic-arm-assisted medial UKA for patients with medial osteoarthritis. We hypothesized that robotic-arm-assisted UKA would result in high survivorship and patient satisfaction.

Materials and Methods

Patient Selection

This prospective multicenter study includes the previously reported initial consecutive series of robotic-arm-assisted, cemented medial UKA cases (Restoris MCK system; Mako Surgical [Stryker]), starting from the implant release date in March 2009[15]. The Restoris MCK system consists of a metal-backed titanium tibial onlay implant, a cobalt-chromium femoral implant, and a fixed-bearing polyethylene insert. All patients who were scheduled to undergo robotic-arm-assisted medial UKA with the Restoris MCK system at 1 of 4 participating centers between March 2009 and December 2011 were prospectively included. Patients provided consent prior to inclusion. Study approval was obtained for all institutions under the Western Institutional Review Board (#20120378).

Procedures were performed by 4 experienced knee arthroplasty surgeons. All surgeons were course-trained prior to the study through a program that involved practicing the robotic-arm-assisted UKA on 2 to 5 cadaveric knees. Annual case volumes during the study period ranged from 54 to 81 cases.

Surgical indications included isolated medial compartment osteoarthritis with a passively correctable varus deformity of <15°, fixed flexion deformity of <10°, and intact cruciate ligaments. Surgical exclusion criteria were clinical or radiographic signs of osteoarthritis in the lateral compartment, or signs of inflammatory arthritis.

Robotic System

A third-generation robotic-guided surgical instrument (Mako Robotic-Arm Assisted System; Mako Surgical [Stryker]) was used in all cases. The robotic-arm-assisted system includes an imaged-based device with a navigation module that uses preoperative computed tomography (CT) scans to enable the planning of component position, component sizes, and bone resection areas. Component positioning has been shown to be accurate within 0.8 mm and 0.9° and within 0.9 mm and 1.7° in all directions for the femoral and tibial components, respectively[12,13,18]. Mechanical alignment has been shown to be accurate within 1.6° of the surgical plan, and soft-tissue balancing, within 0.53 mm of the surgical plan[11,19].

A preoperative plan was individualized for each patient. Following surgeon approval of the plan, the patient's knee anatomy was registered to the CT-based model using tracking arrays fixed to the tibia and femur. If necessary, component position and size were altered on the basis of analyses of component overhang, bone coverage, ligament tension, and kinematics before any bone resection was performed. A robotic arm with a 6-mm burr was used for bone preparation, providing real-time haptic, visual, and auditory feedback to help prevent resection outside of the predefined cutting boundaries.

Data Collection

Patients were contacted by phone at 10-year follow-up to determine implant survivorship and patient satisfaction through a survey. Following confirmation of the patient's surgeon, procedure, and laterality, the patient was asked whether any revisions were performed. In the case of any revisions, follow-up questions were asked to determine the date and reason for revision. Patients without revision were asked to grade their satisfaction with their operative knee on a 5-point Likert scale ("very satisfied," "satisfied," "neutral," "dissatisfied," or "very dissatisfied"). Patients were considered lost to follow-up if they did not answer after a minimum of 3 attempts to contact them. Patients who were lost to follow-up or declined study participation were excluded from the study population.

Statistical Analysis

Continuous variables are reported as the mean and standard deviation and were compared using an independent samples t test. Categorical variables are reported as the number and frequency and were compared using a chi-square test. Survival analyses were performed to determine implant longevity and time to all-cause revision (i.e., revision of ≥1 of the primary components), the primary outcome end points, and revision to TKA, the secondary outcome end point. Kaplan-Meier methods were used to describe the overall time to all-cause revision and conversion to TKA. Cox regression models were used to compare differences in survivorship by sex, after adjustment for age, body mass index (BMI), and bilateral cases. Results from the survival analysis models are presented as hazard ratios (HRs) and 95% confidence intervals (CIs). To control for multiple observations from 1 patient in the bilateral cases, only 1 side of the patient was included in the analysis[20]. Hence, all analyses were performed at the patient level. Annual revision rates (ARRs) were calculated to evaluate differences in survival by age and BMI categories. The ARR describes the risk of revision over time and is expressed as the rate of revision per 100 component years (i.e., number of revisions divided by the total number of observed component-years, times 100)[21]. Patients were categorized by age (≤59, 60 to 69, 70 to 79, or ≥80 years) and by BMI (normal weight [18.5 to 24.9 kg/m^2], overweight [25.0 to 29.9 kg/m^2], obese class I [30.0 to 34.9 kg/m^2], obese class II [35.0 to 39.9 kg/m^2], and obese class III [≥40.0 kg/m^2]) at the time of surgery. Significance was set at $p < 0.05$. Analyses were performed using SPSS (version 25; IBM).

Source of Funding

The study was financially supported by Stryker. The sponsor was involved in the design of the study but had no influence on the collection, analysis, or interpretation of data, nor did the sponsor have a role in the drafting of the manuscript.

Results

A total of 474 patients (531 knees) received robotic-arm-assisted medial UKA. A total of 108 patients (120 knees) were excluded from the study, as 28 patients declined study participation and 80 patients were lost to follow-up (Fig. 1). Forty-one patients died during the study period. At a mean follow-up of 10.2 ± 0.4 years, a total of 366 patients (411 knees) were included for analysis in the study. The mean age at the time of surgery of the enrolled patients was 67.2 ± 9.0 years, mean BMI was 29.6 ± 4.4 kg/m^2, and 158 (43%) of the patients were female (Table I). A total of 45 (12%) of the patients received bilateral UKA. Excluded patients were significantly older compared with enrolled patients (70.5 versus 67.2 years, respectively; $p = 0.003$). While the included cohort had a higher proportion of female patients (43%), the percentages of female and male patients were more equally distributed in the included cohort compared with the excluded cohort (female patients, 27%) (Appendix Table 1).

Survival Analysis

At 10-year follow-up, 29 revisions were reported, corresponding to a survivorship of 91.7% (95% CI, 88.8% to 94.6%) (Fig. 2) and an ARR of 0.91 revisions per 100 component years. The mean time to revision was 5.2 ± 2.4 years. Of all revisions, 26 UKAs were revised to TKA, resulting in a survivorship of 92.6% (95% CI, 90.0% to 95.3%) using revision to TKA as the end point (Fig. 3). An overview of demographics by revision status is provided in Table I. Cox regression models showed a significantly higher risk of all-cause revision (HR, 2.3; 95% CI, 1.1 to 5.1; $p = 0.030$) (Fig. 4) and conversion to TKA (HR, 2.3; 95% CI, 1.0 to 5.3; $p = 0.041$) among female patients compared with male patients.

The ARR by age category was highest (1.47) for patients ≤59 years of age (Table II). The highest ARRs by BMI were observed among patients categorized as class-I obese (1.30) and class-II obese (1.26).

Modes of Failure

In the 29 knees that underwent revision, modes of failure included unexplained pain in 11 (38%) of the knees, aseptic loosening in 10 (35%), development of osteoarthritis in the lateral compartment in 6 (21%), infection in 1 (3%), and polyethylene wear in 1 (3%) (Table III). Thirty-four percent of all revisions were performed by the initial surgeon.

Patient Satisfaction

Of all patients without revision, 91% reported being either very satisfied or satisfied with their operative knee, while 4% were dissatisfied or very dissatisfied (Table IV).

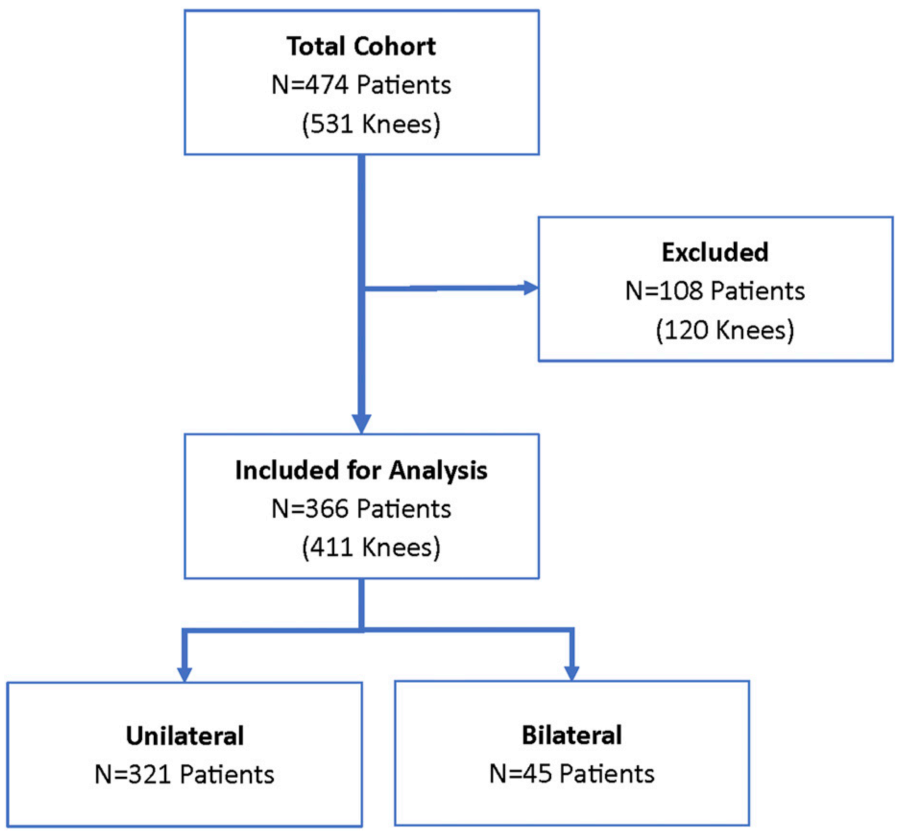


Fig. 1
Flowchart of patient inclusion.

TABLE I Demographics by Revision Status*

	No Revision	All-Cause Revision	P Value	Revision to TKA	P Value
No. of patients (no. of knees)	337 (382)	29 (29)		26 (26)	
Age† *(yr)*	67.4 ± 8.9	65.1 ± 9.6	0.190	65.7 ± 9.1	0.334
BMI† *(kg/m²)*	29.5 ± 4.4	31.0 ± 4.1	0.076	31.0 ± 3.9	0.104
Female‡	139 (41%)	19 (66%)	0.01†	17 (65%)	0.02§
Bilateral‡	42 (12%)	3 (10%)	0.739	3 (12%)	0.890
Age category, in yr‡			0.303		0.301
<50	11 (3%)	1 (3%)		0	
50-59	55 (16%)	9 (31%)		8 (31%)	
60-69	135 (40%)	10 (34%)		10 (38%)	
70-79	100 (30%)	8 (28%)		7 (27%)	
≥80	35 (10%)	1 (3%)		1 (4%)	
Missing	1	0		0	
BMI category, in kg/m²‡			0.293		0.222
18.5-24.9	46 (14%)	1 (3%)		1 (4%)	
25-29.9	140 (43%)	11 (38%)		9 (35%)	
30-34.9	98 (30%)	13 (45%)		13 (50%)	
35-39.9	35 (11%)	4 (14%)		3 (12%)	
≥40	5 (2%)	0		0	
Missing	13	0		0	

*Demographics are presented for patients who had no revision, all-cause revision (i.e., revision of ≥1 of the primary components), or revision to total knee arthroplasty (TKA) following robotic-arm-assisted medial unicompartmental knee arthroplasty. Comparison of demographics between knees with and without revision (no revision vs. all-cause revision and no revision vs. revision to TKA) were conducted using an independent samples t test for continuous variables and a chi-square test for categorical variables. BMI = body mass index. †The values are given as the mean and standard deviation. ‡The values are given as the number, with the percentage of patients in parentheses; percentages are based on the total number of patients with data for the given parameter. §Significant.

Discussion

This prospective multicenter study demonstrated high 10-year survivorship (91.7%) and patient satisfaction (91%) following robotic-arm-assisted medial UKA. Female patients had a higher risk of revision compared with males, and annual revision rates (ARRs) were highest among younger patients and those with class-I and II obesity. Despite the use of a robotic-arm-assisted system, unexplained pain and aseptic loosening remained frequently reported modes of failure following cemented, fixed-bearing medial UKA.

To our knowledge, this is the first large prospective study to report 10-year outcomes of robotic-arm-assisted medial UKA. This study is a sequel to a previous study by our group[15], in which we reported 97.0% survivorship free from revision for any reason at 5.5 years. Based on the current literature, the 10-year survivorship following robotic-arm-assisted medial UKA appears to be consistent with that of conventional UKA procedures reported in large cohort studies (91.7% versus 91.5%, respectively; Table V). Furthermore, our findings are comparable with 10-year survivorship of conventional UKA (90.2%) based on recent data of the New Zealand Joint Registry (NZJR)[7]. Although comparative studies are needed to formally assess outcomes between robotically assisted and conventional procedures, the results of the present study may provide an impression of the long-term performance of robotically assisted medial UKA. While our data demonstrate that this technique yields reliable outcomes, the improved surgical precision of the robotic system[22,23] did not seem to result in substantially improved survivorship compared with recent cohort and registry data for conventional UKA[5,24].

The ability of modern robotic systems to provide better surgical precision compared with conventional techniques for medial UKA has been demonstrated by recent literature[11-14,25,26]. Controlling and optimizing surgical variables (e.g., implant positioning, lower-limb alignment, soft-tissue balancing, and joint-line preservation) may reduce the number of outliers and has been theorized to improve clinical and survivorship outcomes[22,26]. Indeed, some studies have shown initial favorable results after robotic procedures[27,28], and data from the Australian Orthopaedic Association National Joint Replacement Registry[29] demonstrated lower revision rates at 3-year follow-up following robotic-arm-assisted medial UKA compared with conventional techniques. Nevertheless, the greater precision of robotic systems has not yet been shown to translate into better long-term outcomes. Moreover, current literature, including our

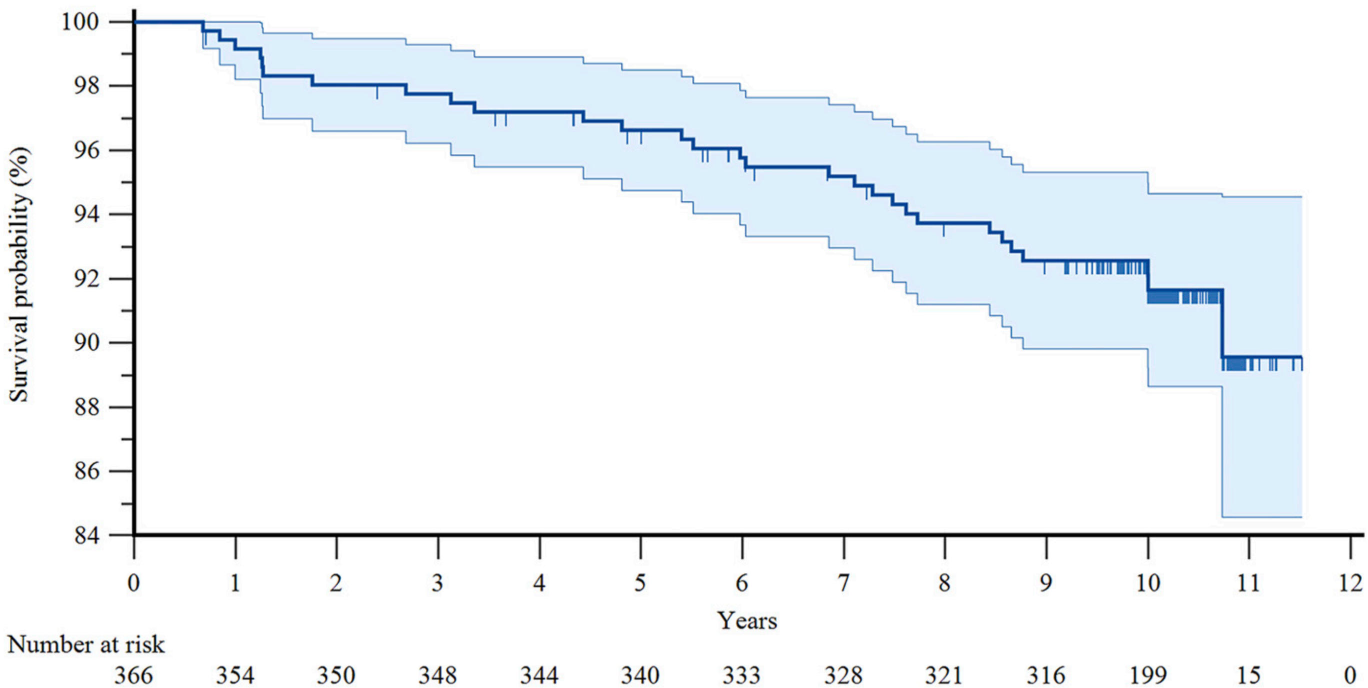


Fig. 2

Kaplan-Meier survival curve for robotic-arm-assisted medial unicompartmental knee arthroplasty (366 patients), with all-cause revision (i.e., revision of ≥1 of the primary components) as the end point. The shaded area indicates the 95% confidence interval.

own study, does not provide conclusive evidence of improved survivorship following robotically assisted UKA, and future research is required to establish this.

In this series, female patients had a more-than-twofold higher revision risk compared with their male counterparts. Significantly higher revision rates in female patients after UKA

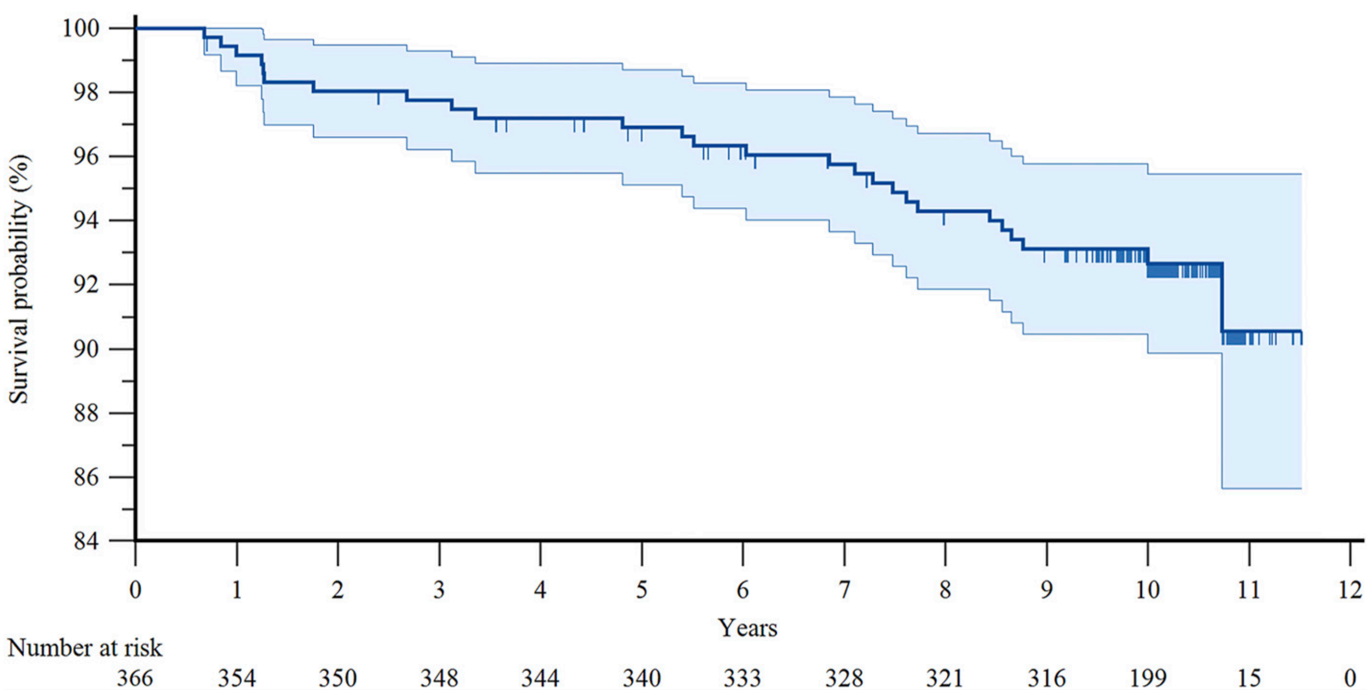
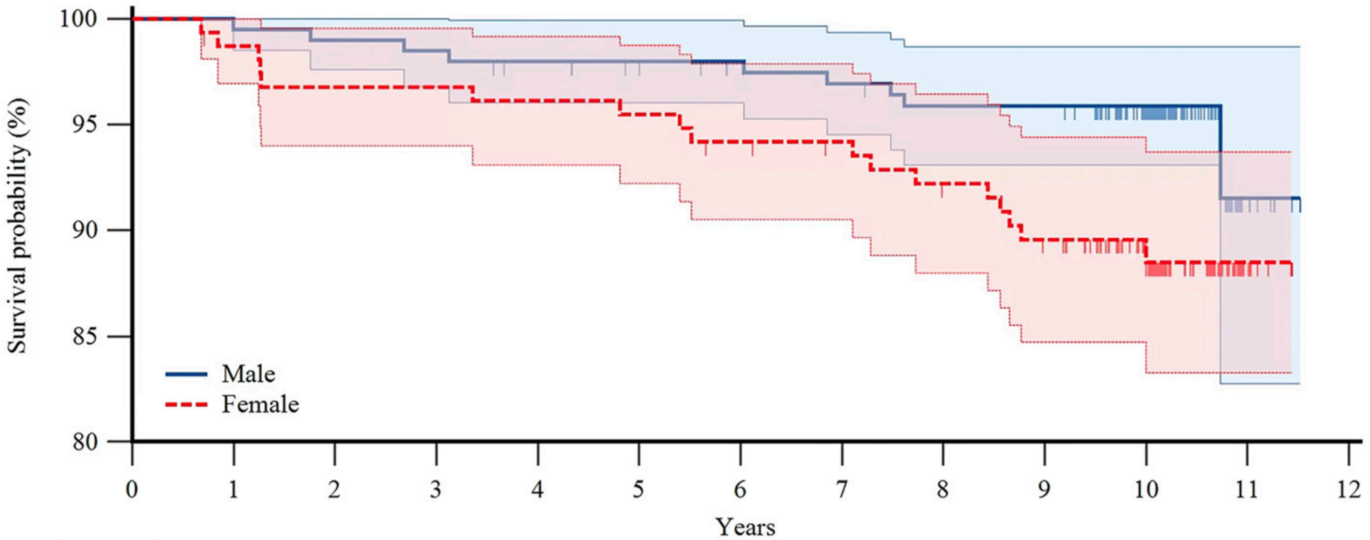


Fig. 3

Kaplan-Meier survival curve for robotic-arm-assisted medial unicompartmental knee arthroplasty (366 patients), with revision to total knee arthroplasty as the end point. The shaded area indicates the 95% confidence interval.



Number at risk												
Group: Male												
208	198	197	196	193	191	188	185	182	182	117	7	0
Group: Female												
158	153	150	150	149	148	145	143	139	134	82	8	0

Fig. 4

Kaplan-Meier survival curves for robotic-arm-assisted medial unicompartmental knee arthroplasty by patient sex, with all-cause revision as the end point. The continuous blue line represents the male patients, while the dotted red line represents the female patients. The shaded areas indicate the 95% confidence interval.

has been reported in several registry reports[5,6,24], and a recent study demonstrated a higher probability of better satisfaction and Forgotten Joint Score results for males compared with females following robotic-arm-assisted medial UKA[16]. The literature is inconclusive with regard to the origin of differences in outcomes of UKA on the basis of sex, although it has been

TABLE II Annual Revision Rates for All-Cause Revision in Age and BMI Categories*

Category	No. of Patients	Mean Follow-up *(yr)*	No. of Revisions	Total Observed Component Years *(yr)*	Annual Revision Rate
Age, in yr					
≤59	73	10.18	10	682.24	1.47
60-69	137	10.17	10	1,373.20	0.73
70-79	96	10.19	8	927.73	0.86
≥80	19	10.02	1	190.47	0.53
BMI, in kg/m^2					
18.5-24.9	37	10.16	1	363.83	0.27
25.0-29.9	137	10.18	11	1,341.75	0.82
30.0-34.9	103	10.17	13	996.88	1.30
35.0-39.9	33	10.22	4	317.22	1.26
≥40.0	4	10.25	0	40.98	0.00
Missing	11	10.27	0	112.98	0.00
Total	325		29	3,173.64	0.91

*Annual revision rates following robotic-arm-assisted medial unicompartmental knee arthroplasty (UKA) are presented per age and body mass index (BMI) categories for all-cause revision (i.e., revision of ≥1 of the primary components). The annual revision rate describes the risk of revision over time (from implantation of the prosthesis until death or revision) and is expressed as the rate of revision per 100 component years. Deceased patients were not included in this analysis.

TABLE III Overview of Revised Robotic-Arm-Assisted Medial UKA Cases*

	Case	Sex	Age *(yr)*	BMI *(kg/m²)*	Time to Revision *(yr)*	Reason for Revision	Procedure
Revision to TKA	1	Female	64.1	28.5	0.7	Pain	Revised to TKA
	2	Female	53.5	25.8	0.8	Aseptic loosening and PF OA	Revised to TKA
	3	Male	51.5	31.7	1.0	Aseptic loosening	Revised to TKA
	4	Female	69.2	25.1	1.2	Pain	Revised to TKA
	5	Female	79.0	26.7	1.3	Aseptic loosening	Revised to TKA
	6	Female	79.0	33.2	1.3	Aseptic loosening	Revised to TKA
	7	Male	76.6	36.0	1.8	Pain	Revised to TKA
	8	Male	81.5	33.5	2.7	Pain	Revised to TKA
	9	Male	73.0	26.7	3.1	Progression of lateral OA	Revised to TKA
	10	Female	55.0	37.4	3.4	Aseptic loosening	Revised to TKA
	11	Female	75.1	28.3	4.8	Progression of lateral OA	Revised to TKA
	12	Female	68.6	23.2	5.4	Aseptic loosening	Revised to TKA
	13	Female	59.6	38.7	5.5	Pain	Revised to TKA
	14	Male	60.9	30.8	6.0	Pain	Revised to TKA
	15	Male	75.4	26.0	6.9	Pain	Revised to TKA
	16	Female	60.4	29.8	7.1	Progression of lateral OA	Revised to TKA
	17	Female	50.1	30.5	7.3	Progression of lateral OA	Revised to TKA
	18	Male	68.5	33.5	7.5	Pain	Revised to TKA
	19	Male	73.3	30.3	7.6	Infection	Revised to TKA
	20	Female	56.5	32.0	7.7	Pain	Revised to TKA
	21	Female	64.7	34.5	8.4	Pain	Revised to TKA
	22	Female	61.6	33.1	8.6	Progression of lateral OA	Revised to TKA
	23	Female	58.3	33.0	8.6	Aseptic loosening	Revised to TKA
	24	Female	67.2	33.5	8.8	Aseptic loosening	Revised to TKA
	25	Female	67.5	29.1	10.0	Pain	Revised to TKA
	26	Male	57.3	34.0	10.7	Progression of lateral OA	Revised to TKA
Revision of UKA Components	27	Male	68.7	27.5	2.4	Aseptic loosening, tibial component	Tibial component and insert replacement
	28	Male	49.6	39.0	4.4	Aseptic loosening, femoral component	Femoral component and insert replacement
	29	Female	54.0	28.1	6.0	Polyethylene wear	Insert replacement

*Summary of patients with revision following robotic-arm-assisted medial unicompartmental knee arthroplasty (UKA), including demographics and reason for revision. BMI = body mass index, PF = patellofemoral, OA = osteoarthritis, and TKA = total knee arthroplasty.

suggested that differences in anatomy may yield suboptimal implant compatibility with knees in female patients[30,31]. Subsequent size mismatching may lead to tibial overhang, which is associated with compromised outcomes[32]. A similar phenomenon has also been observed in female patients following TKA[33]. The current study did not evaluate radiographic outcomes, and potential overhang could therefore not be assessed. However, it could be argued that tibial overhang is less likely to occur after preoperative virtual implant planning and robotic-arm-assisted bone resection. The sex-related differences in revision risks are nevertheless a critical finding that warrants further research into its origin and can be of importance for preoperative consultation and further development of contemporary UKA systems.

The higher ARRs observed among younger patients in this series are consistent with current registry data[5,7]. This trend is often attributed to the generally more active lifestyle and higher functional demands of younger compared with older populations. It is thought that higher loads during increased activity, concentrated on the small surface of the medial

TABLE IV Overall Patient Satisfaction (335 Patients)*

Satisfaction Level	No. (%)
Very satisfied	243 (73%)
Satisfied	63 (19%)
Neutral	13 (4%)
Dissatisfied	8 (2%)
Very dissatisfied	8 (2%)
Very satisfied to satisfied	306 (91%)

*Distribution of patient satisfaction with the operative knee following robotic-arm-assisted medial unicompartmental knee arthroplasty, as rated on a 5-point Likert scale ranging from "very satisfied" to "very dissatisfied."

compartment, may increase the risk of polyethylene wear and aseptic loosening[34]. Indeed, in the present study, aseptic loosening was the mode of failure in over half of all revisions in younger patients (≤59 years of age), and the only case of accelerated polyethylene wear in this series occurred in a 54-year-old patient (Table III). Nevertheless, the ARR in younger patients in the present study was comparable with the overall ARR of 1.15 following conventional UKA reported in the NZJR[24]. Hence, these results suggest that UKA can be an acceptable option for younger patients. In particular, it should be noted that UKA may provide several important advantages over TKA in younger patients with osteoarthritis, such as increased range of motion and faster recovery[35]. However, to establish realistic expectations, it is imperative that these patients are aware of the less predictable survivorship outcomes.

Another key finding in this study was that the majority of revisions were performed for unexplained pain or aseptic loosening. These modes of failure are similar to commonly reported reasons for failure after conventional medial UKA[9]. Initially, a robotic-arm-assisted technique was theorized to decrease the number of revisions for component loosening, owing to improved component positioning and restoration of joint-line orientation[36]. However, despite enhanced surgical precision, fixation failure remained a common cause of revision of cemented medial UKA. This finding emphasizes the need to explore other modalities to improve implant survivorship. Among other strategies, a cementless fixation technique was

TABLE V Cohort Studies Reporting 10-Year Survivorship of Conventional UKA*

Authors	Year of Publication	Start Cohort†	End Cohort†	No. of Knees	10-Year Survivorship
Fixed-bearing systems					
Abdulkarim et al.[39]	2021	1999	2000	147	85.1%
Forster-Horváth et al.[40]	2016	2002	2009	236	91.3%
Porteous et al.[41]	2022	1974	1994	496	86.0%
Qutub et al.[42]	2021	1988	2009	218	94.7%
Redish and Fennema[43]	2018	2002	2005	361	94.6%
Winnock de Grave et al.[44]	2018	2005	2013	460	94.2%
Total				1,918	91.2%
Mobile-bearing systems					
Alnachoukati et al.[45]	2018	2004	2006	825	85.0%
Emerson et al.[46]	2016	2004	2006	213	88.0%
Kim et al.[47]	2015	2002	2002	166	90.5%
Kim et al.[48]	2018	2002	2003	106	89.3%
Kristensen et al.[49]	2013	2002	2011	695	85.3%
Lim et al.[50]	2012	2001	2011	400	94.0%
Pandit et al.[51]	2015	1998	2009	1,000	94.0%
Schlueter-Brust et al.[52]	2014	1991	1999	234	95.6%
Walker et al.[53]	2019	2001	2005	126	92.4%
Xue et al.[54]	2017	2005	2014	708	94.3%
Yoshida et al.[55]	2013	2002	2011	1,251	95.4%
Total				5,724	91.6%
Unspecified bearing design					
Lyons et al.[56]	2012	1978	2009	279	90.4%
Overall conventional UKA				7,921	91.5%

*Summary of large cohort studies (≥100 cases) reporting 10-year survivorship of conventional unicompartmental knee arthroplasty (UKA). Studies are categorized by type of bearing design. †Start and end dates of the index procedures for patients included in the cohort.

introduced to increase survivorship by achieving a more reliable bone-implant fixation[37]. Indeed, in recent registry reports[5,24], revision rates were found to be lower after cementless UKA compared with UKA performed with use of cemented systems. While cementless systems commonly involve mobile-bearing designs with different biomechanical properties than the fixed-bearing system used in the present study, it could be argued that a cementless fixation technique may complement the precise bone preparation enabled by robotic systems, and as such, contribute to improved survivorship of medial UKA. Nonetheless, studies involving robotic-arm-assisted medial UKA using a cementless fixation technique are currently lacking.

There were several limitations to this study. The most important limitation is the potential introduction of selection bias, as 17% of patients could not be contacted by serial phone calls, and 6% had declined study participation. At least 1 of the participating sites changed its electronic health-care record system during the study period, which may have resulted in the loss of up-to-date contact information for some patients. Second, only survivorship and satisfaction were assessed, and no functional or radiographic outcomes were evaluated. Nevertheless, while patient satisfaction may not convey the functional performance of a UKA, we consider it an important element of evaluation, as it reflects the overall satisfaction with the surgical outcome from the patient's perspective, which may also be easier to conceptualize during surgical consultation. In addition, the radiographic outcomes of this technique, including its precision, have already been well documented[11-13,38]. Third, due to the study design, all data were patient-reported, which may contribute to potential bias. Fourth, the study had no control group and, although our data provide an impression of the performance of robotic-arm-assisted medial UKA, its potential benefits over conventional UKA remain to be confirmed or rejected. Nonetheless, the results of the present study were satisfactory overall and support the continued use of the robotic-arm-assisted technique in order to reliably achieve good outcomes, given the sensitivity of traditional UKA to surgical errors.

In conclusion, this prospective multicenter study found high 10-year survivorship and patient satisfaction following robotic-arm-assisted medial UKA. Pain and fixation failure remained common causes for revision following cemented fixed-bearing medial UKA, despite the use of a robotic-arm-assisted technique. Prospective comparative studies are needed to assess the clinical value of robotic assistance over conventional techniques in UKA.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/H488). ■

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