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Original Research

## Favourable mid-term outcomes following unicompartmental knee arthroplasty with wider patient selection: A single-centre experience

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## ABSTRACT

**Objective:** The purpose of this study was to determine surgical outcomes of robotic-assisted UKAs utilizing a wider set of indications than traditionally utilized. Additionally, we seek to determine alternate predictive factors as potential surgical indications and contraindications.

**Methods:** A prospectively maintained institutional joint registry was queried at a single academic centre for all patients that underwent robotic-assisted UKA between January 2010–December 2016. Surgical indication included isolated medial or lateral compartment degenerative disease with a stable knee based on physical exam. In 2013, haemoglobin A1C levels over 7.5% were considered contraindications, which was lowered to 7.0% in 2015. Preoperative alignment, age, activity level and degree of pain were not contraindications for surgery. Preoperative demographics, Oxford scores, radiographic (joint space), comorbidities and operative data were collected and reviewed to determine factors related to conversion to TKA and survivorship of the primary implant.

**Results:** In total, 1878 cases were performed; however, excluding multi-joint knees, there were a total of 1186 knees in 1014 patients with a minimum 4-year follow-up. The mean age was  $63.4 \pm 10.7$  years and mean follow-up was  $76.4 \pm 17.4$  months. Mean BMI was  $32.3 \pm 6.5$  kg/m<sup>2</sup>. (52.9% females, 47.1% males). There were 901 patients undergoing medial UKA, 122 patients undergoing lateral UKA and 69 patients undergoing patellofemoral UKA. In total, 85 (7.2%) knees underwent conversion to TKA. Preoperative factors such as the degree of preoperative valgus deformity ( $p = 0.01$ ), greater operative joint space ( $p = 0.04$ ), previous surgery ( $p = 0.01$ ), inlay implant ( $p = 0.04$ ) and pain syndrome ( $p = 0.01$ ) were associated with increased risk of revision surgery. Factors associated with decreased implant survivorship included patients with history of previous surgery ( $p < 0.01$ ), history of pain syndrome ( $p < 0.01$ ) and greater preoperative joint space ( $>2$  mm) ( $p < 0.01$ ). There was no association of BMI to conversion to TKA.

**Conclusion:** Robotic-assisted UKA with wider patient selection demonstrated favourable outcomes at 4 years with survivorship greater than 92%. The present series agree with emerging indications that do not exclude patients based on age, BMI, or degree of deformity. However, increased operative joint space, inlay design, history of surgery and coexistence of pain syndrome are factors that increase risk of conversion to TKA.

**Level of evidence:** Level III.

## What are the new findings

- Increased preoperative joint space predicts failure after UKA
- Unexplained pain or a pain syndrome predicts failure after UKA
- Patient age, BMI and degree of deformity should not preclude patients from a UKA

## Introduction

Unicompartmental knee arthroplasty (UKA) is an established alternative to total knee arthroplasty (TKA) in patients with unicompartmental disease. Currently, UKAs constitute approximately 8–10% of all knee arthroplasties; however, it is estimated that 21%–48% of patients undergoing TKR meet the criteria for UKA [9,12,13,25] and may benefit from a UKA. Traditionally, TKA has been preferred over UKA

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due to a reportedly higher revision rate of UKA [1]. However, large database analyses revealed that patients undergoing TKA had increased medical complications as compared to UKA patients [14,26]. In addition to the lower complication rate, advantages of the UKA include shorter operating time, reduced blood loss, reduced soft tissue trauma, bone stock preservation, improved restoration of knee kinematics, improved functional outcomes and patient satisfaction [8]. Choosing the correct patients for UKA is challenging but is important to obtain maximum benefit and prevent complications for our patients.

One limiting factor to patient access to UKAs has been the traditional indications. UKAs have traditionally been reserved for patients over the age of 60 years old, under 180 pounds, avoidance of heavy labour, minimal baseline pain, preoperative range of motion of 90° or less with less than a 5° flexion contracture and angular deformity less than 15° [11]. However, emerging indications would suggest that patients that are heavier, younger, with patellofemoral arthritis and with anterior cruciate ligament insufficiency may still be candidates for UKA [7,8,15]. Traditional indications may restrict candidates from receiving UKA that could benefit from its advantages that are currently outside the original inclusion criteria [8]. In order to improve access to UKAs, it is important to determine what patient selection criteria to utilize to optimize outcomes and longevity of UKA implants.

The purpose of this study was to determine if utilizing newer more relaxed indications resulted in comparable outcomes. Additionally, this study will seek to identify alternate perioperative patient factors and surgical characteristics predictive of UKA failure to be used as alternative indications and contraindications. The hypothesis of this observational study is that utilizing a wider patient selection will result in comparable results and that specific radiographic and patient comorbidities are linked to a higher likelihood of treatment failure through UKA that can be utilized for better patient selection to decrease the conversion rate of UKA to TKA.

## Methods

A prospectively maintained, institutional joint registry was used to identify patients who underwent robotic-assisted UKA implant (Restoris MCK, Mako, Stryker Corp, Kalamazoo Michigan, USA) through a medial parapatellar approach between January 2010 and December 2016. Patients with an age greater than 18 years without previous ipsilateral knee arthroplasty and follow-up greater than 2 years were included in the study. Ethical approval was obtained for this retrospective study by the institutional review board committee.

Surgical indication included isolated medial or lateral compartment degenerative disease. This was determined by preoperative radiographs. Narrowing of one of the compartments with maintenance of at least one tibial femoral joint with a stable knee based on physical exam was required. Starting in 2013, preoperative haemoglobin A1C levels over 7.5% were considered contraindications. After 2015 the threshold was lowered to 7.0% as recommended by the latest research.

### Surgical technique

The patient was positioned supine with a thigh tourniquet. A medial parapatellar approach was utilized. Two schanz pins were inserted into the femur and tibia and appropriate arrays were attached. Tibial and femoral landmarks were registered by the computer. Prior to 2015, all implants provided by the manufacturer were an inlay design, and subsequently all implants were an onlay design. The change in implant type was directed by the currently utilized and available implants at the time. The prosthesis was placed digitally on the computer and then the knee was carried through a range of motion. The placement of the prosthesis was adjusted until there was appropriate tension through a full range of motion. Robotic burr was used to prepare both femoral and tibial surfaces according to the revised digital plan. Trial components were taken through a range of motion. Posterior capsular injection was performed

for pain control. The final prostheses of appropriate size were cemented into place. Closure was performed in a layered fashion.

### Preoperative factors evaluated for risk of TKA conversion

Patients had preoperative Oxford scores repeated at 6 months, one year and yearly thereafter. Patients were contacted via e-mail, phone administered surveys and mail-out surveys to obtain outcomes from patients without recent clinic visits. All patients had preoperative weight-bearing knee radiographs from the AP, lateral and merchant views. Angular deformity (Varus-valgus angle) was measured as femoral tibial angle from the AP view. The operative side joint space was measured on weight-bearing lateral radiographs. Post-operatively the knee radiographs were repeated yearly.

Unexplained pain was another preoperative factor evaluated (noted pain syndrome). This was defined as one or more of these diagnoses documented by a physician in the hospital EMR system before or after index surgery: complex regional pain syndrome (CRPS), reflex sympathetic dystrophy (RSD), fibromyalgia, chronic pain syndrome, neuropathic pain, dystrophic pain, diabetic neuropathy, or lumbar radiculopathy if ipsilateral. Additionally, this included patients that presented with global knee pain that was unable to be explained with clinical exam or radiographic evidence. The intention of this variable was to define patients who may have pain unrelated to a mechanical or surgical issue to determine if UKAs provide relief of pain due to causes other than directly observable orthopaedic illness or disease.

All preoperative factors were subsequently analysed to determine correlations to UKA survivorship and function outcomes.

### Statistical analysis

Descriptive statistics were calculated for continuous (mean, standard deviation, range) and categorical (counts, percentages) variables for each variable of interest, both overall and then stratified by TKA revision status (yes/no) and unexplained pain during study (yes/no). Comparisons between groups [TKA (yes/no) and unexplained pain during study (yes/no)] were made using 2-sample *t*-tests for continuous variables and Chi-square tests for categorical variables.

Kaplan Meier survival curves were estimated for time to TKA revision to compare patients using log-rank tests. Next, Cox proportional hazards regression models were fit to examine predictors for time to TKA revision. The covariates of age, unexplained pain at baseline (yes/no) and joint space at baseline were considered as possible predictors in these models.

All analyses were performed using R Studio (Boston, MA).

## Results

In the study period, UKA was performed in 1878 knees by three surgeons in 1568 patients. Following inclusion/exclusion criteria, there were a total of 1186 knees and 1014 patients with minimum 4-year follow-up (52.9% females, 47.1% males). The mean age was  $63.4 \pm 10.7$  years and mean follow-up was  $76.4 \pm 17.4$  months. Mean BMI was  $32.3 \pm 6.5$  kg/m<sup>2</sup>. There were 901 patients undergoing medial UKA, 122 patients undergoing lateral UKA and 69 patients undergoing patellofemoral UKA. A total of 859 patients received inlay implants, while 258 patients received onlay implants. Patients with varus deformities on average had  $4.61 \pm 4.34^\circ$  of varus pre-operatively, while those with valgus deformities on average had  $9.85 \pm 3.96^\circ$  of valgus deformity.

### Complications and readmissions

In total, there were 36 readmissions (3.6%) within 90 days of surgery. Reasons for readmission include acute heart failure (1), constipation/ileus (1), oesophageal tear (1), necrotizing fasciitis (1), periprosthetic fracture managed conservatively (1), sepsis (1), vertebral osteomyelitis (1), wound dehiscence (4) and unknown reason (25) (see Table 1).

## TKA conversion predictors

There were 85 (7.2%) knees that underwent conversion to TKA within 4 years. A multivariate analysis was performed to determine variables associated with revision surgery. Inlay implant ( $p = 0.04$ ), greater operative joint space ( $p = 0.04$ ), pain syndrome ( $p = 0.01$ ), degree of preoperative valgus deformity ( $p = 0.01$ ) and previous surgery ( $p = 0.01$ ) were associated with increased risk of revision surgery (Table 2).

## Inlay vs onlay TKA conversion

At 4-year follow-up, there were 63 (7.3%) knees with inlay implants that were converted to TKA, and 14 (5.4%) patients with onlay implants that were converted to TKA. There was no statistical difference in survivorship between patients with inlay vs onlay implants ( $p = 0.5$ ) (see Fig. 1).

## Operative joint space TKA conversion

On average, preoperatively, from AP and Lateral radiographs, mean preoperative operative compartment joint space was  $1.3 \pm 1.2$  mm. There was a statistically greater probability of conversion to TKA in patients with greater preoperative joint space with an odds ratio of 1.19 ( $p = 0.043$ ) for every mm increase (Table 2, Fig. 2).

## Other variables TKA conversion

Survivorship of UKA implants were analysed with respect to previous surgery, preoperative pain syndrome, preoperative BMI and age. Patients with previous surgery had a statistically lower survivorship of UKA implant ( $p < 0.01$ ). Patients with history of pain syndrome also had a significantly lower survivorship of UKA implant ( $p < 0.01$ ). There was no association of BMI with the predicted probability of conversion to TKA. Patients of age younger than 50 years had a statistically lower survivorship of UKA implant ( $p = 0.05$ ) (Fig. 3).

Furthermore, subsets of the patient population were created based on medial vs lateral UKA. Analysis demonstrated that there was a greater predicted probability of conversion to TKA in patients with lesser preoperative varus deformity, though, no statistically significant association

Table 1

Patient demographics undergoing unicompartmental knee arthroplasty for treatment of unicompartmental osteoarthritis.

	Mean/Count	Standard Deviation
<b>Demographics</b>		
Age (years)	63.4	10.7
Gender	M: 478, F: 536	–
Side	R: 569, L: 445, B/L: 172	–
BMI ( $\text{kg}/\text{m}^2$ )	32.3	6.5
Coronal deformity	Varus: 1,057, Valgus: 127	–
Follow-up (months)	76.4	17.4
<b>Operative Details</b>		
Compartment	M: 995, L: 122, PF: 69	–
Inlay vs onlay	Inlay: 859, Onlay: 258	–
Surgical time (mins)	52.7	19.1
<b>Radiographic Parameters</b>		
Degree Varus	4.61	4.34
Degree Valgus	9.85	3.96
Operative joint space (mm)	1.57	1.50
Nonop joint space (mm)	6.08	1.39
<b>Comorbidities</b>		
Previous knee UKA1019%>% group by (hba1c) %>% tally (sort = F)surgery	Y: 215, N: 971	–
Opioid naïve	Y: 966, N: 220	–
Pain syndrome	Y: 312, N: 874	–

Table 2

Multivariate analysis of variables associated with conversion to total knee arthroplasty following unicompartmental knee arthroplasty.

Variable	p-value	Odds Ratio	95% CI
Age	0.153	0.98	0.96, 1.00
Preoperative BMI	0.110	0.97	0.93, 1.01
Onlay	<b>0.042</b>	0.64	0.41, 0.98
Previous Surgery	<b>0.014</b>	1.93	1.15, 3.26
Pain syndrome	<b>0.013</b>	1.90	1.15, 3.16
Opioid User	0.111	1.57	0.90, 2.72
Degree valgus	<b>0.011</b>	1.08	1.02, 1.14
Operative Joint space	<b>0.043</b>	1.19	1.01, 1.42
Compartment	0.061	0.35	0.12, 1.05

Bold signifies statistically significant.

was demonstrated with greater valgus deformity. There was no statistical difference in predicted conversion to TKA with respect to degree of deformity and inlay vs onlay implant (Fig. 2).

## Functional outcomes

Mean preoperative Oxford score was  $27.6 \pm 15.7$ , while mean Oxford score at the final follow-up was  $36.6 \pm 10.1$  ( $p < 0.001$ ). The mean final follow-up for survey collection was  $71.3 \pm 22.9$  months following surgery. Utilizing the distribution method, the threshold of improvement required to achieve MCID was 5.02. In total, MCID was achieved in 836 cases (70.5%) (Table 3).

## Discussion

The present study evaluates a single academic medical centre series with midterm follow-up of UKA performed for both medial and lateral unicompartmental osteoarthritis. Notably, the patient population does not adhere to the traditional Kozinn and Scott criteria for UKA, which includes varus deformity  $<5^\circ$ ,  $>60$  years of age and weight  $<82$  kg [11]. Instead, only the presence of isolated degenerative disease, i.e. narrowing of one joint space with maintenance of at least one other tibial femoral compartment in a stable knee, was used as an indication without concern for the degree of deformity, age, activity level, pain level or weight as long as the BMI was below 40 after 2015. The relaxed indication was due to emerging data that the previous contraindications were too stringent and denied patients access to a UKA who could benefit from it [4]. The salient findings from the present study, would suggest a lesser varus deformity, greater operative joint space, diagnosis of pain syndrome, history of prior surgery and inlay implants have a greater correlation with failure of UKA and conversion to TKA. Furthermore, there were statistically significant improvements in functional outcomes with the Oxford score. Additionally, over 70% of patients achieved MCID, calculated by the distribution method. Overall, the present case series found high implant survival in delaying the need for TKA (92.8%) over the 4-year follow-up period.

The treatment of unicompartmental osteoarthritis has long been controversial. High tibial osteotomy (HTO) has historically been a useful option in the correction of coronal plane deformities, particularly in young and active patients [20]. However, perioperative complication rates are high (9.9% within 30 days), and this necessitates limited weight-bearing in the post-operative period [3,21]. UKA offers an alternative to delay the need for TKA with reported survivorship at 15 years of 81.9 and 79% by Canadian and Australian data, 83.3% at 14 years from New Zealand data and 72% at 20 years from Norwegian data [5,10]. Additionally, UKA has a high safety profile with fewer post-operative complications, less estimated blood loss and operative time than TKA [2]. Emerging indications challenge those traditionally held by Kozinn and Scott [4,11]. Hamilton et al. demonstrated no differences in functional outcome scores, 15-year implant survival, time to failure, or mechanism. Their analysis was on the Kozinn and Scott indication of age

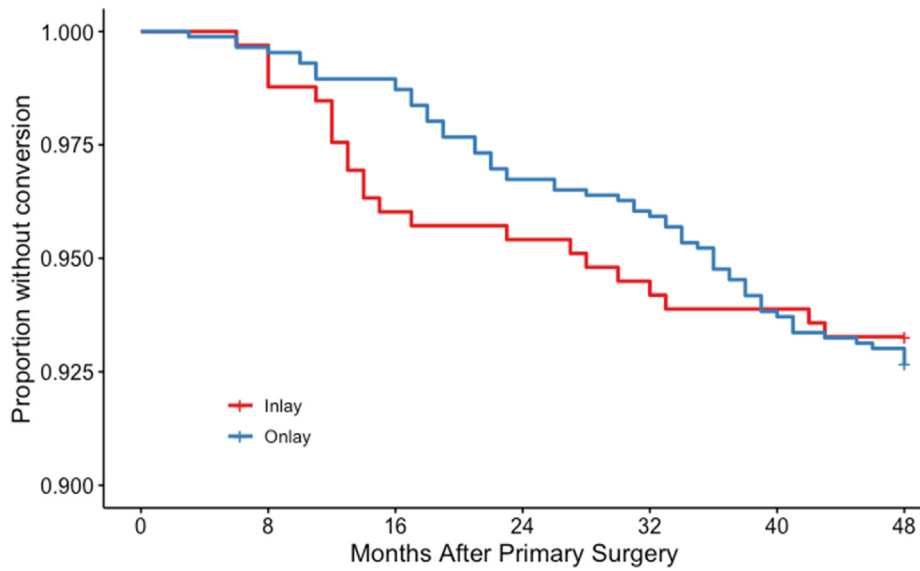


Fig. 1. Survivorship comparing rates of conversion to total knee arthroplasty in patients undergoing inlay vs onlay unicompartmental knee arthroplasty.

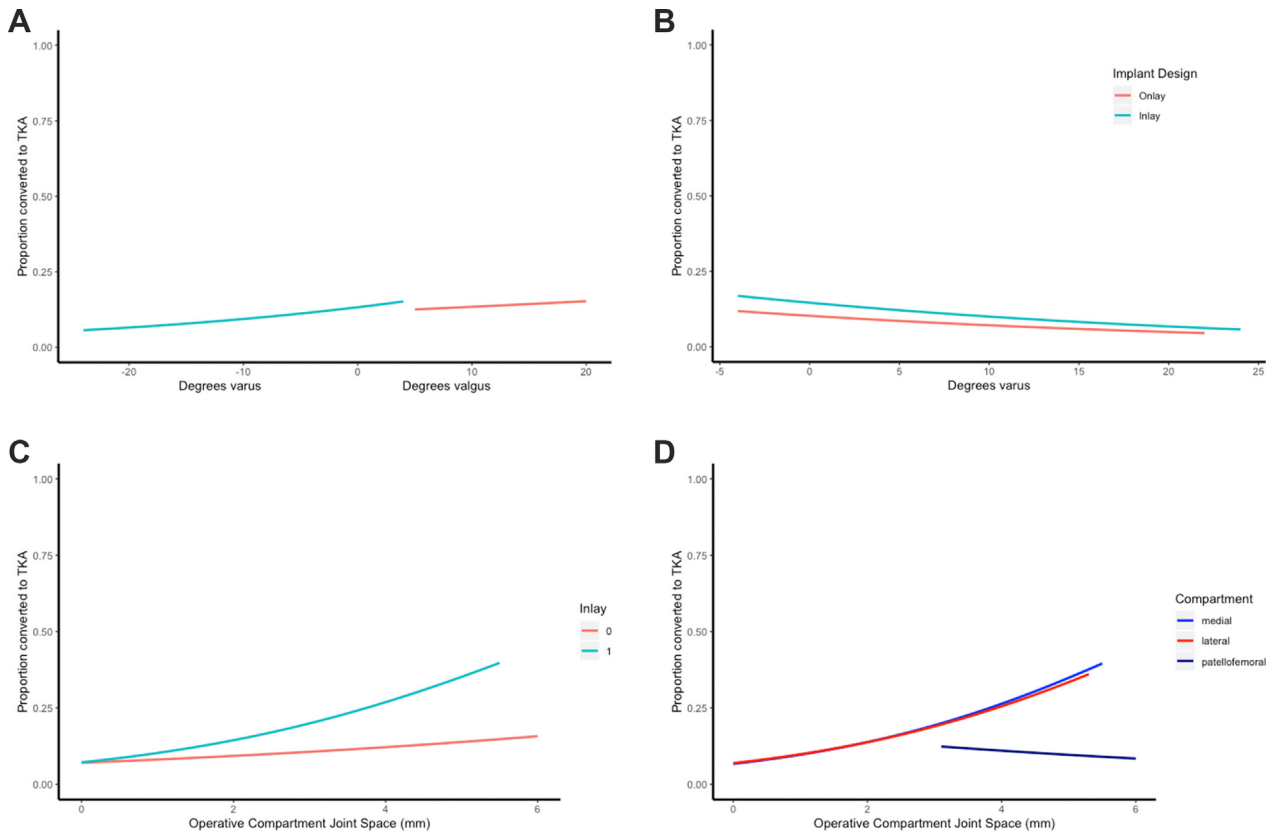
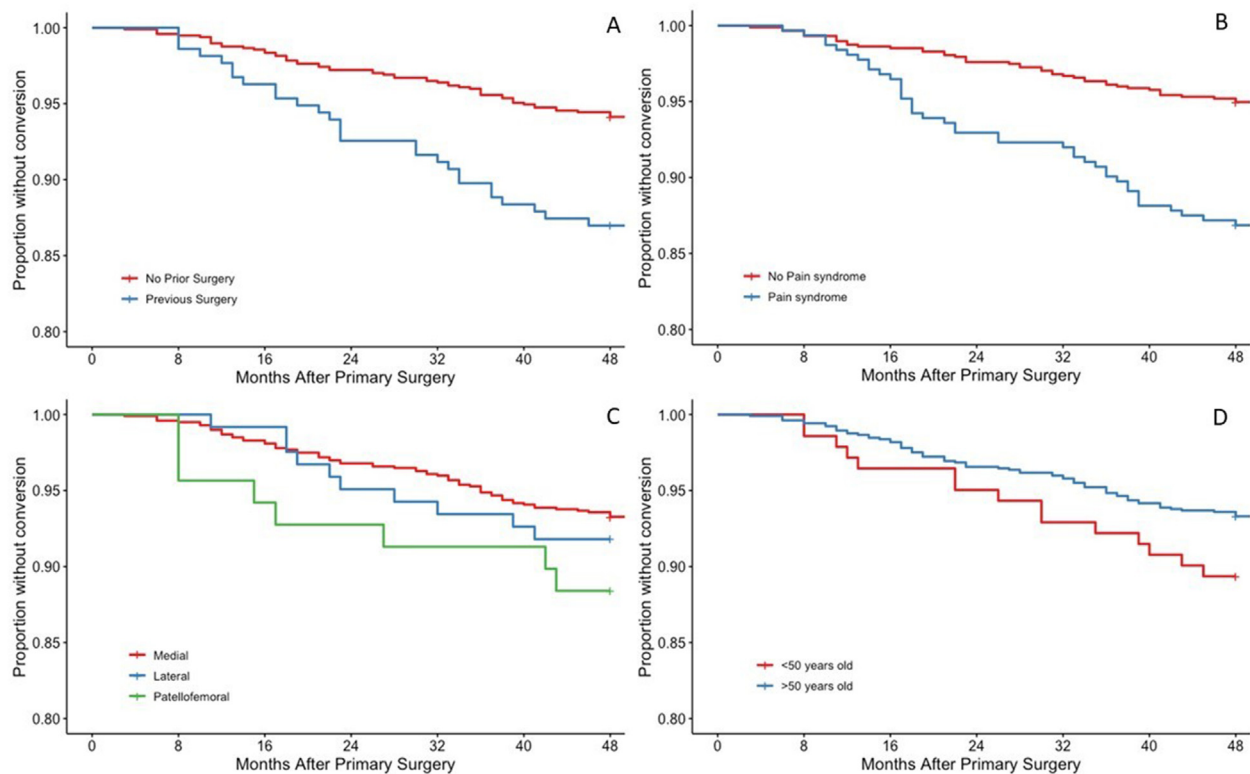


Fig. 2. Predicted probability of conversion to total knee arthroplasty between A) unicompartmental implants with respect to coronal plane deformity and B) inlay and onlay designs in varus deformities. C) inlay vs onlay implant with respect to operative joint space and, D) medial vs lateral compartment with respect to operative joint space.

greater or less than 60 years, weight greater or less than 180lbs and arthrosis in the patellofemoral joint in patients undergoing mobile-bearing UKA [8]. Similarly, the findings of the present study did not find any association of BMI in future conversion to TKA. However, patients younger than 50 years old were found to have decreased survivorship of implants though not present on multivariate analysis. Ekhtiari et al. found age younger than 50 years to be associated with

increased risk of revision in addition to male sex, diabetes and use of cementless implants [5], which was not corroborated by the present study.

The association of high preoperative joint space to TKA conversion emphasizes the importance of the preoperative evaluation of this radiographic measurement as there may be limited clinical benefit to those without joint space narrowing. Ninimaki and co-authors found that



**Fig. 3.** Examination of implant survivorship of unicompartmental knee arthroplasty implants in conversion to total knee arthroplasty with respect to A) previous surgery, B) preoperative pain syndrome, C) medial, lateral and patellofemoral compartments, and D) age.

**Table 3**

Functional outcomes by Oxford score before and after unicompartmental knee arthroplasty.

	Mean/Count	Standard Deviation
Preoperative Oxford Score	27.6	15.7
Post-operative Oxford Score	36.6	10.1
Achieve MCID Oxford	836 (70.5%)	–

#### Failure in Unicompartmental Knee Arthroplasty.

greater than 2 mm or 40% of the M/L ratio on weight-bearing radiographs was the strongest risk factor for conversion to TKA [18]. Maier et al. found similar findings, albeit with binary classifications of full and partial thickness cartilage loss [17]. Both authors discuss that greater joint space may suggest that patient symptomatology may be related to a reason other than medial compartment arthrosis. Interestingly, this relationship was validated in the present study for the medial compartment, but not for the lateral. This is biased by the fewer number of lateral compartment UKAs performed; however, the results of the present study found relatively consistent with lateral compartment UKA independent of joint space.

There is limited clinical data comparing inlay polyethylene designs to onlay metal backed. Inlay components are cemented atop a carved area over cancellous bone, while onlay designs utilize a tibial cut with a metal baseplate overlying the cortex [6,19]. Several biomechanical studies suggest increased strain in inlay designs that may lead to tibial subsidence and aseptic loosening [22–24]. A plausible explanation is that inlay designs are largely reliant on subchondral bone, while onlay designs are implanted upon more robust cortical bone. Van der List et al. found lower functional outcome scores in inlay designs when compared to onlay with a 5.1-year follow-up; however, there were no differences in revision rates [16]. This study was limited by sample size of only 111 patients. The present study analysed a large portion of inlay implants and

found inlay implants to be associated with an increased conversion to TKA on multivariate analysis; however, there was no significant difference in the time to failure between implants on survivorship analysis.

While preoperative joint space can be measured objectively, unexplained pain is much more elusive and more difficult to quantify. There are wide variations of opinions on the diagnosis and treatment of unexplained pain. Unexplained pain in our series was a major cause for revision. These patients may not have any radiographic evidence of mechanical problems on CT arthrogram or physical examination. They often complain of constant pain increased by activity which interferes with their sleep. They may describe the pain as a deep ache that may have sharp, stabbing qualities and is often described as burning. Generally, the pain is not well localized. The real difficulty is that making the diagnosis of unexplained pain preoperatively is difficult, imprecise and nuanced. Thus, it is less valuable preoperatively since it is difficult to quantitate. The presence of a pain syndrome should be evaluated pre-operatively as this limits the potential clinical benefit from UKA. A referral to pain management may be considered to maximize outcomes.

#### Limitations

The present study is limited by its retrospective nature. The included patient population is heterogeneous due to the evolving indications for UKA. This allows for greater multivariate analysis; however, selection bias also exists that may affect the interpretation of results. Lateral, medial and patellofemoral cases were included, and this was used as a variable in determining the likelihood of failure. Furthermore, data is from a single centre, multiple surgeons at a single academic centre and utilized robotic techniques rather than conventional UKA technique which may limit its external validity to different populations, institutions and countries. The use of robotic techniques has not been associated with decreased revision rates [27]. However, in doing so, this may also limit bias introduced by varying techniques and regional differences. Lastly,

not all patients were seen in clinic at latest follow-up as some were contacted by telephone. This may introduce bias as not all patients received a thorough physical exam and may have inferior outcomes that were subclinical and did not require surgery.

## Conclusions

Robotic-assisted UKA demonstrated favourable outcomes at 4 years with survivorship greater than 92% while utilizing a wider patient section than traditional indication would allow for. The results of this study agree with emerging indications that do not exclude patients based on age, BMI, or degree of deformity. Factors that were found to increase the risk of conversion to TKA were increased operative joint space, inlay design, history of surgery and coexistence of a pain syndrome.

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## Ethical approval

Ethical approval was obtained for this retrospective study by the institutional review board committee.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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