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Postoperative outcomes of total knee arthroplasty compared to unicompartmental knee arthroplasty: A matched comparison

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ABSTRACT

Background: The purpose of this study was to evaluate early postoperative outcomes in patients following UKA (unicompartmental knee arthroplasty) compared to a matched cohort of TKA (total knee arthroplasty) patients.
Methods: Patients who met radiographic criteria for a medial UKA who underwent either a TKA or UKA at a single institution were matched based on age, gender, and BMI.
Results: One hundredy and fifty UKA in 138 patients and 150 TKA in 148 patients were included in this retrospective analysis. Mean age was 62.6 ± 9 years and 65.2 ± 9 years in the UKA and TKA groups respectively ($p = .01$). Patients who underwent UKA had significantly less pain at two and six weeks postoperatively compared to TKA patients with mean Numeric Pain Rating Scale (NPRS) scores of 3.7 ± 1.1 vs. 7.8 ± 1.2, $p < .001$ and 2.6 ± 1.3 vs. 4.6 ± 1.6, $p < .001$ respectively. Knee Society Scores (KSS) were higher in the UKA group at six weeks and two years postoperative (86.5 ± 2.8 vs. 81.4 ± 3.6, $p < .001$ and 89.5 ± 2.4 vs. 84.5 ± 3.3, $p < .001$ respectively). Return to work was faster in the UKA group (mean 20.6 ± 7.89 vs. 38.6 ± 6.23 days, $p < .001$). The UKA group also had higher mean Forgotten Joint Scores of 90.5 ± 3.6 vs. 79.5 ± 9.5 ($p < .001$).
Conclusions: Patients with primarily medial compartment OA who underwent UKA had less postoperative pain, earlier return to work, and higher KSS compared to a matched group who underwent TKA.

1. Introduction

The incidence of joint replacement procedures has increased in recent years due in part to an increase in life span, an increasingly active population, and rising obesity rates [1]. Total knee arthroplasty (TKA) has been reported as the gold standard for treatment of patients with severe knee osteoarthritis (OA). However, there continues to be patient dissatisfaction with modern implant designs. Part of this dissatisfaction is related to postoperative pain, stiffness and a lengthy and difficult rehabilitation [1]. Initially, unicompartmental knee arthroplasty (UKA) was controversial [2]. As techniques and implant designs have improved, studies have demonstrated that UKA is a durable and reliable procedure that is a viable surgical option for treating a subset of medial OA of the knee [2,3].

Unicompartmental knee arthroplasty currently constitutes eight to 10% of arthroplasties performed in the United States and United Kingdom [4]. The potential advantages of UKA over TKA include improved functional outcomes, gait, proprioception, faster

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recovery, and less blood loss [4]. However, there have been lower reported implant survival rates of UKA cohorts that potentially limit its widespread use. Lyons et al. reported Kaplan–Meier survivorship at five and 10 years of 95% and 90% for UKA versus 98% and 95% for TKA in a large retrospective database analysis [5]. In contrast, Price et al. reported 91% survivorship at 20 years of 682 Oxford mobile bearing medial compartment UKAs [2]. Similarly, a recent multicenter study reported 97.5% survivorship of 432 robotic-arm-assisted fixed bearing medial UKAs at mean 5.7 years follow-up [6].

Indications for a medial UKA vary amongst surgeons. Deshmukh et al. defined unicompartmental candidates as having (1) non-inflammatory arthritis, (2) a mechanical axis that deviates no more than 10 degrees from neutral for a varus knee, (3) an intact anterior cruciate ligament without signs of mediolateral subluxation of the femur on the tibia, and (4) the patellofemoral (PF) compartment can have Grade II or III changes without PF symptoms [7]. These criteria are more inclusive than the traditional Kozinn and Scott criteria [8].

Prior studies have sought to compare results of unicompartmental versus total knee arthroplasty [1,5,9–11]. Despite controlling for a number of different factors such as comorbidities, BMI, and age, these study groups did not control for the severity of osteoarthritis in each compartment of the knee. It is not a fair assumption that patients with tricompartmental OA are the same as patients with primarily medial compartment osteoarthritis. Identifying patients based on radiographic parameters that meet defined criteria to receive a medial UKA will allow for a more meaningful comparison of outcomes. Cost-effectiveness analyses have evaluated UKA versus TKA and have demonstrated that results are sensitive to survivorship and risk of revision for UKA's [9,10]. In addition, these analyses have generally assumed that functional outcomes are similar with UKA and TKA [12,13]. As advances in implant design and surgical techniques have improved implant survivorship in UKA, a matched comparison of UKA and TKA for isolated medial compartment degenerative joint disease is critical in assessing the differences in early functional outcomes [4–6]. We hypothesized that UKA patients would have less pain and return to work faster while achieving higher postoperative function compared to patients who underwent TKA.

2. Methods

Institutional Review Board approval was obtained for this study. All patients undergoing a primary UKA or TKA for a diagnosis of OA by one of the fellowship trained surgeons (ADP, MPB, SBH, TPS, SAJ, DJM) participating in this study were prospectively enrolled in an institutional registry at a single high volume orthopedic specialty hospital as potential participants in the study. Patients were included in the study based on review of preoperative knee radiographs of all patients undergoing either TKA or UKA from 2013 to 2015. Knee radiographs were graded by two trained investigators (JLB and JAB) using the Kellgren–Lawrence (K–L) grading system in each of the three compartments. The K–L grading system has five categories based on the presence of osteophytes and joint space narrowing [14]. Inter-observer reliability between the two investigators was assessed using Interclass correlation coefficients (ICCs) [15–17]. ICCs <0.40 were interpreted as a poor inter-observer reliability, 0.40–0.59 as fair, 0.60–0.74 as good, and 0.75–1.0 as excellent [16]. ICCs for all compartments were good (medial: 0.701; lateral: 0.656; patellofemoral: 0.723).

Inclusion criteria for the cohorts included: BMI (Body Mass Index) 18–35, age 18–80 years, primarily medial compartment joint space narrowing, undergoing a primary unilateral medial UKA or unilateral TKA, with a minimum of two years of follow-up. Patients who underwent UKA or TKA on both sides in a staged manner with minimum three months separating the surgeries were included in the analysis. Exclusion criteria were: inflammatory arthritis, prior ACL or other reconstructive surgery, revision surgery, implant removal, and excessive preoperative deformity (>10 degrees of varus). Patients underwent a TKA or UKA by their respective surgeon per their standard surgical procedure and postoperative treatment protocols. The use of computer navigation and additional techniques were at the discretion of the individual surgeons. All UKAs were performed using the MAKO® robotic interactive orthopedic arm and cemented tibial onlay implant designs (MAKO® Surgical Corp., Ft. Lauderdale, FL, USA). Total knee arthroplasty patients had cemented posterior stabilized implant designs of multiple manufacturers (Smith and Nephew® Genesis II [Smith & Nephew, London, United Kingdom] (n = 84), Smith and Nephew® Journey II [Smith & Nephew, London, United Kingdom] (n = 38), Exactech® Optetrak Logic [Exactech, Gainesville, Florida] (n = 23), and Biomet® Vanguard [Zimmer Biomet, Warsaw, Indiana] (n = 5)). To account for differences between TKA implant brands and designs, sensitivity analysis tests comparing outcomes (NPRS Pain, KSS, FJS, return to work, and complications) between the four TKA implant designs were performed. No statistically significant differences were observed between these four implant designs. Pain scores via Numeric Pain Rating Scale (NPRS) and return to work were assessed postoperatively by questionnaires completed by each patient. Knee Society Scores (KSS) and Forgotten Joint Scores (FJS-12) were obtained at periodic follow-up visits out to two years postoperatively. Patients were matched 1:1 for age ± 5 years, gender, and BMI ± 3.

Prior to initiation of the study, a power analysis was performed to determine the required enrollment. The primary outcome was the average NPRS pain score at two weeks postoperative. The NPRS is reported in mean ± standard deviation. The two comparison groups were UKA versus TKA. Using an expected effect size of 1.1 with a standard deviation of 3, our power analysis showed a sample size of 102 matched pairs would achieve 96% power with two-sided significance level of 0.05.

Statistical analyses were performed using SPSS Statistics® (IBM®, Armonk, New York, USA). Comparative statistics were used for baseline demographics including student's t-test and Chi-Square and Fisher's Exact test for proportional comparisons where appropriate. The NPRS pain, KSS, and FJS-12 scores were compared using Mann Whitney U test. Return to work was compared using student's t-test. Complication rates were analyzed using Fisher's Exact test. All analyses were two-tailed. p-Values <.05 were considered statistically significant.

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Table 1
Baseline demographics in UKA and TKA groups. Values reported as means ± standard deviation or otherwise noted. BMI: Body Mass Index. The p-values were calculating using student's t-test for age and BMI assuming unequal variance, two-tailed. Gender was analyzed using Chi-Square test.

Demographics	UKA (n = 150)	TKA (n = 150)	p-Value
Age (years)	62.6 ± 9.0	65.2 ± 9.0	0.01
Gender (% male)	56%	56%	1
BMI (kg/m^2)	28.9 ± 2.4	29.0 ± 2.6	0.6

3. Results

There were 150 UKA in 138 patients and 150 TKA in 148 patients included in this study. Mean age was 62.6 ± 9.0 years and 65.2 ± 9.0 years in the UKA and TKA groups respectively (p = .01). There was no significant difference in gender and BMI between the two groups (Table 1). A comparison of the preoperative radiograph K–L grading was performed demonstrating comparable medial compartment K–L grades in both cohorts (Table 2). There was a statistically significant higher grade of PF and lateral compartment changes in the UKA group, however this was not likely clinically meaningful (Table 2). Ninety-five percent of the UKA group had Grade 0 or 1 lateral compartment changes compared to 100% of patients in TKA group. Eighty-seven percent of the UKA group had Grade 0 or 1 PF changes and 13% had Grade 2 changes. Ninety-seven percent of the TKA group had Grade 0 or 1 PF changes. Both cohorts met radiographic inclusion criteria for the comparison.

Baseline pain scores were worse in the TKA group (Figure 1). At two weeks postoperative, patients in the UKA group had lower mean NPRS scores of 3.7 ± 1.1 compared to 7.8 ± 1.2 in the TKA group (p < .001). At six weeks postoperative, UKA patients continued to have on average less pain compared to TKA patients (2.6 ± 1.3 vs 4.6 ± 1.6 p < .001) (Table 3). Baseline KSS were lower in the UKA group (mean 69.6 ± 4.2 vs 73.0 ± 6.4 p < .001). However, the UKA group had higher KSS compared to the TKA group (86.5 ± 2.8 vs 81.4 ± 3.6, p < .001) at six weeks and two years postoperative (89.5 ± 2.4 vs 84.5 ± 3.3 p < .001) (Table 3). Both groups had improvement in KSS from baseline (Figure 2). The UKA group had larger mean improvements in KSS from baseline of 19.9 ± 4.3 vs 11.5 ± 7.0, p < .001. On average, the UKA group returned to work faster than the TKA group (20.6 days ±7.89 [Range six to 41 days] vs. 38.6 ± 6.23 days [Range 20–80 days], p < .001) (Figure 3). At two years, the UKA group had a significantly higher mean FJS-12 of 90.5 ± 3.6 compared to 79.5 ± 9.5 in the TKA group (p < .001).

There were eight additional surgeries in seven patients in the UKA group and nine additional surgeries in seven patients in the TKA group (Table 4). There were a significantly higher number of manipulations under anesthesia in the TKA group (6 vs 0, p = .03). The two groups had a similar number of additional arthroscopic surgeries. The TKA group underwent five arthroscopic lysis of adhesions for treatment of postoperative stiffness. The UKA group underwent four additional arthroscopic procedures for treatment of symptoms in other compartments (patella chondroplasty, lateral meniscectomy, synovectomy). There were no major revisions in either group at two years of follow-up. However, three minor revisions (polyethylene exchanges) were performed in each group for periprosthetic joint infection (PJI) or instability (Table 4).

4. Discussion

There continues to be a debate over what is the most effective treatment for symptomatic primary medial compartment OA. This study demonstrated that in a matched cohort of patients who met radiographic criteria for a UKA, those who underwent UKA had improved function, pain, and similar complication rates to those who underwent TKA. The importance of accurate restoration of ideal alignment in the prevention of opposite compartment degeneration and component failure is critical in UKA [1]. Recently, robotic assisted UKA has been employed to improve postoperative alignment with demonstrated accuracy in a randomized controlled trial comparing MAKO® robot assisted versus traditional Oxford instrumentation UKA [4]. By maximizing the success of both groups in this study using all available technology at hand, accurate component positioning is achieved and a reliable comparison can be made between the two procedures.

Return to activity continues to be an important factor after knee arthroplasty. Patients often present with the expectation of return to the activities they enjoyed prior to their limitations from knee OA. A recent systematic review by Waldstein et al. reported that patients following a UKA were physically active, and had a significant increase in low-impact activities and a decrease in high-impact activities [18]. Furthermore, the return to activity rate ranged from 87 to 98% [18]. Our study analyzed return to work as a measure of return to activity with significant benefit shown in the UKA group.

Table 2
Comparison of Kellgren-Lawrence Scale Grading of each compartment on preoperative radiographs between UKA and TKA groups. Analysis was performed using the Fisher's exact test.

Compartment	UKA (n = 150)	TKA (n = 150)	p-Value
Medial (% KL ≥ 3)	86%	91%	0.280
Lateral (% KL ≥ 2)	5%	0%	0.007
Patellofemoral (% KL ≥ 2)	13%	3%	0.002

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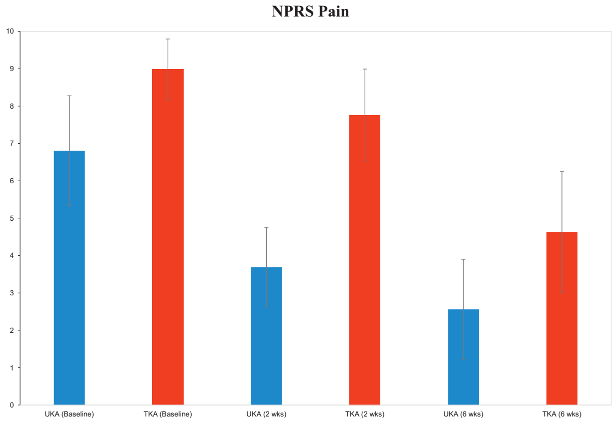

Figure 1. Comparison of Numeric Pain Rating Scale (NPRS) pain scores between UKA and TKA groups at preoperative and postoperative time points. Error bars are standard deviations. There were statistically significant differences ($p < .05$) in pain scores at all time points as calculated by Mann Whitney U test.

Numerous studies have reported faster recovery and clinical benefit of UKA compared to TKA [11,19,20]. However, concerns regarding long-term survivorship have been voiced for UKA. Changes in implant designs and techniques have sought to improve long-term survivorship and function. Recently, a meta-analysis of survivorship of UKA vs. TKA reported annual revision rates of 0.49% in TKA patients compare to 1.07% in medial UKA patients [21]. Prospective mid-term survivorship analysis of the type of fixed-bearing robotic-assisted medial UKA utilized in this study has recently been reported with 98.8% survivorship at 2.5 years and 97.5% survivorship at mean 5.7 years of follow-up [3,6]. Our study had no both component revisions at two years of follow-up. There were three polyethylene exchanges in each group. The UKA group had three polyethylene exchanges for the treatment of acute PJI without need for two-stage revision. These infections may have been related to a reported higher incidence of infection attributed to the use of a barbed absorbable suture in these patients [22]. The TKA group had two polyethylene exchanges for treatment of acute PJI and one for the management of mid-flexion instability. Overall, complications were similar with the exception of a higher number of additional interventions related to stiffness in the TKA group (Table 4).

There are a small number of studies who have attempted to compare outcomes in patients with comparable preoperative radiographs with limited medial compartment OA and symptoms [19,23,24]. Siman et al. performed a retrospective review of registry data from the Mayo Clinic of patients over the age of 75 years who underwent TKA or UKA. They analyzed preoperative radiographs and included those who met criteria for a medial UKA with a final comparison of 120 UKA and 188 TKA at mean 3.5 years of follow-up. The authors found no significant difference in KSS between the included UKA and TKA patients (85.4 vs 84.0) at minimum two-year follow-up. They found no difference in five-year survivorship estimates of UKA and TKA at 98.3% vs 98.8% respectively in their analysis [19]. Similar to our findings, there were similar complication rates in the two groups. Our study differed in the inclusion of younger patients and the analysis of early pain and functional outcomes. Our study demonstrated statistically significant larger improvements in pain and KSS scores at two years in the UKA group compared to the TKA group. Additionally, our study captured important patient outcomes such as return to work and awareness of their joint with demonstrated advantages in the UKA group (Figure 3, Table 3). Newman et al. reported their 15-year results of a randomized trial of UKA vs TKA for treatment of medial compartment OA and reported no difference in survivorship or complications with durable improved clinical outcomes in the UKA group [23]. Yang et al. compared the six-month outcomes of patients who underwent UKA or TKA with primarily medial compartment OA, demonstrating a quicker recovery of function, improved range of motion, and shorter hospitalization [24]. Limitations of these studies are the lack of direct analysis of the radiographic degenerative disease in each compartment and analysis of early pain control and return to work.

A NPRS pain score difference of two points or more is considered clinically relevant in arthroplasty pain outcome studies [25,26]. Salaffi et al. demonstrated that a two point difference on the NPRS was correlated with a “much better” improvement of a patient's global impression of change [26]. With this threshold in mind, the findings in this study are clinically meaningful

Table 3
Comparison of mean outcome measures post UKA and TKA. Values reported as means ± standard deviations. NPRS: Numeric Pain Rating Scale, KSS: Knee Society Score, FJS-12: Forgotten Joint Score-12. p-Values calculated using Mann Whitney U test.

Outcome Scores	UKA (n = 150)	TKA (n = 150)	p-Value
NPRS Pain (2 weeks)	3.7 ± 1.1	7.8 ± 1.2	<0.001
NPRS Pain (6 weeks)	2.6 ± 1.3	4.6 ± 1.6	<0.001
KSS (6 weeks)	86.5 ± 2.8	81.4 ± 3.6	<0.001
KSS (2 years)	89.5 ± 2.4	84.5 ± 3.3	<0.001
FJS-12 (2 years)	90.5 ± 3.6	79.5 ± 9.5	<0.001

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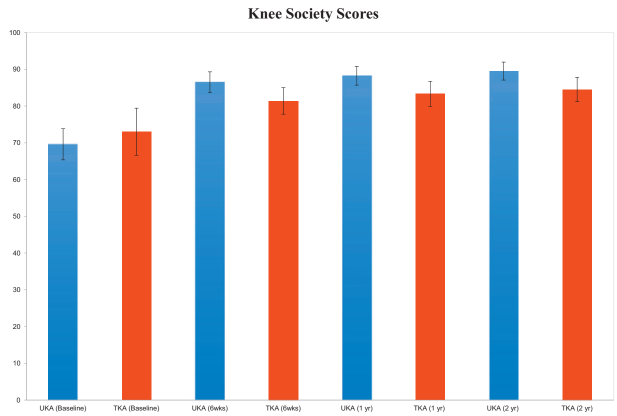

Figure 2. Comparison of Knee Society Scores at preop and follow up time points. Error bars are standard deviations. There were statistically significant differences ($p < .05$) in pain scores at all time points as calculated by Mann Whitney U test.

with significant differences in average pain scores between UKA and TKA groups at two weeks (mean difference 4.1 points) and six weeks (mean difference two points) postoperatively (Table 3).

The Knee Society Score is a commonly reported outcome measure following TKA and UKA. Lee et al. defined the minimum clinically important difference (MCID) for this outcome measure using two anchor-based approaches based on patient satisfaction and the reported MCID of the Oxford Knee Score [27]. The authors determined that a difference of 5.3–5.9 based on these two anchor-based methods represented the MCID of the KSS Knee Score [27]. In our study, both groups achieved MCID at two years postop. However, the UKA group had larger mean improvements in KSS from baseline of 19.9 ± 4.3 compared to 11.5 ± 7.0 in the TKA group ($p < .001$). The differences in KSS at six weeks (mean 5.1 points) and at two years (mean 5.0 points) did not reach MCID however they were statistically better at both time points in the UKA group ($p < .001$).

The Forgotten Joint Score (FJS-12) was used in this study as a measure of patient awareness of their knee at two years postop. This score is a validated measure of joint awareness with limited ceiling effects and has been used in a number of studies comparing outcomes of knee arthroplasty [20,28–31]. Kim et al. (demonstrated a significant difference in FJS-12 of UKA compared to TKA (67.3 ± 19.8 and 60.6 ± 16.6, respectively) in a propensity score matched analysis [20]. Our study supported their findings and demonstrated higher average FJS-12 scores in both groups with a mean difference of 11 points between the UKA and TKA groups (Table 3).

There are several limitations of our study. This was a retrospective review of data collected in a registry. Only those patients who completed follow-up questionnaires were included which may have biased the results towards those patients who were doing better or were more pleased with their outcomes. The reviewer of radiographs was not blinded to whether patients underwent TKA or UKA. Some patients may have followed up elsewhere with complications not captured in the analysis. Additional confounders may not have been controlled for such as comorbidities and other preoperative factors including potentially different disease related symptoms, baseline activity levels, and disability and higher baseline NPRS pain and KSS in the TKA cohort. Our investigation did not match for every demographic characteristic which could influence the

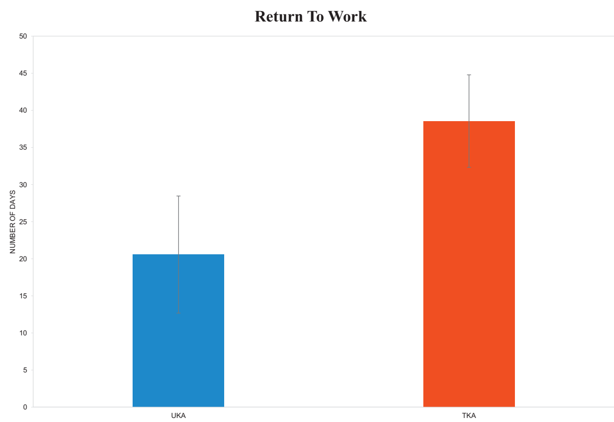

Figure 3. The UKA group returned to work at an average of 20.6 days ±7.89 [Range 6–41 days] compared to the TKA group, which returned to work at an average of 38.6 ± 6.23 days [Range 20–80 days] ($p < .001$). Error bars are standard deviations. P-value calculated using Mann Whitney U test.

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Table 4
Complications post UKA and TKA. MUA: Manipulation under anesthesia, LOA: Lysis of adhesions, PJI: Periprosthetic joint infection, I&D: Irrigation and debridement. P-values calculated using Fisher's Exact Test.

Complications	UKA (n = 150)	TKA (n = 150)	p-Value
Additional surgeries	8	9	1.0
MUA	0	6	0.03
Arthroscopic LOA	0	5	0.06
Arthroscopic Debridement	4	0	0.1
Polyethylene exchange for instability	0	1	1.0
PJI	2	1	1.0
I&D Polyethylene Exchange	3	2	1.0
Superficial I&D	1	1	1.0

decision-making between surgeon and patient (e.g. patient activity level, patient expectations, radiographic characteristics, and a patients' overall health) [32].

The Mako robotic interactive arm was used for the UKA's but not for the TKA's included in this study. This may have been a potential confounder for differences in postoperative outcomes in the TKA group; however, all arthroplasties were performed by high volume fellowship-trained arthroplasty surgeons. Use of the robotic arm helps protect the soft tissues around the knee during surgery by restricting movement of the cutting instrument to a haptic boundary in comparison to the use of conventional guides [33–35]. This soft tissue protection may have potentially contributed to the decreased postoperative pain and allowed for earlier return of function in the UKA group [36–38]. To our knowledge there are no published comparisons of early recovery and PROMs of robotic assisted UKA compared to robotic assisted TKA in a matched cohort of patients and this would require further investigation.

Furthermore, use of UKA for treatment of primarily medial compartment OA remains controversial to some surgeons owing to the higher reported revision rates in registries and controversies over appropriate indications [32]. Although robotic assisted UKA may potentially improve early revision rates, this has not been clearly proven with high-quality randomized controlled data, which could influence the choice of the surgeons. A recent randomized controlled trial by Beard et al. of 528 patients who underwent UKA or TKA found equivalent revision and complication rates at five years supporting the choice of UKA in the setting of end stage medial compartment osteoarthritis [39]. The higher rate of revision in published registries may be a manifestation of poor technique, however it can also be a result of inappropriate indications, which will not be solved by a robotic assisted UKA. Additionally, a recent study has shown that a high volume UKA surgeon can achieve accurate component placement at a level comparable to or exceeding robotic navigation [40].

Postoperative protocols were not standardized between groups and between individual surgeons, however this may make the findings more generalizable to other practices. Not all surgeons in this study routinely performed UKA and therefore only offered TKA. Only UKA and TKA performed by high volume fellowship-trained surgeons were included in this study. This investigation included four different TKA posterior stabilized knee designs in the TKA cohort. While different TKA implant designs may have an effect on PROM's, a recent study found no clinically meaningful differences between five commonly used implant designs (three of which were included in this study) at two years [41]. A sensitivity analysis of our cohort did not find a statistically significant effect on any of the outcome measures collected in this study. We will continue to follow these cohorts at five- and 10-year follow-up to determine the durability of the reported outcomes and survivorship.

5. Conclusions

This study demonstrated that in a matched cohort of patients who met radiographic criteria for a UKA, those who underwent UKA had improved function, pain, lower joint awareness, and similar complication rates to those who underwent TKA. These findings may be used in counseling patients with primarily medial compartment OA in the preoperative setting to help patients decide between these two arthroplasty options.

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