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Predictors of Subjective Outcome After Medial Unicompartmental Knee Arthroplasty

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A B S T R A C T

Background: Unexplainable pain after medial unicompartmental knee arthroplasty (UKA) remains a leading cause for revision surgery. Therefore, the aim of this study is to identify the patient-specific variables that may influence subjective outcomes after medial UKA to optimize results.
Methods: Retrospectively, we analyzed 104 consecutive medial UKA patients. The evaluated parameters consisted of age, body mass index, gender, preoperative radiographic severity of the various knee compartments, and preoperative and postoperative mechanical axis alignments.
Results: At an average of 2.3-year follow-up, our data demonstrate that body mass index, gender, and preoperative severity among the various knee compartments do not influence Western Ontario and McMaster Universities Arthritis Index (WOMAC) results. Preoperatively, patients aged <65 years had inferior WOMAC stiffness (4.6 vs 2.9, $P = .001$), pain (9.7 vs 7.6, $P = .041$), and total (37.2 vs 47.6, $P = .028$) scores vs patients aged ≥65 years. Postoperatively, only the difference on the WOMAC stiffness subscale remained significant between both age groups, in favor of patients aged ≥65 years (1.0 vs 1.5, $P = .035$). A postoperative varus mechanical axis alignment of 1°-4° correlated to significantly superior WOMAC pain ($P = .03$), function ($P = .04$), and total ($P = .04$) scores compared to a varus of ≤1° or ≥4°.
Conclusion: Our data suggest that greater pain relief can be expected in patients aged <65 years and that a postoperative lower limb alignment of 1°-4° varus should be pursued. Taking these factors into consideration will help to maximize clinical outcomes, fulfill patient expectations after medial UKA, and subsequently minimize revision rates.

Treatment options for isolated medial unicompartmental osteoarthritis (OA) of the knee have long been a subject of debate. Operative techniques for isolated medial compartmental OA include high tibial osteotomy, unicompartmental knee arthroplasty (UKA), and total knee arthroplasty. Early results of UKA were discouraging, with failure rates of up to 30% reported by Insall and Aglietti [1]. In response to these initial results, Kozinn and Scott [2] proposed a set of criteria to define the ideal medial UKA candidate. These criteria included (1) low functional demand, (2) age >60 years, (3) weight <82 kg, (4) range of motion >90°, (5) minimal pain at rest, (6) flexion contracture <5°, and (7) a passively correctable angular deformity.

Strict adherence to these guidelines improved implant designs, and advanced surgical techniques have contributed to a resurgence of UKA as a treatment modality, evidenced by satisfying survivorship results, excellent outcome scores, and a constant growth trend in the utilization of UKA [3-7]. Although various series report similar survivorship results of UKA and total knee arthroplasty [8-10], national registries continue to show higher revision rates after UKA [11-15]. Persistent unexplainable pain continues to be a leading cause of revision surgery [12,15].

To optimize outcomes and minimize the incidence of revision, it is essential to clarify the various patient-specific characteristics that may influence subjective outcomes. Using a large prospective cohort, the purpose of this study was to identify and evaluate the impact of various preoperative patient variables, including radiographic parameters, on the subjective outcomes of patients

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undergoing medial UKA. This study aims to optimize the outcomes of patients receiving medial UKA by better managing patient expectations and decreasing the risk of subsequent revision.

Methods

This study is based on a prospective cohort of patients assembled for the OA database of the senior author. After institutional review board approval by our hospital, an electronic registry search was performed for all patients who underwent medial UKA between October 2010 and June 2012. Surgical inclusion criteria for UKA were (1) isolated medial unicompartmental OA, (2) intact anterior cruciate ligament, (3) correctable varus deformity of the medial compartment, and (4) a fixed flexion deformity of <10°. The presence of preoperative radiographic Kellgren and Lawrence [16] grade III-IV OA in the lateral compartment was considered to be a contraindication for UKA. Furthermore, patellofemoral (PF)-related joint symptoms (anterior knee pain with sitting, ie, “movie theater sign”) were also considered as a contraindication. Patients with any history of trauma, anterior cruciate ligament deficiency or reconstruction, inflammatory arthritis, or prior simultaneous bilateral UKA were excluded from the study.

Implant and Surgical Technique

All enrolled patients received the identical cemented fixed-bearing RESTORIS MCK Medial Onlay implant (MAKO Surgical Corporation, Fort Lauderdale, FL). This tibial onlay implant has a metal base plate and is placed on the top of a flat tibial cut, supported by a rim of cortical bone for direct support. A robot-assisted surgical platform [17,18] (MAKO Tactile Guidance System; MAKO Surgical Corporation) was used for preparation of the tibial and femoral surfaces during medial UKA. The goal was a relative undercorrection from the preexisting varus deformity to avoid osteoarthritic progression of the lateral compartment.

The senior author, who has extensive experience in robot-assisted UKA, performed all surgeries.

Investigated Parameters

The investigated variables were divided into 2 groups: (1) patient specific and (2) radiographic. The potential subjective influence was retrospectively analyzed using the database that consisted of the prospectively collected data. Patient-specific variables consisted of age, gender, and body mass index (BMI). Patients were classified as young or old based on a cutoff value of 65 years of age. Using the official World Health Organization definition, a cutoff of 30 kg/m^2 was used to classify patients as nonobese or obese.

Radiographic variables included preoperative severity of OA in the medial compartment, lateral compartment, PF compartment, and mechanical axis alignment. OA severity was classified on the Kellgren and Lawrence scale, using preoperative weight-bearing anteroposterior radiographs of the knee [16]. The mechanical axis alignment was measured on weight-bearing hip-to-ankle radiographs, using the hip-knee-ankle (HKA) angle [19]. Preoperative HKA angles were subdivided into 3 groups by varus (A: <5°, B: 5°-10°, C: >10°) to evaluate their effects on postoperative functional outcomes. Postoperative HKA angles were similarly divided into 3 groups by varus: (1) ≤1°, (2) 1°-4°, (3) ≥4°. Radiographs were obtained preoperatively and at 6 weeks postoperatively.

Outcomes

Patients with inadequate follow-up or missing data that were operated between October 2012 and June 2012 were excluded from the study. Patients were asked to complete the Western Ontario and McMaster Universities Arthritis Index (WOMAC) questionnaire as part of the routine workup, preoperatively and at a minimum of 2.0 years (average: 2.3 years, range: 2.0-3.7 years) after surgery. The WOMAC is a broadly used questionnaire used to evaluate physical function and symptoms in patients with OA of the hip or knee. The survey consists of 24 items, subdivided within 3 domains: pain (5 questions, range: 0-20), stiffness (2 questions, range: 0-8), and physical function (17 questions, range: 0-68). The sum of the 3 domain scores produces a total score (range: 0-96). A score of 0 represents the best possible outcome and a score of 96 the worst (Likert Scale). This study evaluated both the total WOMAC score and individual domain scores for each parameter studied, both preoperatively and at 2-year follow-up.

Statistical Analysis

Descriptive analyses were reported using means and standard deviations (±) for continuous variables and frequencies and percentages for discrete variables. Inferential statistics of all patient-reported outcome measures were performed using independent sample *t* tests (or one-way analysis of variance) for differences in continuous variables and chi-square or Fisher's exact tests for categorical variables. All analyses were performed using SPSS version 21.0 (IBM SPSS Statistics for Windows, version 21.0; IBM Corp., Armonk, NY). A *P* value <.05 was considered as statistically significant.

Results

Overall, 232 patients underwent medial UKA between October 2010 and June 2012. Preoperative or postoperative WOMAC scores were absent in 72 patients. Standardized radiographic follow-up evaluation (which included long leg alignment films) was unable in 56 patients. As such, 104 medial UKA patients (55 men, 49 women) with both a complete radiographic survey and patient-reported outcome measures were available for inclusion in this study. None of these patients underwent revision surgery during the follow-up time. The average age at the time of surgery was 65.0 years (±9.2, range: 47.1-86.8). Seventy-two patients (69.2%) had a BMI <30 kg/m^2 (average: 26.2, range: 18.3-29.7) and 32 patients (30.8%) had a BMI ≥30 kg/m^2 (average: 33.2, range: 30.0-39.1). A significant improvement of all WOMAC domains was noted after UKA implantation (Fig. 1).

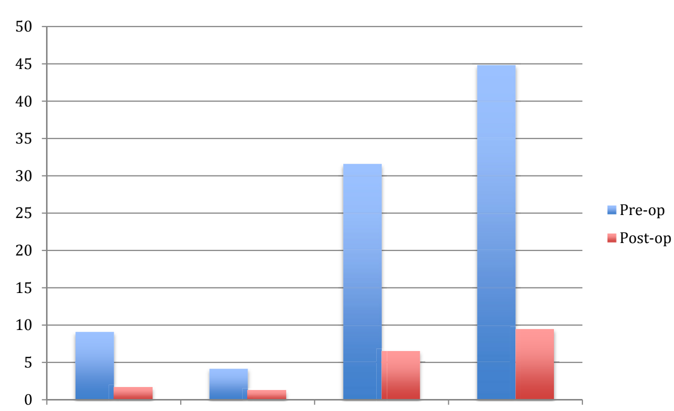

Fig. 1. Improvement of the various Western Ontario and McMaster Universities Arthritis Index domains after medial unicompartmental knee arthroplasty at an average of 2.3-year follow-up. All domains showed a significant (*P* < .01) improvement at the time of follow-up.

Table 1
Distribution of the Preoperative and Direct Postoperative Varus Mechanical Axis Alignment.

HKA Angle (Varus)	N
Preoperatively	
0°-5°	23
5°-10°	56
10°-15°	25
Postoperatively	
0°-<1°	28
1°-4°	42
>4°	32

Two patients were overcorrected into valgus.
HKA, hip-knee-ankle.

The average preoperative mechanical axis alignment was 7.6° (±3.8°) of varus, which decreased to 2.8° (±2.2°) of varus postoperatively ($P < .0001$). Twenty-three patients had a preoperative varus deformity of <5° (average: 3.1°, range: 0.1°-4.6°), 56 a varus deformity of 5°-10° (average: 7.1°), and 25 a varus deformity of >10° (average: 12.9°, range: 10.1°-16.0°). Postoperatively, 2 patients were overcorrected (respectively 3.4° and 1.6° of valgus). Twenty-eight patients had an HKA angle between 0° and ≤1° varus (average: 0.6°), 42 an HKA angle between 1° and 4° of varus (average: 2.5°) and 32 a varus deformity of ≥4° (average: 5.6°, range: 4.1°-8.1°; Table 1). The distribution of osteoarthritic severity by compartment is displayed in Table 2. Radiolucent lines were present in 38% of cases. None of them were identified as pathologic.

Preoperative WOMAC Scores

Preoperatively, we noted that patients aged <65 years reported significantly more pain (9.7 vs 7.6, respectively, $P = .041$) and stiffness (4.6 vs 2.9, respectively, $P = .001$) than patients >65 years. In addition, total preoperative WOMAC scores were significantly inferior among the younger group (37.2 vs 47.6, $P = .028$). No significant differences were noted between groups for the remaining patient-specific or radiographic parameters examined (Table 3).

Improvement After Medial UKA

Evaluation of improvement after medial UKA revealed significant differences in favor of patients aged <65 years vs patients aged >65 years on the WOMAC pain subscale (Δ7.7 vs Δ6.3, $P = .04$) and WOMAC total score (Δ36.4 vs Δ29.4, $P = .002$). The other investigated parameters did not show significant differences in the magnitude of improvement after medial UKA implantation.

Postoperative WOMAC Scores

Postoperative WOMAC stiffness scores differed significantly in favor of patients aged >65 years ($P = .035$). The preoperative significant WOMAC pain subscale and total subscale differences were absent between young and old patients at an average of 2.3 years after surgery. BMI, gender, and the preoperative severity of OA did not significantly influence the WOMAC domains at final follow-up (Table 4). Evaluation of radiographic parameters revealed a strong correlation between postoperative mechanical axis alignment and WOMAC scores across multiple domains. Patients with a postoperative HKA between 1° and 4° reported significantly superior WOMAC scores in the domains of pain, function, and total score vs patients with a postoperative HKA angle ≤1° or ≥4° (Table 5).

Table 2
Distribution of the Number of Patients With the Measured Kellgren and Lawrence (KL) Grades of the Various Compartments Preoperatively.

	KL Grade				
	0	1	2	3	4
Medial compartment	—	—	30	50	24
Lateral compartment	51	32	21	—	—
Patellofemoral compartment	41	49	14	—	—

Discussion

A limited number of articles have been published about the potential factors that can influence subjective outcomes of patients undergoing UKA [20,21]. To our knowledge this is the first cohort study of patients undergoing medial UKA receiving the same medial unicondylar implant using an identical robot-assisted technique in which clinical and radiographic parameters have been examined.

When considering the potential influence of patient-specific preoperative factors, our data suggest that younger patients reported significantly more pain preoperatively ($P = .041$). This supports our opinion that higher baseline physical activity levels in a younger population result in a relatively greater imposition of limitations on daily function stemming from isolated unicompartmental OA. These limitations are exacerbated by the progression of OA as a direct consequence of greater physical activity, creating a self-perpetuating cycle. Furthermore, the data suggest that younger patients benefit from a higher degree of pain relief than patients aged ≥65 years who underwent medial UKA. Postoperatively, these reported pain differences were no longer present (Fig. 2 and Table 4). Scores in the stiffness domain, however, remained significantly different between both age groups at final follow-up. However, it should be questioned if this difference (WOMAC stiffness score: Δ0.5) is clinically relevant.

The optimal range of lower limb alignment after UKA remains a subject of debate. Various authors have stated that varus alignment of >8°-10° is associated with accelerated polyethylene wear and implant loosening [22-24]. This has led some to suggest that lower limb alignment after UKA should aim for a neutral angle [25,26], whereas others opine that mild varus within 6° is preferable [27]. However, the majority of such studies use implant failure as an end point. In contrast, this study evaluates the potential effect of postoperative lower limb alignment on functional outcomes with successful implants. Our findings suggest that a postoperative varus angle of 1°-4° should be pursued when performing medial UKA to optimize subjective results. This corresponds with the results of a recent retrospective report by Vasso et al [28]. Evaluating 125 medial fixed-bearing UKA samples at an average follow-up of 7.6 years (range: 3.5-9.3), the authors reported higher International Knee Society Score (IKS) knee scores among patients with a mild postoperative varus deformity (ie, 1°-7°) in comparison to patients with a postoperative neutral alignment. Future studies are needed to evaluate the relation and mechanism between lower leg alignment, clinical outcome, and revision over a longer follow-up period.

To our knowledge, only 2 studies have been published evaluating the effect of various factors and their influence on patient-reported outcomes. Thompson et al [21] performed a similar study in 229 patients who underwent UKA. Using the Knee Society Score (KSS), they noted that patients aged <60 years had significantly superior KSS scores at 2-year follow-up, suggesting that younger patients are better candidates to undergo UKA. Although our data did not display significant differences at final follow-up, the findings suggest that younger patients did benefit from

Table 3
Preoperative WOMAC Subscales and WOMAC Total Scores.

	Number	Pain (95% CI)	Stiffness	Function	WOMAC Total
Age					
<65	56	9.7 (8.6-10.7)	4.6 (4.1-5.1)	33.3 (29.8-36.8)	47.6 (42.8-52.3)
65+	48	7.6 (5.8-9.3)	2.9 (2.0-3.7)	26.9 (21.1-32.7)	37.2 (29.3-45.1)
P value		.041	.001	.064	.028
Gender					
Male	55	8.7 (7.5-9.9)	4.2 (3.6-4.9)	29.4 (25.3-33.6)	42.4 (36.7-48.1)
Female	49	9.5 (8.2-10.8)	4.1 (3.4-4.7)	33.9 (29.5-38.3)	47.4 (41.4-53.4)
P value		.39	.741	.144	.235
BMI					
<30	72	9.1 (8.0-10.2)	4.2 (3.7-4.8)	31.2 (27.6-34.9)	44.5 (39.5-49.5)
30+	32	9.1 (0.8-7.4)	4.0 (3.1-4.9)	32.2 (26.6-37.9)	45.3 (37.6-53.0)
P value		.981	.681	.768	.869
Medial KL grade					
I-II	30	9.9 (8.3-11.4)	4.1 (3.3-4.9)	35.5 (30.4-40.6)	49.5 (42.5-56.4)
III-IV	74	8.7 (7.5-9.8)	4.2 (3.6-4.8)	29.4 (25.6-33.1)	42.1 (37.0-47.3)
P value		.211	.832	7.5	.096
Lateral KL grade					
0	51	9.1 (8.1-10.1)	3.7 (3.1-4.3)	31.0 (26.8-35.1)	43.8 (40.8-46.7)
I	32	9.2 (8.1-10.3)	4.4 (4.0-4.9)	32.6 (27.6-37.6)	46.1 (41.9-50.3)
II	21	9.0 (8.1-10.0)	3.4 (2.9-3.8)	30.8 (28.0-33.7)	43.2 (39.8-46.5)
P value		*	*	*	*
PF KL grade					
0	41	9.1 (8.2-10.3)	3.6 (3.0-4.1)	30.2 (25.0-35.2)	42.9 (36.8-49.0)
I	49	9.1 (8.2-10.2)	4.4 (3.7-5.0)	33.6 (27.8-37.3)	47.0 (41.5-52.6)
II	14	8.7 (7.5-10.0)	4.0 (3.3-4.6)	30.4 (26.0-34.1)	43.0 (39.3-46.8)
P value		*	*	*	*

Patients <65 years had inferior WOMAC pain (*P* value = .041), stiffness (*P* value = .001) and WOMAC total (*P* value = .028) scores pre-operatively compared to patients >65 years.
All the preoperative differences between the various preoperative severity classes of osteoarthritis were not significant (*$P > .05$).
BMI, body mass index; KL, Kellgren and Lawrence; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

greater pain relief after medial UKA. Thompson et al also found that patients with a BMI >35 may experience slower postoperative improvement, as significant differences were still present at 1-year follow-up. Despite these results, however, there are some factors in the design of this study that should be taken into account when interpreting the results. The aforementioned study included patients who underwent medial UKA and patients who had undergone lateral UKA. As both compartments differ considerably [29,30], it can be inaccurate and misleading to draw conclusions about medial UKAs based on lateral UKA results. Secondly, 4 different implants were used vs a single uniform implant in the present study.

The second study regarding potential factors influencing subjective outcomes was performed by Xing et al [20], including patients who underwent UKA at an average follow-up of 33 months (range: 17-66). The study did not find any significant influence of age, BMI, or PF OA on the final WOMAC scores. However, Xing et al

Table 4
Postoperative WOMAC Subscales and WOMAC Total Scores.

	Number	Pain (95% CI)	Stiffness	Function	WOMAC Total
Age					
<65	56	2.0 (1.3-2.7)	1.5 (1.2-1.8)	7.6 (5.2-10.0)	11.1 (7.9-14.4)
65+	48	1.3 (0.6-2.1)	1.0 (0.6-1.3)	5.6 (3.0-8.1)	7.9 (4.4-11.3)
P value		.175	.035	.261	.175
Gender					
Male	55	2.0 (1.3-2.7)	1.4 (1.0-1.7)	7.7 (5.3-10)	11.1 (7.8-14.3)
Female	49	1.3 (0.6-2.1)	1.1 (0.7-1.5)	5.5 (2.9-8.0)	7.9 (4.3-11.4)
P value		.165	.368	.221	.195
BMI					
<30	72	1.8 (1.1-2.4)	1.3 (1.0-1.6)	6.7 (4.5-8.8)	9.8 (6.8-12.7)
30+	32	1.5 (0.6-2.5)	1.1 (0.6-1.6)	6.6 (3.4-9.7)	9.2 (4.9-13.6)
P value		.684	.534	.949	.836
Medial KL grade					
II	30	1.9 (0.8-2.9)	1.5 (1.0-2.0)	7.6 (4.1-11.2)	11.0 (6.2-15.9)
III-IV	74	1.6 (1.0-2.3)	1.3 (1.0-1.6)	6.7 (4.6-8.9)	9.6 (6.8-12.5)
P value		.686	.449	.666	.618
Lateral KL grade					
0	51	1.6 (1.2 -2.0)	1.3 (0.9-1.7)	5.7 (4.5-6.8)	8.6 (6.4-10.6)
I	32	1.8 (1.4-2.2)	1.5 (1.2-1.8)	7.5 (5.5-9.3)	10.8 (8.8-12.6)
II	21	1.8 (1.4-2.3)	0.9 (1.6-1.1)	7.0 (6.0-8.0)	9.7 (8.3-11.0)
P value		*	*	*	*
PF KL grade					
0	41	1.8 (1.4-2.2)	1.3 (0.9-1.7)	5.3 (4.5-6.1)	8.4 (7.1-9.9)
I	49	1.5 (1.1-1.9)	1.3 (0.9-1.8)	6.7 (5.3-7.9)	9.5 (8.0-11.0)
II	14	2.1 (1.5-2.5)	1.0 (0.7-1.4)	9.8 (8.1-11.7)	12.9 (10.3 -14.5)
P value		*	*	*	*

Only the post-operative stiffness score remained significant in favor of patients >65 years ($P = .035$).
All the postoperative differences between the various preoperative severity classes of osteoarthritis were not significant (*$P > .05$).
BMI, body mass index; KL, Kellgren and Lawrence; PF, patellofemoral; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

Table 5
WOMAC Scores in the Various Pre-and Post-Operative Alignment Groups.

Pre-op varus (SD)	Pain	Stiffness	Function	Total
<5°	8.2 (±0.8)	4.3 (±1.8)	29.0 (±7.1)	41.5 (±7.6)
5°-10°	9.6 (±4.4)	4.4 (±1.6)	31.9 (±12.5)	45.9 (±17.2)
>10°	8.7 (±2.6)	3.6 (±1.7)	32.7 (±10.7)	45.0 (±13.6)
P value	*	*	*	*
Post-op varus (SD)	**Pain**	**Stiffness**	**Function**	**Total**
<1°	2.3 (±2.8)	1.2 (±1.4)	7.1 (±9.2)	10.6 (±13.0)
1°-<4°	1 (±1.5)	1.2 (±1.2)	4.6 (±6.4)	6.8 (±8.5)
>4°	2.1 (±2.7)	1.3 (±1.4)	8.6 (±8.9)	11.9 (±12.5)
P values				
<1° vs 1°-<4°	0.01	0.95	0.04	0.03
<1° vs >4°	0.77	0.83	0.52	0.68
1°-<4° vs >4°	0.03	0.75	0.03	0.04

A postoperative varus mechanical axis alignment of 1-4° correlated to significantly superior WOMAC pain, function and total scores compared to a varus of ≤1° or ≥4°.
None of the preoperative p-values were considered significant between the different groups (*P-value > .05).
HKA, hip-knee-ankle; SD, standard deviation; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

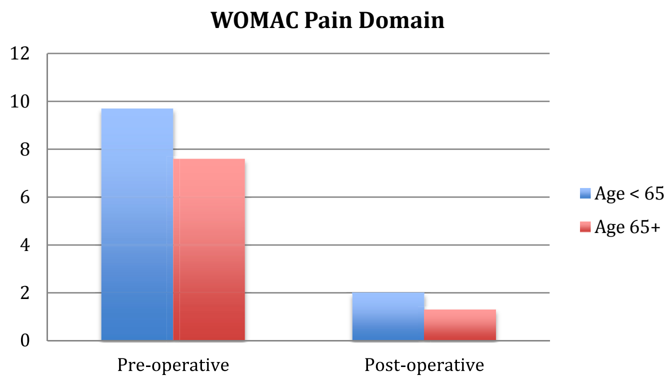

Fig. 2. Preoperatively, patients aged >65 years had less pain than patients <65 years (7.6 vs 9.7, $P = .041$). Two years after surgery, these differences were absent (1.3 vs 2.0, $P = .175$), meaning that younger patients will have a greater relieve of pain after medial unicompartmental knee arthroplasty. WOMAC, Western Ontario and McMaster Universities Arthritis Index.

also combined results of medial and lateral UKAs with the same analytical limitations as discussed previously. Secondly, all-polyethylene tibial components (n = 89) and metal-backed tibial components (n = 89) were included. Recent studies have demonstrated that these are functionally nonequivalent, as load across the tibial surface may be better transferred using metal-backed tibial components [31], leading to superior WOMAC scores [32] and lower rates of failure [33].

In our cohort, the BMI does not appear to influence subjective outcomes after medial UKA. The literature surrounding this relationship is ambiguous. Using a cohort of 80 knees undergoing medial UKA (minimum follow-up: 2 years, BMI cutoff: 35 kg/m^2), Bonutti et al [34] concluded that UKA should be approached with caution in obese patients in the setting of higher failure rates and inferior outcome scores. Murray et al [35] found no influence of BMI on implant survival among 2438 medial Oxford UKA subjects but a significant deteriorating trend of functional outcome scores with an increasing BMI. Naal et al [36] reported findings similar to those of the present study, noting no significant differences in the KSS or University of California at Los Angeles activity scores between obese and nonobese patients at 2 years after medial UKA. The authors concluded that longer follow-up is necessary to determine the impact of obesity on revision rates of medial UKA.

This study has several limitations. Although the data from a prospective arthritis registry were used, the analysis performed is a retrospective manner. Second, the data reflect the experience of a single surgeon with extensive experience in unicompartmental resurfacing surgery using a robot-assisted arm technique, and results therefore may not be applicable to low-volume centers [37] or to UKA performed without robot-assisted technology. The use of robotic technology, however, offers the advantage of controlling the surgical technique [38-40], a crucial variable in determining outcomes [41,42]. At last, although an adequate follow-up was used, this study evaluates the effect on subjective outcomes. Longer follow-up in a multicenter setting is necessary to study the effect of these separate factors on the rate of revision.

In conclusion, our findings suggest that BMI, gender, and preoperative osteoarthritic severity of the various knee compartments do not influence subjective outcomes in patients undergoing medial UKA. Greater pain relief can be expected in medial UKA candidates aged <65 years, and a postoperative lower limb alignment of 1°-4° varus should be pursued. Taking these factors into consideration is critical, not only toward maximizing clinical outcomes and minimizing revision rates but also toward appropriately establishing and fulfilling patient expectations after medial UKA. Future studies, however, are required to evaluate the long-term significance of these parameters and their influence on implant longevity.

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