

Early functional outcome after lateral UKA is sensitive to postoperative lower limb alignment

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Abstract

Purpose The predictive role of patient-specific characteristics and radiographic parameters on medial unicompartmental knee arthroplasty (UKA) outcomes is well known, but knowledge of these predictors is lacking in lateral UKA. Therefore, purpose of this study was to assess the predictive role of these parameters on short-term functional outcomes of lateral UKA.

Methods In this retrospective cohort study, Western Ontario and McMaster Universities Arthritis Index scores were collected at 2-year follow-up (median 2.2 years, range 2.0–4.0 years) in 39 patients who underwent lateral UKA. Patient-specific characteristics included age, BMI and gender, while radiographic parameters included osteoarthritis severity of all three compartments and both preoperative and postoperative hip-knee-ankle alignment.

Results BMI, gender, age and preoperative valgus alignment were not correlated with functional outcomes, while postoperative valgus alignment was correlated with functional outcomes (0.561; $p = 0.001$). Postoperative valgus of 3°–7° was correlated with better outcomes than more neutral (–2° to 3° valgus) alignment (96.7 vs. 85.6; $p = 0.011$). Postoperative alignment was a predictor when corrected for patient-specific characteristics (regression coefficient 4.1; $p < 0.001$) and radiological parameters (regression coefficient 3.8; $p = 0.002$).

Conclusions Postoperative valgus alignment of 3°–7° was correlated with the best short-term functional outcomes in lateral UKA surgery, while patient-specific parameters and preoperative alignment were not correlated with functional outcomes. Based on these findings, a surgeon should aim for valgus alignment of 3°–7° when performing lateral UKA surgery for optimal functional outcomes.

Level of evidence Prognostic study, Level II.

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Introduction

Historically, poor results of unicompartmental knee arthroplasty (UKA) in the setting of isolated unicompartmental osteoarthritis (OA) have been reported [14]. Kozinn and Scott [20] therefore proposed strict patient selection criteria in 1989, which led to better outcomes and lower revision rates [2, 19, 33]. Nowadays, high BMI is identified as a predictor of poor functional outcomes [6, 16], while contradictory findings were reported regarding age and gender [21, 34]. It has also been shown in medial UKA

Table 1 Preoperative patient-specific characteristics with preoperative and postoperative total WOMAC scores

	<i>N</i>	WOMAC total	Difference
<i>Preoperative WOMAC scores</i>			
<i>Age</i>			
<65 years	11	42.8 ± 15.9	n.s.
≥65 years	14	47.5 ± 16.7	
<i>BMI</i>			
<25 kg/m ²	7	48.6 ± 12.1	n.s.
25–30 kg/m ²	14	42.7 ± 19.6	
≥30 kg/m ²	4	49.5 ± 7.3	
<i>Gender</i>			
Female	15	43.9 ± 14.6	n.s.
Male	10	47.7 ± 18.9	
<i>Postoperatively</i>			
<i>Age</i>			
<65 years	19	89.3 ± 13.9	n.s.
≥65 years	20	91.3 ± 12.0	
<i>BMI</i>			
<25 kg/m ²	8	91.1 ± 8.3	n.s.
25–30 kg/m ²	16	91.6 ± 12.7	
≥30 kg/m ²	6	82.8 ± 21.1	
<i>Gender</i>			
Female	24	92.0 ± 10.9	n.s.
Male	15	87.5 ± 15.4	

WOMAC Western Ontario and McMaster Universities Arthritis Index, *N* number of patients, *BMI* body mass index

slight postoperative varus of 1°–4° is correlated with better functional outcomes than neutral (–2° to 1°) or more varus (5°–7°) alignment [41].

Because several anatomic and kinematic differences between the medial and lateral compartment exist [13, 15, 25, 32, 35, 43], it is not justified to simply use these optimal alignment angles for lateral UKA. Harrington described that in patients with moderate valgus deformity, which is often the case in lateral OA [36], the mechanical load was transferred through the medial compartment during the dynamic phase [11]. Based on these findings, Ohdera et al. advised aiming for more valgus alignment (5°–7°) during lateral UKA.

To our knowledge, however, no study has assessed the role of postoperative alignment on functional outcomes besides the general statement that “overcorrection should be avoided to prevent medial OA progression” [26, 28, 31, 38]. In addition, to our knowledge no studies have assessed the influence of other patient-specific characteristics on outcomes of lateral UKA procedures. The purpose of this study therefore is to assess the role of patient-specific characteristics and radiographic parameters on short-term functional outcome in patients undergoing lateral UKA. The

hypothesis of this study was that young patients with a high BMI and neutral alignment have poor functional outcomes at short-term follow-up.

Materials and methods

An electronic search was performed for all patients who underwent lateral UKA surgery between 2008 and 2013. Surgical inclusion criteria consisted of (1) isolated lateral OA as primary indication, (2) intact cruciate ligaments, (3) passively correctable valgus deformity and (4) fixed flexion-deformity <10°. All patients were included who completed minimum 2-year follow-up of patient-reported outcomes. Of the 116 patients undergoing lateral UKA, 39 patients completed minimum of 2-year follow-up and were included.

Using a robotic-assisted surgical platform (MAKO Tactile Guidance System, MAKO Surgical Corporation, Ft. Lauderdale, FL, USA), all patients received a lateral RESTORIS® MCK Onlay Tibial implant (MAKO Surgical Corporation, Ft. Lauderdale, FL, USA) as previously described [27, 30]. Surgical alignment goal was a relative undercorrection of the preoperative valgus alignment in order to avoid OA progression in the medial compartment [26, 28, 31, 38]. One author performed all surgeries (AP).

Patients were categorized by gender, age (i.e. <65 and ≥65 years) and BMI according to the World Health Organization (i.e. <25, 25–30 and ≥30 kg/m²) [29]. BMI was missing in nine patients. Preoperative radiographic-collected parameters included OA severity and lower limb alignment. OA severity of the medial compartment, lateral compartment and patellofemoral compartment was measured using the Kellgren–Lawrence (KL) grading system [17]. Alignment was measured preoperatively and 1 month postoperatively using weight-bearing hip-knee-ankle radiographs as described by Moreland et al. [23]. Alignment was defined as the angle between the femoral and tibial mechanical axis, and this method has a reliability measurement of <1.0° [37, 39]. The femoral axis was measured as the line from the centre of the femoral head to the centre of the femoral notch, whereas the tibial axis was measured as the line from the centre of the tibial spine to the centre of the talus. A positive angle value indicates valgus alignment, and a negative angle value indicates varus alignment. Patient-specific demographic data are displayed in Table 1 and pre- and postoperative radiographic data in Table 2.

Patient-reported outcomes were collected using the Western Ontario and McMaster Universities Arthritis Index (WOMAC). WOMAC is a questionnaire, which quantifies the functional outcome using 24 Likert-scale questions and is validated in the setting of knee OA [4, 5]. Questionnaires were collected routinely during clinic visits and by

Table 2 Pearson correlations between radiographic parameters and postoperative WOMAC scores

	Correlation with WOMAC score
OA severity lateral compartment	−0.027 (n.s.)
OA severity medial compartment	−0.235 (n.s.)
OA severity patellofemoral compartment	−0.221 (n.s.)
Preoperative valgus (°)	−0.044 (n.s.)
Postoperative valgus (°)	0.546 ($p = 0.001$)*

WOMAC Western Ontario and McMaster Universities Arthritis Index, OA osteoarthritis

* Indicates significant correlation ($p < 0.05$)

Table 3 Groups of postoperative (valgus) alignment with postoperative WOMAC scores

	N	WOMAC total
Postoperative alignment		
−2° to 1° valgus	9	79.6 ± 17.2
1° to 4° valgus	18	92.1 ± 10.8
4° to 7° valgus	9	97.1 ± 4.7
−2° to 3° valgus	21	85.6 ± 15.4
3° to 7° valgus	15	96.7 ± 4.1
Statistical analysis		
−2° to 1° versus 1° to 4°		0.030*
−2° to 1° versus 4° to 7°		0.013*
1° to 4° versus 4° to 7°		n.s.
−2° to 3° versus 3° to 7°		0.011*

WOMAC Western Ontario and McMaster Universities Arthritis Index

* Indicates significant difference ($p < 0.05$)

electronic mail both preoperatively and 2 years postoperatively (median 2.2 years; range 2.0–4.0 years). The Institutional Review Board of Hospital for Special Surgery approved this study (2013-056).

Statistical analysis was performed using SPSS version 21 (SPSS Inc., Armonk, NY, USA). Independent *t* tests and one-way analysis of variance (ANOVA) with post hoc LSD tests were used to assess differences in WOMAC scores between patient-specific demographics. Pearson correlation analysis was then used to assess correlations between pre- and postoperative radiographic parameters and postoperative WOMAC scores. A correlation coefficient <0.20 was considered as a very weak correlation, between 0.20 and 0.39 as weak, between 0.40 and 0.59 as moderate, between 0.60 and 0.79 as strong and ≥ 0.80 as very strong [10]. Postoperative alignment was both categorized in three groups (i.e. −2° to 1°, 1°–4° and 4°–7° as used by Vasso et al. [41]) and two groups (i.e. −2° to 3° and 3°–7°). One-way ANOVA and independent *t* tests were used to compare

these groups. Finally, linear regression analysis was used to assess the predictive value of postoperative alignment on functional outcome using total WOMAC score. Because only 39 patients could be included, we used a maximum of four factors per linear regression analysis. All statistical tests were two-sided, and differences were considered statistically significant when $p < 0.05$.

Results

Patient-specific characteristics

No significant differences were found between age, BMI and gender in preoperative total WOMAC scores. Similarly, no significant differences in postoperative WOMAC scores were found in the patient-specific characteristics (Table 1).

Radiographic parameters

No correlation was found between WOMAC score and preoperative valgus. Similarly, no correlation was found between OA severity of all three compartments and the WOMAC score. Postoperatively, however, a correlation was found between postoperative valgus alignment and total WOMAC score (0.546; $p = 0.001$) (Table 2).

Postoperative alignment

Patients with postoperative valgus alignment between 1° and 4° (92.1 ± 10.8) and between 4° and 7° (97.1 ± 4.7) had significant better functional outcomes than with postoperative alignment between −2° and 1° (79.6 ± 17.2 , respectively, $p = 0.030$ and $p = 0.013$). Furthermore, patients with postoperative valgus of 3°–7° had better outcomes (96.7 ± 4.1) than patients with postoperative valgus of −2° to 3° (85.6 ± 15.4 ; $p = 0.011$) (Table 3).

Linear regression showed that postoperative valgus was the only predictor of a higher WOMAC score. This was both seen when corrected for preoperative patient-specific characteristics (regression coefficient 4.1; $p < 0.001$) and when corrected for preoperative radiographic parameters (regression coefficient 3.8; $p = 0.002$). The R^2 of the models were 0.459 and 0.399, respectively (Table 4).

Discussion

The most important finding of the present study was that postoperative alignment was an independent predictor of functional outcomes in lateral UKA patients. More specific, valgus alignment of 3°–7° was correlated with the best

Table 4 Two linear regression models are shown below

WOMAC total		Regression coefficient	95 % CI		p value
Postop. valgus	Degrees (°)	4.1	2.1	6.5	<0.001*
Age	<65 versus ≥65	−1.7	−10.6	7.3	n.s.
BMI	<25 versus 25–30 versus ≥30	−4.6	−11.1	1.9	n.s.
Gender	Female versus male	−4.7	−13.8	4.4	n.s.
Postop. valgus	Degrees (°)	3.8	1.5	6.1	0.002*
LTFC	KL 2 versus 3 versus 4	−2.7	−11.8	6.4	n.s.
MTFC	KL 0 versus 1 versus 2	−1.6	−10.9	7.6	n.s.
PFC	KL 0 versus 1 versus 2	−2.9	−10.0	4.3	n.s.

In the first model, postoperative valgus is corrected for preoperative patient-specific characteristics, whereas in the second model postoperative valgus is corrected for preoperative radiographic characteristics R^2 of the upper linear model is 0.459 and R^2 of the lower linear model is 0.399

WOMAC Western Ontario and McMaster Universities Arthritis Index, KL Kellgren–Lawrence score, LTFC lateral tibiofemoral compartment, MTFC medial tibiofemoral compartment, PFC patellofemoral compartment, *postop.* postoperative

* Indicates that predictive factor is significant ($p < 0.05$)

short-term functional outcomes. The patient-specific characteristics such as age, BMI and gender were not correlated with postoperative WOMAC scores at 2-year follow-up.

Several authors have discussed the role of overcorrection and undercorrection of preoperative varus alignment in patients who undergo medial UKA procedure. Hernigou and Deschamps [12] performed a study in which they compared the postoperative varus angle with Knee Society Score (KSS) and Hospital for Special Surgery scores. They compared scores between patients with a postoperative valgus angle, a varus angle between 0° and 10° and a varus angle >10°. They found that a varus angle of 0°–10° was correlated with the best functional outcomes. Overcorrection of varus deformity to a valgus angle was associated with increased OA progression at the lateral compartment, while undercorrection to a varus >10° was correlated with increased polyethylene wear. Similarly, Chatellard et al. [7] showed in a retrospective study of 559 medial UKAs that a postoperative varus angle >5° was associated with mechanical failure. More recently, Vasso et al. [41] performed a retrospective study in which they compared functional outcomes in patients who had different postoperative varus angles following medial UKA surgery. Patients with a postoperative varus angle of 1°–4° reported the best outcomes and they therefore recommended aiming for slight varus.

To our knowledge, however, no studies have assessed the role of postoperative alignment on functional outcomes following lateral UKA surgery. Differences between the medial and lateral compartment exist [11, 13, 15, 25, 32, 35, 43] and simply using 1°–4° of valgus as a goal of lateral UKA surgery is therefore not likely to be appropriate [41]. Harrington assessed the load carried by the medial and lateral compartment in patients with varus or valgus deformity in both the static phase and dynamic phase [11].

He showed in his study that in patients with varus deformity the load was transferred through the medial compartment in both the static and dynamic phase. In patients with valgus deformity, the load was transferred through the lateral compartment during the static phase, but this load was surprisingly shifted through the medial compartment during the dynamic phase in patients with moderate valgus alignment. This difference in kinematics in patients with varus and valgus deformity suggests that different postoperative alignment might be necessary for lateral UKA when compared to medial UKA. Ohdera et al. [26] therefore advised to aim for 5°–7° of postoperative valgus in patients with lateral UKA. Although several authors acknowledge the avoidance of overcorrection in lateral UKA [18, 22, 28, 31, 38], this is to our knowledge the first study that quantified the influence of postoperative alignment on functional outcomes. The data confirmed the statement of Ohdera that surgeons should aim for postoperative valgus with lateral UKA. When comparing the three postoperative alignment groups, data showed that patients with a neutral alignment do significantly worse compared to patients with valgus alignment. Although patients with a postoperative alignment of 4°–7° had better functional outcomes than patients with a postoperative alignment of 1°–4°, these differences were not significant. Analysis also showed that patients with a postoperative valgus of 3°–7° had better postoperative outcomes than patients with more neutral alignment. The optimal amount of valgus alignment is different from the aforementioned optimal varus alignment that is seen in medial UKA procedures [7, 18, 41]. This is likely to be explained by the aforementioned anatomic and kinematic differences between both compartments.

Correlation analysis and linear regression models in this study showed that postoperative alignment is a predictor



Fig. 1 Radiographs of an 85-year-old man are shown. Preoperatively (*left radiograph*), a valgus angle of 6.7° was measured on hip-knee-ankle radiographs and no medial OA was seen. Unfortunately, the

alignment was overcorrected to 2.0° of varus. At 2.3-year follow-up, this patient reported a total WOMAC score of 52 with medial compartment OA progression (*right radiograph*)

for functional outcomes. Furthermore, the R^2 were high, which indicates that alignment was a strong predictor of functional outcomes. Interestingly, preoperative OA severity of the compartments was not predictive for functional outcomes at short-term follow-up even though OA progression in these compartments is considered as the most common failure mode [2, 8, 9]. It seems that, when appropriate patient selection is performed, OA progression

is not related to the amount of OA severity at the time of surgery but is caused by the amount of valgus alignment. One patient in this study had a preoperative valgus of 6.7° , but alignment was overcorrected to a varus of 2.0° (measured at hip-knee-ankle radiographs). At 2.3-year follow-up, patient reported a total WOMAC score of 52 and medial OA progression was seen at radiographic follow-up (Fig. 1).

Although any differences in outcomes between younger and older patients could not be detected, some controversy exists around the role of age on functional outcomes [40, 42]. Thompson et al. [40] reported higher KSS in patients younger than 60 years, while Von Keudell et al. [42] could not find any difference in patient satisfaction between younger and older patients. With regard to BMI, several studies showed that a higher BMI is correlated with poor functional outcomes [6, 24, 40]. However, most patients in these studies underwent medial UKA and studies assessing functional outcomes following lateral UKA are lacking. In this study, patients with BMI ≥ 30 had worse functional outcomes (82.8 ± 21.1) compared to patients with a BMI < 25 (91.1 ± 8.3) and a BMI between 25 and 30 (91.6 ± 12.7), but these differences were not statistically significant. This could be explained by the fact only six patients had a BMI ≥ 30 . Large studies or registries are necessary to further assess the role of these factors on outcomes due to the low frequency of lateral UKA.

This study has several limitations. As previously mentioned, the number of patients with preoperative data ($n = 25$) and follow-up ($n = 39$) is relatively small. Therefore, future studies are necessary to show differences in functional outcome between BMI ≥ 30 and < 30 . This low number of patients is seen in the literature due to the low frequency of UKA procedure at the lateral compartment (5–10 %) [1, 3]. Another limitation is that no optimal upper limit of postoperative valgus alignment could be found. Due to the tight control of alignment afforded by the robotic-assisted system, the largest postoperative valgus was 7° and therefore studies with larger differences in postoperative alignment are needed to assess the optimal upper limit of postoperative valgus alignment in lateral UKA. Finally, this study reported patient-reported functional outcomes and did therefore not report objective clinical results.

The findings of this study showed that postoperative alignment is correlated with short-term functional outcomes. Based on these findings, a surgeon should aim for an undercorrection of 3° – 7° of valgus, when performing lateral UKA surgery, in order to achieve optimal short-term functional outcomes.

Conclusions

In lateral UKA, postoperative alignment appears to be a key predictor of early functional outcomes. As in medial UKA, functional outcome is sensitive to postoperative alignment; interestingly, however, more undercorrection appears to be necessary in lateral UKA (3° – 7° of undercorrection) compared to medial UKA (1° – 4° of undercorrection). Future studies are needed to evaluate the effect of

valgus alignment on both long-term functional outcomes and revision rates.

Compliance with ethical standard

Conflict of interest The authors declare that they have no conflict of interest.

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