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Different optimal alignment but equivalent functional outcomes in medial and lateral unicompartmental knee arthroplasty

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ABSTRACT

Introduction: Several differences in kinematics, functional outcomes and alignment exist between medial and lateral unicompartmental knee arthroplasty (UKA). Therefore, the purpose of this study was (1) to compare functional outcomes between both procedures with the hypothesis that both have equivalent outcomes and (2) to assess the role of preoperative and postoperative alignment on functional outcomes in both procedures.
Methods: Patients who underwent UKA were included when overall function — using Western Ontario and McMaster Universities Arthritis (WOMAC) score – and joint awareness – using Forgotten Joint Score (FJS) — were available preoperatively and at minimum two-year follow-up. A total of 143 medial UKA and 36 lateral UKA patients reported outcomes at mean 2.4-years follow-up (range 2.0 to 5.0 year).
Results: Preoperatively and postoperatively, no differences were seen between medial and lateral UKA in overall function (89.8 ± 11.7 vs. 90.2 ± 12.4, respectively, $p = 0.855$) and joint awareness (71.2 ± 24.5 vs. 70.9 ± 28.2, respectively, $p = 0.956$).
With neutral postoperative alignment (−1° to three degrees), less joint awareness was noted following medial UKA than lateral UKA (72.6 ± 22.6 vs. 55.3 ± 28.5, $p = 0.024$). With undercorrection (three degrees to seven degrees), however, following lateral UKA less joint awareness (85.3 ± 19.5 vs. 68.2 ± 26.8, $p = 0.020$) and better functional outcomes (96.0 ± 5.4 vs. 88.5 ± 11.6, $p = 0.001$) were noted than medial UKA.
Conclusion: Equivalent functional outcomes were noted between medial and lateral UKA at short-term follow-up but different optimal alignment angles seem to exist for both procedures.
Level of evidence: Level III therapeutic study.

1. Introduction

Unicompartmental knee arthroplasty (UKA) has gained popularity over the last decade in the treatment of isolated unicompartmental osteoarthritis (OA). It is estimated that UKA comprises 8 to 12% of all knee arthroplasties according to national registries in Europe [1,2] and United States [3]. Advantages of UKA to total knee arthroplasty (TKA) include faster recovery [4], better range of motion [5], better functional outcomes [6,7] and easier TKA revision [8] in the setting of isolated compartmental OA.

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Medial and lateral UKA differ in several ways. Medial UKA is 10 times more frequently performed than lateral UKA [2] and several anatomical [9] and kinematic [10,11] differences exist between both compartments, such as an increased laxity at the lateral side [12,13]. Because of these differences, more failures were historically reported at the lateral side [14,15] and lateral UKA was considered a technically more challenging procedure [16,17]. Therefore, some surgeons preferred TKA to lateral UKA in patients with isolated lateral OA, which resulted in UKA underutilization at the lateral side [18,19].

Recently, however, some high-volume centers showed that a larger portion of all UKA surgeries were performed at the lateral side (17% to 23%) [20,21] and a recent systematic review showed equivalent survivorship of medial and lateral UKA [22]. Despite these recent trends, superior functional outcomes following medial UKA to lateral UKA have still been reported [21]. Because of this contradiction, the first goal of this study was to compare short-term functional outcomes between medial and lateral UKA in a single-surgeon clinic.

Furthermore, it has been shown that for both procedures a slight undercorrection provides optimal functional outcomes [23,24]. However, a comparison between the exact optimal alignment for medial UKA and lateral UKA has not yet been performed while some individual studies suggested a different amount of undercorrection for both procedures [23–25]. Therefore, we aimed to assess the role of preoperative and postoperative alignment on functional outcomes and the differences in exact optimal post-operative alignment in medial and lateral UKA.

2. Methods

2.1. Study design

Following institutional review board approval, an electronic search was performed within the database of the senior author (***) for all patients who underwent UKA surgery between January 2009 and August 2013. Surgical inclusion criteria consisted of (1) isolated medial or lateral OA as primary indication, (2) tibial onlay implant, (3) intact cruciate ligaments, (4) passively correctable varus or valgus deformity and (5) less than 10° fixed flexion-deformity or contracture. Surgical exclusion criteria were (1) inflammatory arthritis and (2) body mass index (BMI) >45 kg/m [2]. Study inclusion criteria were patient-reported functional outcomes preoperatively and at two- to five-year follow-up in order to assess short-term follow-up. One hundred forty-three medial and 36 lateral UKA patients met the inclusion criteria (Table 1).

Preoperative demographic data collected included patient age, gender and BMI. Radiographic data included OA severity of the ipsilateral (affected), contralateral and patellofemoral compartment using the Kellgren–Lawrence (KL) grading system [26]. Weight-bearing hip-knee-ankle radiographs were obtained using a standardized protocol, in which patients were positioned in a bi-pedal stance with a source to image distance of 120 in. The central ray is at the level of the knees and the knees are positioned straight without rotation. Mechanical alignment was measured both preoperatively and six weeks postoperatively by measuring the angle between the femoral and tibial mechanical axis, as is previously desribed [27]. This method is shown to have intra- and interobserver reliability above 0.98 [28,29] with variability of <1° [28,29]. Demographic and radiologic data are displayed in Table 1.

2.2. Surgical technique

One surgeon performed all surgeries. UKA surgery was performed using a robot-assisted guidance system (MAKO Surgical Corp., Ft. Lauderdale, FL, USA) as described previously [30,50]. All patients received a medial or lateral RESTORIS ® MCK Onlay

Table 1
Mean (±SD) preoperative parameters and WOMAC scores and alignment measurements of included patients are displayed.

Preoperative characteristics	Medial UKA (n = 143)	Lateral UKA (n = 36)	Independent t-Test
Age (years)	65.4 ± 9.4	65.0 ± 13.0	0.850
Gender (M/F)	75/68	14/22	0.146
BMI (kg/m2)	27.2 ± 4.2	28.9 ± 4.7	0.060
Affected compartment (KL)	3.0 ± 0.7	2.8 ± 0.7	0.118
Contralateral compartment (KL)	0.7 ± 0.8	0.5 ± 0.7	0.166
Patellofemoral compartment (KL)	0.7 ± 0.7	0.7 ± 0.7	0.597
Preoperative WOMAC Scores			
Total	54.9 ± 14.9	50.3 ± 13.4	0.304
Pain	55.9 ± 17.3	54.3 ± 12.5	0.741
Stiffness	47.6 ± 18.9	44.0 ± 16.9	0.521
Function	55.3 ± 15.9	49.8 ± 14.6	0.253
Preoperative and postoperative alignment			
Preoperative alignment (°)	7.3 ± 3.7 varus	6.4 ± 3.8 valgus	0.188
Postoperative alignment (°)	2.3 ± 2.1 varus	2.9 ± 2.1 valgus	0.119

UKA indicates unicompartmental knee arthroplasty; BMI, Body Mass Index; KL, Kellgren and Lawrence Score; WOMAC, Western Ontario and McMaster Universities Arthritis Index.

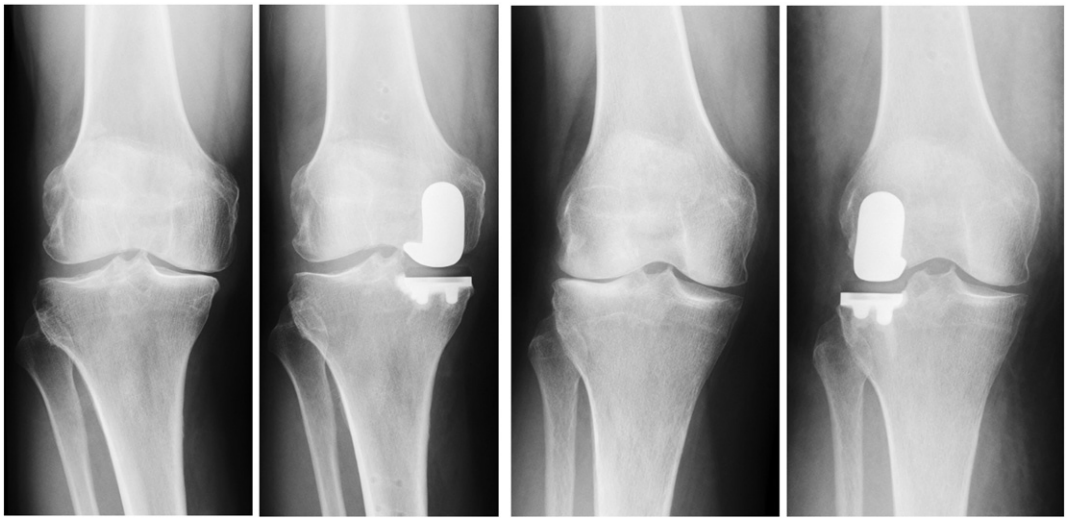

Figure 1. Preoperative and postoperative radiographs of an onlay unicompartmental knee arthroplasty are shown at the medial (left) and lateral compartment (right).

Tibial implant (MAKO Surgical Corp., Ft. Lauderdale, FL, USA) (Figure 1). Surgical alignment goal was undercorrection of lower leg alignment between 0° and five degrees in order to avoid OA progression in the contralateral compartment. Intraoperative alignment was measured using the robotic system although this is known to have a mean 1.33° and 1.86° difference for medial and lateral UKA, respectively, with weightbearing radiographic hip-knee-ankle radiographs [25].

2.3. Functional outcome methods

Western Ontario and McMaster Universities Arthritis index (WOMAC) and Forgotten Joint Score (FJS) questionnaires were collected during routine follow-up. The WOMAC score is validated in the setting of knee OA [31,32] and quantifies patient-reported pain (five questions), stiffness (two questions), function (17 questions) and overall outcomes (all 24 questions). FJS is validated in the setting of UKA [33,34] and quantifies the amount of artificial joint awareness. Because FJS has less ceiling effect (9%) than WOMAC (17 to 47%) [35], it may better discriminate high scores and was therefore included in this study. Preoperative FJS surveys were not collected due to the nature of a postoperative questionnaire. All scores were indexed with 0 as worst and 100 as best possible score. WOMAC scores were available for 143 medial and 36 lateral UKA patients with mean follow-up of 2.4 years (range 2.0 to 5.0 years). FJS was available for 95 medial and 25 lateral UKA patients with mean follow-up of 2.5 years (range 2.0 to 5.0 years).

2.4. Sample size and statistical analysis

For the sample size calculation, a minimally clinical difference of 10 points in WOMAC score was chosen based on other studies [21,36]. Using a 13-point standard deviation (based on preliminary results), a 4:1 medial UKA to lateral UKA enrollment ratio, 0.05 alpha and 80% power, sample size calculation showed that 88 medial UKA and 22 lateral UKA patients were needed to detect this 10-point difference. Both preoperatively and postoperatively for both questionnaires a sufficient amount of patients was included.

Statistical analysis was performed using SPSS Version 21 (SPSS Inc., Armonk, NY. USA). Independent t-tests and Chi-square tests were used to compare mean WOMAC and FJS scores between medial and lateral UKA preoperatively and at two-year follow-up. Pearson correlation tests were used to assess a relationship between outcome scores and pre- and postoperative alignment. FJS and WOMAC outcomes were then used to analyze the role of pre- and postoperative alignment on joint awareness. All statistical tests were two-sided and differences were considered statistically significant at $p < 0.05$.

3. Results

3.1. Patient characteristics

Preoperatively, no differences were noted in age, gender, BMI, OA severity of the affected, contralateral or patellofemoral compartment. Furthermore, no differences were seen in preoperative and postoperative varus alignment in medial UKA compared to valgus alignment in lateral UKA (Table 1).

3.2. Medial vs. lateral UKA

Preoperatively, no differences were noted between medial and lateral UKA in overall function (54.9 ± 14.9 vs. 50.3 ± 13.4, respectively, $p = 0.304$) and subdomain scores (Table 1). Postoperatively, patients undergoing medial UKA and lateral UKA reported equivalent overall functional outcomes (89.8 ± 11.7 vs. 90.2 ± 12.4, respectively, $p = 0.855$) and joint awareness (71.2 ± 24.5 vs. 70.9 ± 28.2, respectively, $p = 0.956$).

3.3. Preoperative and postoperative alignment

No significant correlations between preoperative alignment and either overall function or joint awareness were found for medial and lateral UKA (Table 2, Figures 2 and 3). A significant correlation was found between more postoperative valgus alignment and less joint awareness for lateral UKA (−0.540; $p = 0.005$) while no such correlation was seen for medial UKA (−0.191; $p = 0.069$) (Table 2, Figures 4 and 5).

3.4. Undercorrection vs. neutral alignment

In medial UKA, no differences were noted between postoperative neutral alignment (−1° to three degrees) and undercorrection (three degrees to seven degrees) in functional outcomes ($p = 0.199$) or joint awareness ($p = 0.214$). In lateral UKA, patients with postoperative undercorrection reported better functional outcomes (96.0 ± 5.4 vs. 87.2 ± 12.5, $p = 0.005$) and less joint awareness (85.3 ± 19.5 vs. 55.3 ± 28.5, $p = 0.010$) when compared to neutral alignment (Table 3).

3.5. Medial vs. lateral UKA alignment outcomes

In patients with postoperative neutral alignment (−1° to three degrees), patients undergoing medial UKA reported less joint awareness when compared to lateral UKA (72.6 ± 22.6 vs. 55.3 ± 28.5, $p = 0.024$). On the contrary, in patients with postoperative relative undercorrection (three degrees to seven degrees), it was noted that patients undergoing lateral UKA reported less joint awareness (85.3 ± 19.5 vs. 68.2 ± 26.8, p = 0.020) and better function (96.0 ± 5.4 vs. 88.5 ± 11.6, p = 0.001) than medial UKA (Table 3). A similar trend was also seen when dividing postoperative alignment into four groups (Figure 6).

3.6. Postoperative alignment outliers

Three patients were significant outliers in postoperative alignment. An 85-year old man who underwent lateral UKA and had a significant overcorrection of 3.0° (varus) and reported poor functional outcome (WOMAC 52). The second patient was a 55-year old man who underwent medial UKA and had an overcorrection of 4.5° (valgus). He reported at follow-up a WOMAC score of 71 and had significant joint awareness (FJS 31). The third patient was a 61-year old man with a BMI of 41 who underwent medial UKA. He had a large undercorrection of 10.4° varus and reported a WOMAC score of 80 at follow-up.

4. Discussion

This study demonstrated equivalent functional outcomes and joint awareness between medial and lateral UKA at short-term follow-up using the WOMAC and the relatively more stringent FJS, respectively. Differences in optimal postoperative alignment were noted between both procedures. More undercorrection was correlated with better outcomes and less joint awareness in lateral UKA when compared to medial UKA. Aiming for more neutral alignment was correlated with better outcomes in medial UKA than lateral UKA.

Lateral UKA surgery was historically considered more challenging than medial UKA [16,17]. This led to the fact that surgeons preferred TKA to lateral UKA and made lateral UKA an underutilized procedure [19,20]. Recently, however, more familiarity with the procedure and more satisfying outcomes following lateral UKA than TKA in the setting of isolated lateral OA are seen [20,21,37]. In this same trend, the results in this study showed that equivalent functional outcomes could be obtained with

Table 2
Pearson correlations between preoperative and postoperative alignment with the WOMAC and FJS for both medial and lateral UKA.

	WOMAC	FJS
Medial UKA		
Preoperative alignment	−0.031 ($p = 0.720$)	0.054 ($p = 0.605$)
Postoperative alignment	−0.143 ($p = 0.104$)	−0.191 ($p = 0.069$)
Lateral UKA		
Preoperative alignment	0.090 ($p = 0.614$)	−0.146 ($p = 0.485$)
Postoperative alignment	−0.355 ($p = 0.039$)*	−0.540 ($p = 0.005$)*

UKA indicates unicompartmental knee arthroplasty; FU, follow-up; WOMAC, Western Ontario and McMaster Universities Arthritis Index; FJS, Forgotten Joint Score.
* Indicates a significant correlation with $p < 0.05$.

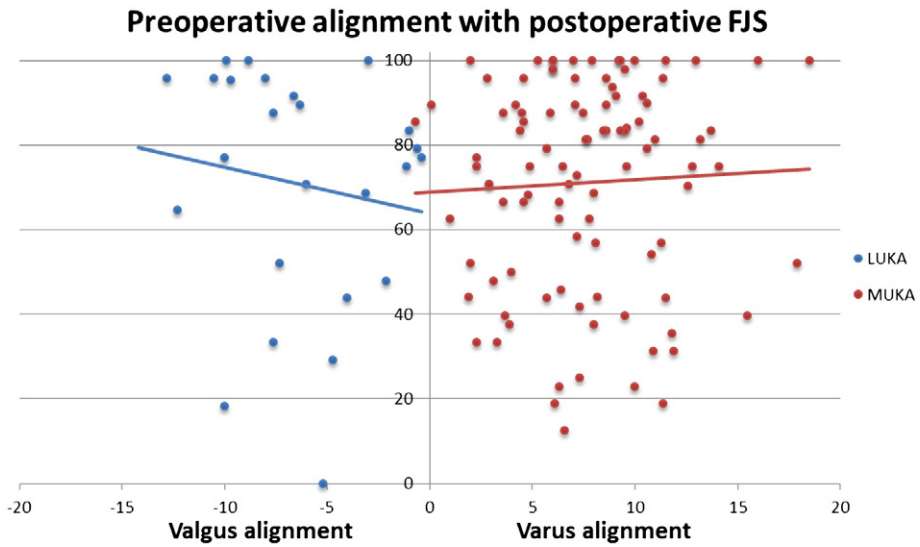

Figure 2. Scatter plot with trend lines is shown of lateral (blue) and medial (red) unicompartmental knee arthroplasty with the correlation between preoperative alignment and postoperative outcomes using the FJS.

both medial and lateral UKA, in contrary to what was previously reported [21]. At short-term follow-up, total WOMAC scores of 89.9 and 90.2 and FJS scores of 71.2 and 70.9 were reported in patients undergoing medial and lateral UKA, respectively. These scores are comparable with other studies in the literature [33,38].

One study, however, previously reported superiority of medial UKA over lateral UKA with regard to functional outcomes, which was not found in this current study [21]. The authors reported better WOMAC scores and SF-36 physical score at mean follow-up of six years. A likely explanation for the disparity between their study and our study may be explained by the fact that they used mobile-bearing implants for both medial and lateral UKA while in our study fixed-bearing implants were used. Several studies have shown that mobile-bearing implants at the lateral side have inferior outcomes [14,15,39]. This is likely to be caused by increased laxity of the lateral compartment [12,13] since this is correlated with less optimal outcomes and higher incidence of bearing dislocation [14,15,39]. We therefore feel that the use of mobile-bearing and fixed bearing implants may explain the differences in outcomes between these studies. Two other studies have reported separate functional outcomes for medial and lateral UKA [19,20] but are lacking analysis of results.

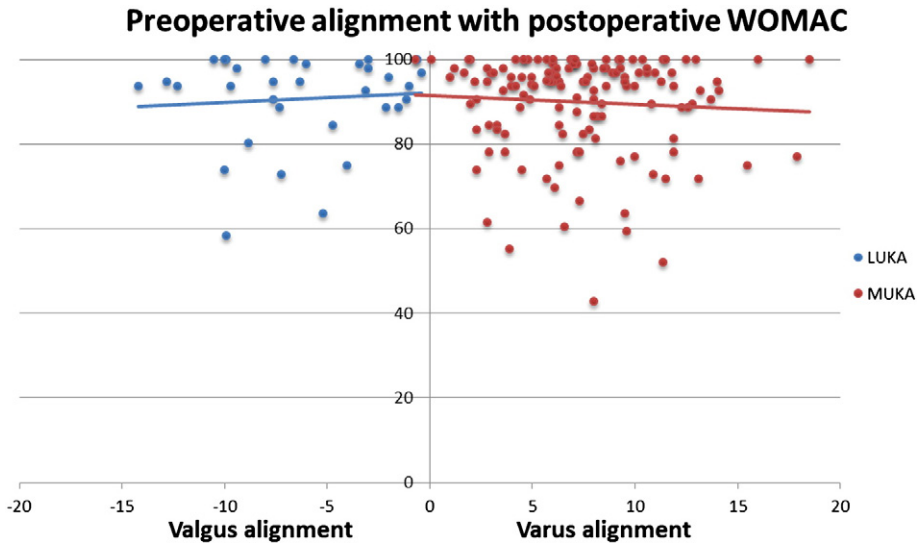

Figure 3. Scatter plot with trend lines is shown of lateral (blue) and medial (red) unicompartmental knee arthroplasty with the correlation between preoperative alignment and postoperative outcomes using the WOMAC.

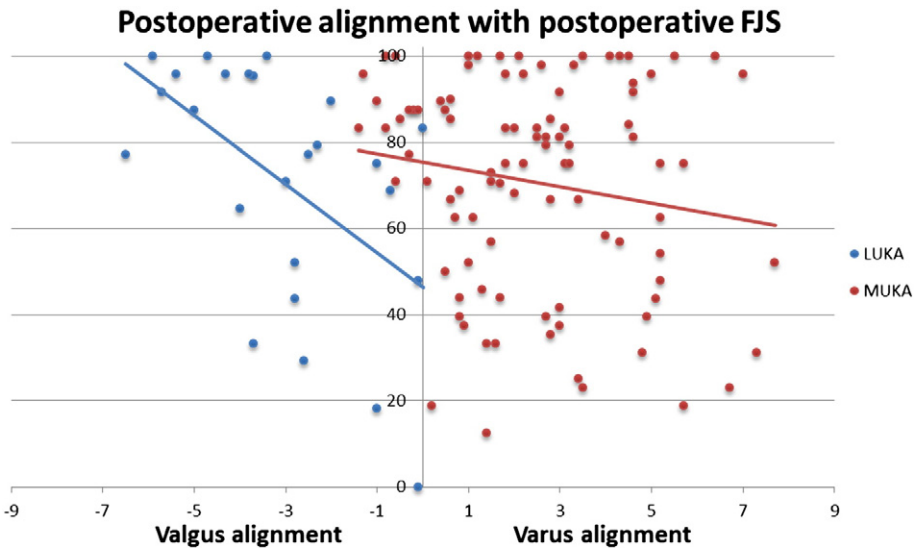

Figure 4. Scatter plot with trend lines is shown of lateral (blue) and medial (red) unicompartmental knee arthroplasty with the correlation between postoperative alignment and postoperative outcomes using the FJS.

In both medial and lateral UKA, no significant correlation between preoperative alignment and both functional outcomes and joint awareness could be found. The trend lines in Figures 2 and 3 show that slightly better results can be expected with a stronger preoperative varus or valgus but the R [2] of both trend lines was very weak (both <0.03). A correlation between stronger preoperative varus or valgus with better outcomes could be expected since more preoperative varus or valgus is correlated with relatively more isolated medial or lateral compartment OA, respectively, and more sparing of the contralateral compartment [40]. However, in this study no such correlation was found, which may be explained by strict patient selection. In our clinic, patients with doubtful isolated compartment OA on radiographs undergo MRI to assess if true isolated OA is present. Park et al. recently showed in patients with painful UKA that, despite the fact that OA in the contralateral compartment was not visible on radiographs, it was present on MRI in 100% of the cases [41]. Since patients with doubtful isolated OA underwent MRI, they were not indicated for UKA when contralateral OA was seen on MRI. Therefore only patients with 'true' isolated OA underwent UKA surgery in this study [42], which may explain the lack of correlation between preoperative alignment and functional outcomes in this study.

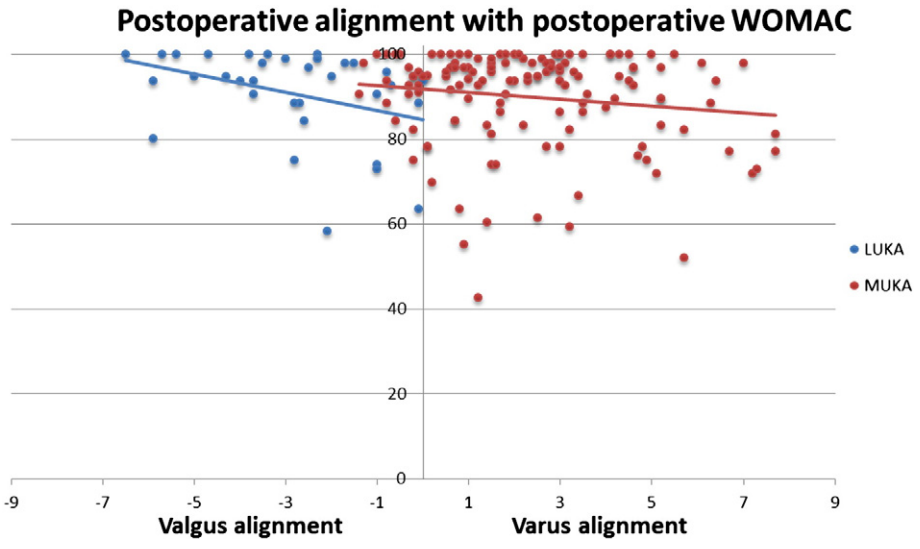

Figure 5. Scatter plot with trend lines is shown of lateral (blue) and medial (red) unicompartmental knee arthroplasty with the correlation between postoperative alignment and postoperative outcomes using the WOMAC.

Table 3
Mean (±SD) scores of WOMAC and FJS of all patients undergoing medial and lateral UKA and stratified by postoperative alignment as neutral or undercorrected.

Postoperative alignment	Score	N	Medial UKA		Lateral UKA	Medial vs. lateral
All patients[a]	WOMAC	143	89.8 ± 11.7	36	90.2 ± 12.4	0.855
	FJS	95	71.2 ± 24.5	25	70.9 ± 28.2	0.956
Neutral aligned patients (−1° to 3°)	WOMAC	85	90.9 ± 11.4	19	87.2 ± 12.5	0.200
	FJS	57	72.6 ± 22.6	12	55.3 ± 28.5	0.024*
Undercorrected patients (3° to 7°)	WOMAC	51	88.5 ± 11.6	15	96.0 ± 5.4	0.001*
	FJS	38	68.2 ± 26.8	13	85.3 ± 19.5	0.020*
Neutral vs. undercorrected	WOMAC		0.214		0.005*	
	FJS		0.199		0.010*	

UKA indicates unicompartmental knee arthroplasty; FU, follow-up; WOMAC, Western Ontario and McMaster Universities Arthritis Index; FJS, Forgotten Joint Score.
Neutral alignment for medial UKA indicates one degree of valgus to three degrees of varus and for lateral UKA indicates one degree of varus to three degrees of valgus.
Undercorrected alignment for medial UKA indicates three degrees to seven degrees of varus and for lateral UKA indicates three degrees to seven degrees of valgus.
* Indicates a significant difference with $p < 0.05$.
[a] 12 patients with medial UKA and 2 patients with lateral UKA had no postoperative hip-knee-ankle radiograph and could not be included for subgroup analysis.

Interestingly, differences in optimal postoperative alignment between both procedures were noted. It was found that lateral UKA was sensitive to postoperative alignment with regard to functional outcomes and joint awareness while no differences in postoperative alignment were found in medial UKA. The finding that postoperative lower leg alignment plays an important role in functional outcomes of UKA is not new [42,43]. However, to our knowledge, this study is the first showing a difference in optimal postoperative alignment between medial and lateral UKA. These differences can be explained by different load distributions over the compartments. Harrington assessed the regional load in the medial and lateral compartment in patients with valgus and varus deformity [10]. The author found that in patients with varus deformity the mechanical loads were the highest on the medial condyle during both the static and dynamic phase. In patients with moderate valgus deformity, however, the mechanical loads were high on the lateral condyle during the static phase but shifted towards the medial condyle during the dynamic phase while in patients with severe valgus deformity the loads were high on the lateral condyle during both phases.

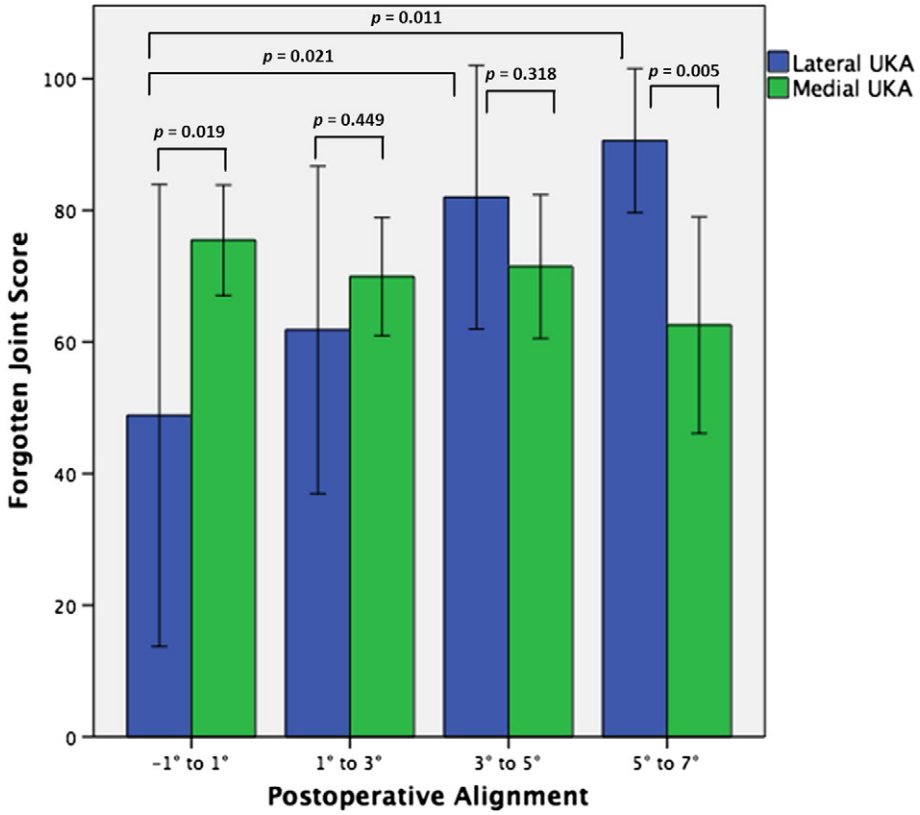

Figure 6. Different postoperative alignment groups with Forgotten Joint Scores at minimum two-year follow-up are shown. The postoperative alignment for medial unicompartmental knee arthroplasty (UKA) is displayed in varus while alignment for lateral UKA is displayed in valgus. Less joint awareness is noted with increasing valgus alignment following lateral UKA while no trend is noted following medial UKA.

Harrington stated that this could be explained by the normal tendency of the joint to transmit forces through the medial compartment [10]. Based on these findings, Ohdera et al. recommended correcting knee alignment during lateral UKA towards 5 to 7° of valgus in order to prevent load on the medial compartment and subsequent OA progression and pain at the medial side [44]. More recently, van der List et al. showed that better postoperative WOMAC scores were found with a postoperative alignment of more than three degrees of valgus alignment when compared to valgus alignment of less than three degrees [24]. Taking these studies into account, the findings of this current study are not surprising since a more neutral alignment will cause more force transmitting over the contralateral (medial) compartment, which will subsequently result in medial OA progression, pain and eventually the need for revision to TKA [45,46].

At the medial side, however, functional outcomes were less sensitive to postoperative alignment when compared to lateral UKA (Figures 4 and 5). This could be explained by the previously mentioned findings in the study of Harrington in which he showed that the joint forces were transmitted over the medial compartment when the knee is in slight valgus, neutral alignment or varus alignment. He, however, also noted that the joint forces increased with an increasing varus. This could explain the trend of slightly less optimal results with a postoperative varus of five degrees to seven degrees as was noted in this study (Figures 4 and 5). Increased forces on the medial compartment in the setting of medial UKA can eventually lead to pain and failure due to aseptic loosening and polyethylene wear [43,47]. Vasso et al. recently showed that a postoperative alignment between two degrees and four degrees of varus was correlated with better functional outcomes in medial UKA compared to more neutral (−2° to one degree) or more varus alignment (five degrees to seven degrees) [23]. We found similar differences between slight varus alignment and more varus alignment although this was not significant (Table 3, Figure 6), possibly due to the smaller group of patients with five degrees to seven degrees of varus alignment (n = 14). Interestingly, we could not find differences between neutral alignment and slight varus alignment as was found by Vasso et al. [23].

Three patients were excluded from postoperative alignment analysis because they were considered outliers. In two patients overcorrection was performed which resulted in OA progression of the contralateral compartment and poor functional outcome scores and this is commonly described in the literature [42]. In the third case, the patient was undercorrected to 10.4° and reported less favorable functional outcomes. Too much undercorrection can lead to pain, polyethylene wear and aseptic loosening [42,43] although in this patient no radiographic cause of the pain and stiffness could be detected.

This study is subject to several limitations. The first limitation was that although all patients completed the WOMAC questionnaire, not all patients completed the FJS. Using FJS, however, enabled better analysis since less ceiling effect was noted in our data and therefore better discrimination at the higher scores was noted. Secondly, measurements were performed on standing HKA radiographs and that despite a standardized protocol of performing these radiographs, small variations in limb rotation cannot be excluded. Furthermore, intraoperatively anatomical alignment is measured using the robotic system while on weightbearing hip-knee-ankle radiograph the mechanical alignment is measured and this may explain why a wide range of postoperative alignment can be seen postoperatively [48,49]. This indicates that further research is necessary in order to improve this incongruence. Thirdly, one author performed all surgeries using a robot-assisted surgical platform. These results may therefore not be applicable to centers with a lower UKA volume or manual UKA procedures. Finally, follow-up was relatively short and longer follow-up studies will ultimately be necessary since OA progression is sensitive to lower leg alignment and frequently occurs at a later stage than two- to five-years following UKA procedure [42,46].

In conclusion, our data suggest that postoperative functional outcomes and joint awareness are similar following medial and lateral UKA at short-term follow-up. However, the data suggests that in medial and lateral UKA different degrees of undercorrection are correlated with optimal short-term functional outcomes and joint awareness. Future studies are necessary to prospectively assess the correlation between postoperative alignment and functional outcomes in medial and lateral UKA and assess the role of postoperative alignment on survivorship in both procedures.

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