■ KNEE

What is the impact of patellofemoral joint degeneration and malalignment on patient-reported outcomes after lateral unicompartmental knee arthroplasty?

J. A. Burger,
M. S. Dooley,
L. J. Kleeblad,
H. A. Zuiderbaan,
A. D. Pearle

From Hospital for Special Surgery, New York, New York, USA

Aims

It remains controversial whether patellofemoral joint pathology is a contraindication to lateral unicompartmental knee arthroplasty (UKA). This study aimed to evaluate the effect of preoperative radiological degenerative changes and alignment on patient-reported outcome scores (PROMs) after lateral UKA. Secondarily, the influence of lateral UKA on the alignment of the patellofemoral joint was studied.

Methods

A consecutive series of patients who underwent robotic arm-assisted fixed-bearing lateral UKA with at least two-year follow-up were retrospectively reviewed. Radiological evaluation was conducted to obtain a Kellgren Lawrence (KL) grade, an Altman score, and alignment measurements for each knee. Postoperative PROMs were assessed using the Kujala (Anterior Knee Pain Scale) score, Knee Injury and Osteoarthritis Outcome Score Joint Replacement (KOOS JR), and satisfaction levels.

Results

A total of 140 knees (130 patients) were identified for analysis. At mean 4.1 years (2.0 to 8.5) follow-up, good to excellent Kujala scores were reported. The presence of mild to moderate preoperative patellofemoral joint osteoarthritis had no impact on these scores (KL grade 0 vs 1 to 3, p = 0.203; grade 0 to 1 vs 2 to 3, p = 0.674). Comparable scores were reported by patients with osteoarthritis (Altman score of ≥ 2) evident on either the medial or lateral patellofemoral joint facet (medial, p = 0.600 and lateral, p = 0.950). Patients with abnormal patellar congruence and tilt angles (≥ 17° and ≥ 14°, respectively) reported good to excellent Kujala scores. Furthermore, lateral UKA resulted in improvements to patellofemoral alignment.

Conclusion

This is the first study demonstrating that mild to moderate preoperative radiological degenerative changes and malalignment of the patellofemoral joint are not associated with poor patient-reported outcomes at mid-term follow-up after lateral fixed-bearing UKA. Our data suggest that this may be explained by realignment of the patella and thereby redistribution of loads across the patellofemoral joint.

Cite this article: *Bone Joint J* 2020;102-B(6):727–735.

Introduction

The clinical relevance of degenerative changes in the patellofemoral joint as a contraindication for unicompartmental knee arthroplasty (UKA) has been subject to discussion. Several studies have shown that patellofemoral joint osteoarthritis (OA), depending on the degree and location, has no effect on outcome after medial UKA.[1-4] Many authors have explained this results from realignment of the patellofemoral joint after medial UKA, thereby redistributing the contact pressure across the joint.[1,5,6] However, drawing conclusions for lateral UKA from medial UKA studies may be inappropriate, as the anatomical and kinematic

Correspondence should be sent to J. A. Burger; email: yoostburger@gmail.com

doi:10.1302/0301-620X.102B6.BJJ-2019-1429.R1 $2.00

Bone Joint J 2020;102-B(6):727–735.

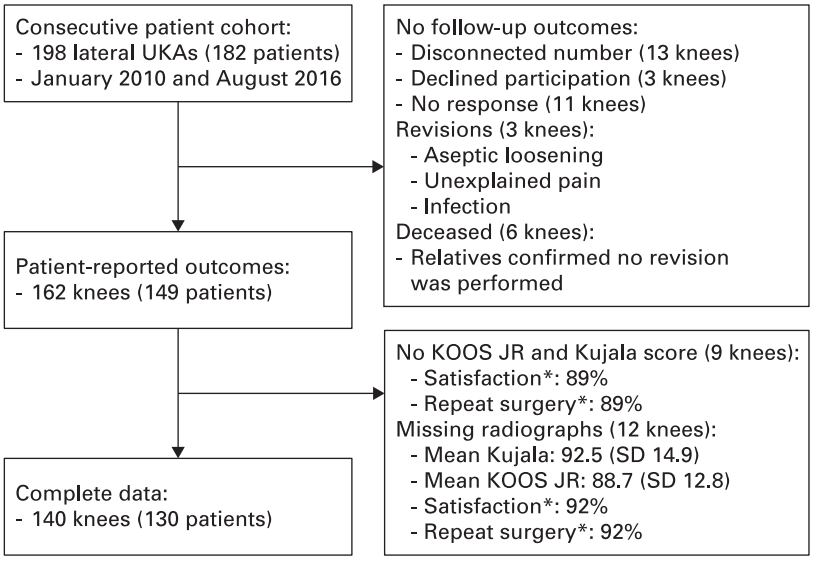


Fig. 1

Flow chart of the inclusion process. *The values are given as the number (and percentage) of knees from patients who were either very satisfied or satisfied with the results of the surgery or who would opt to undergo the surgery again if given the choice. KOOS JR, Knee Injury and Osteoarthritis Outcome Score Joint Replacement; UKA, unicompartmental knee arthroplasty.

properties are different in the medial and lateral compartments, which could require specific surgical considerations.[7-9]

A recent study showed faster progression of OA in the patellofemoral joint after lateral UKA compared to medial UKA.[10] Moreover, Hernigou and Deschamps[11] reported patellar impingement on the leading edge of the femoral component more frequently after lateral UKA than medial UKA. While the relationship between the patellofemoral joint and medial UKA has been investigated,[3,5,12] we are unaware of any study evaluating the effect of patellofemoral joint degenerative changes or preoperative patellar alignment on the effectiveness of lateral UKA.

The first aim of this study was to investigate whether the presence of preoperative radiological patellofemoral joint degenerative changes and alignment influence mid-term patellofemoral-specific and general knee outcomes following fixed-bearing lateral UKA. The second aim was to evaluate the influence of lateral UKA on postoperative radiological patellofemoral joint alignment. We hypothesized that preoperative radiological OA and alignment do not adversely affect patient-reported outcomes following lateral UKA and furthermore, that lateral UKA improves patellofemoral joint congruence.

Methods

Patient selection. A retrospective review was performed on patients who underwent fixed-bearing lateral UKA with at least two-year follow-up, performed by a single surgeon (ADP). A total of 198 procedures (182 patients) were identified from the surgeon's database. All these patients received a fixed-bearing lateral onlay UKA (RESTORIS MCK System; Stryker, Fort Lauderdale, Florida, USA) using robotic assistance (MAKO System, Stryker) between January 2010 and August 2016. Indications for surgery were symptomatic, end-stage, lateral compartment OA; a passively correctable coronal plane deformity; and fixed flexion deformity of < 15°. Exclusion criteria were signs of radiological inflammatory arthritis; the presence of Kellgren Lawrence (KL)[13] grade 3 to 4 OA in the contralateral tibiofemoral compartment; or patellofemoral joint-related symptoms (anterior knee pain with prolonged knee flexion, or pain specific to stair-climbing rather than descending stairs). Degenerative changes of the patellofemoral joint were not considered to be a contraindication, unless there were KL grade 4 degenerative changes at the lateral or medial facet of the patellofemoral joint. Patients were only included when a complete follow-up and set of radiographs (preoperative and six-week postoperative Merchant views and standing long-leg radiographs) were available.[14] Patients who were deceased or underwent revision were excluded from analyses.

A total of 140 knees (130 patients) were considered eligible for analysis (Figure 1). The mean follow-up of this cohort was 4.1 years (SD 1.6). The mean age at the time of surgery was 63.4 years (SD 10.5), and mean BMI was 26.6 kg/m^2 (SD 4.7). There were 59 (42.1%) males and 81 (57.9%) females. No statistical differences were observed regarding baseline characteristics and preoperative radiological measures between respondents and those without follow-up outcomes (age: p = 0.993, independent-samples *t*-test; BMI: p = 0.973, independent-samples *t*-test; sex: p = 0.834, Fisher's exact test; patellofemoral joint (PFJ) KL grade: p = 0.618, chi-squared test; patellar congruence angle: p = 0.593, independent-samples *t*-test; and patellar tilt angle: p = 0.330, independent-samples *t*-test; mechanical alignment angle: p = 0.580, independent-samples *t*-test). The study was approved by the institutional review board.

Radiological evaluation. The patellofemoral joint was evaluated using a Merchant view radiograph (skyline view of the patellofemoral joint at 45° of knee flexion with a leg-holding device).[14] Preoperative patellofemoral joint OA was graded according to KL classification grades of 0 to 4 (0 = none, 1 = doubtful, 2 = minimal, 3 = moderate, 4 = severe).[13] In addition,

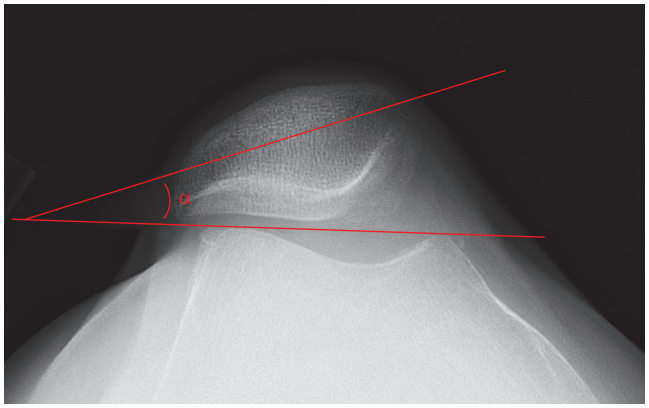


Fig. 2

Assessment of the patellar tilt angle on a Merchant view radiograph. The patellar tilt angle (α) is the angle between the line joining the edges of the patella and the line joining the highest points of the lateral and medial condyle.

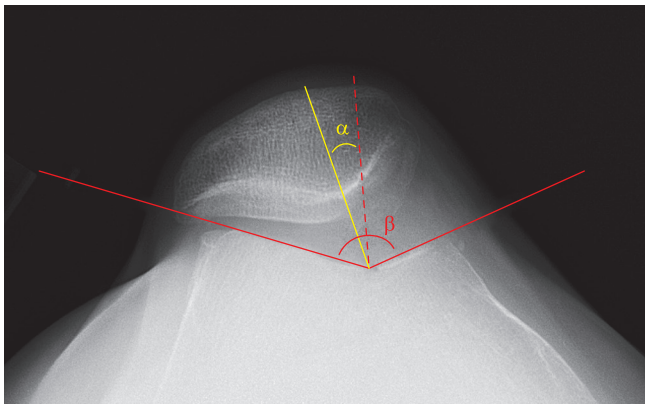


Fig. 3

Assessment of the patellar congruence angle on a Merchant view radiograph. The sulcus angle (β) is the angle between the lines intersecting the highest points of the lateral and medial condyle at the lowest point of the intercondylar sulcus. The congruence angle (α) is determined by the (dotted) line bisecting the sulcus angle and the line connecting the patellar median ridge and the lowest point of the intercondylar sulcus. Angles medial to the zero line are considered as negative, and those lateral to the zero line are considered as positive.

the Altman score[12] was used to grade the lateral and medial facet of the patellofemoral joint separately. This score consists of four individual parameters of OA (presence of osteophytes, joint space narrowing, subchondral sclerosis, and bone destruction), each scored between 0 and 3, with a highest possible score of 12.[15] Altman scores ≥ 2 were classified as degenerative changes.[1] Preoperative and postoperative alignment of the patellofemoral joint were measured using the patellar tilt and congruence angle (Figures 2 and 3).[14,16] Based on prior studies, a tilt angle of ≥ 14° and a congruence angle of ≥ 17° were considered abnormal.[14,16,17] Preoperative and postoperative long-leg standing radiographs were used to obtain lower limb mechanical axis angles.[18]

Table I. The interobserver reliability score of the radiological measurements.

Radiological measurement	ICC (95% CI)
Preoperative patellar congruence angle	0.938 (0.914 to 0.955)
Postoperative patellar congruence angle	0.933 (0.907 to 0.951)
Preoperative patellar tilt angle	0.948 (0.928 to 0.962)
Postoperative patellar tilt angle	0.928 (0.901 to 0.948)
Kellgren Lawrence grade PFJ	0.837 (0.779 to 0.881)
Altman grade (lateral PFJ)	0.854 (0.802 to 0.893)
Altman grade (medial PFJ)	0.851 (0.797 to 0.891)
Preoperative mechanical alignment angle	0.993 (0.990 to 0.995)
Preoperative mechanical alignment angle	0.979 (0.970 to 0.985)

CI, confidence interval; ICC, intraclass correlation coefficient; PFJ, patellofemoral joint.

All radiographs were independently evaluated in the Patient Archiving and Communication System (PACS, Sectra IDS 7 version 20.2, Linköping, Sweden) by two trained observers (JAB and MSD), who were blinded to outcomes. Interobserver reliability between the two observers was determined using intraclass correlation coefficients (ICCs). ICCs for all measurements were considered good to excellent and were similar as reported by earlier studies (Table I).[5,19]

Outcomes. Patients were required to report their demographics (date of birth, height, and weight) and whether they had any surgery after their lateral UKA. Furthermore, patients were asked to complete the Anterior Knee Pain Score (Kujala score)[20] and the Knee Injury and Osteoarthritis Outcome Score Joint Replacement (KOOS JR).[21] The KOOS JR provides information about the overall knee problems while the Kujala score provides information on patellofemoral joint-related function and symptoms. Both were reported on a scale from 0 to 100, with higher scores reflecting better outcomes. In addition, patients were asked to report their satisfaction with the outcomes of the surgery using a five-point Likert scale ('very dissatisfied', 'dissatisfied', 'neutral', 'satisfied', 'very satisfied') and whether or not they would opt to undergo the surgery again. All patients were contacted by email or postal mail, and non-responders followed up by telephone. A total of 157 (86%) patients completed the follow-up questionnaire, of which three patients reported a revision and five patients died, whose relatives confirmed no revision was performed. Revisions were performed for aseptic loosening, unexplained pain, and infection. Preoperative patient-reported outcome measures were not collected.

Statistical analysis. All statistical analyses were performed using SPSS version 25 (IBM, Armonk, New York, USA). Continuous data were presented as means and SDs. Incidence data were reported using frequencies and percentages. The differences in continuous variables were analyzed using the Mann-Whitney U test for non-normally distributed data and the independent-samples *t*-test for normally distributed data. Fisher's exact test and chi-squared test were used for the comparison of categorical data. The results of the five-point Likert scale were dichotomized into satisfied versus neutral and dissatisfied for statistical analyses. Among the patient-reported outcome measures, Kujala score was used as the primary outcome

Table II. Outcomes after lateral unicompartmental knee arthroplasty according to patellofemoral osteoarthritis severity.*†

Outcome	Knees, n	Mean Kujala (SD)*	Mean KOOS JR (SD)*	Satisfaction, n (%)†	Repeat surgery, n (%)†
PFJ Kellgren Lawrence grade					
Grade 0	39	80.9 (17.1)	83.2 (16.1)	36 (92)	35 (90)
Grade 1 to 3	101	85.2 (14.9)	86.3 (13.5)	96 (95)	95 (94)
p-value		0.203	0.378	0.685	0.465
Grade 0 to 1	66	83.0 (16.3)	84.7 (14.8)	62 (94)	61 (92)
Grade 2 to 3	74	84.8 (14.9)	86.0 (13.8)	70 (95)	69 (93)
p-value‡		0.674	0.656	1.000	1.000
Altman score					
Medial facet of PFJ					
≤ 1	94	83.1 (16.1)	84.8 (14.4)	87 (93)	85 (90)
≥ 2	46	85.6 (14.5)	86.7 (14.1)	45 (98)	45 (98)
p-value‡		0.600	0.414	0.272	0.166
Lateral facet of PFJ					
≤ 1	69	83.6 (16.1)	85.1 (14.8)	65 (94)	64 (93)
≥ 2	71	84.3 (15.2)	85.7 (13.8)	67 (94)	66 (93)
p-value‡		0.950	0.852	1.000	1.000
Both facet of PFJ					
≤ 1 on at least one facet	98	83.8 (16.0)	85.3 (14.3)	91 (93)	89 (91)
≥ 2 on both facet	42	84.4 (14.6)	85.6 (14.3)	41 (98)	41 (98)
p-value		0.739	0.924	0.435	0.282

*The ranges from 0 to 100, with higher scores indicating better outcomes. Mann-Whitney U test was used for statistical comparison.
†The values are given as the number (and percentage) of knees from patients who were either very satisfied or satisfied with the results of the surgery or who would opt to undergo the surgery again if given the choice. Fisher's exact test was used for statistical comparison.
‡A p-value of < 0.05 represents a significant difference between subgroups.
KL, Kellgren Lawrence; KOOS JR, Knee Injury and Osteoarthritis Outcome Score Joint Replacement; PFJ, patellofemoral joint

measure. Multivariate regression analyses were performed to analyze associations between radiological parameters and the primary outcome score, while correcting for potential confounders (body mass index (BMI), age, sex, and time since surgery). Wilcoxon signed rank test was used for the comparison of preoperative and postoperative alignment measurements. A sensitivity analysis was conducted comparing preoperative radiological measurements and baseline characteristics between respondents and those without follow-up outcomes. A p-value of < 0.05 was considered significant for all tests.

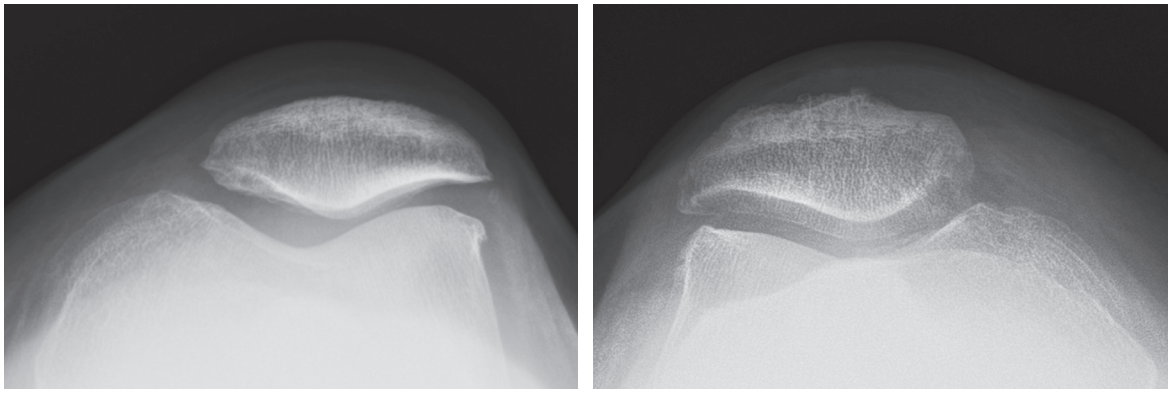
Results

Presence of OA. Radiological evaluation of the preoperative Merchant view showed that 39 knees (27.9%) had no patellofemoral joint degenerative changes (KL grade 0), 27 knees (19.3%) had doubtful changes (KL grade 1), 62 knees (44.3%) had mild changes (KL grade 2), and 13 knees (8.6%) had moderate changes (KL grade 3). There were no knees that showed severe degenerative changes (KL grade 4). Evaluation of the medial and lateral facet of the patellofemoral joint individually revealed that degenerative changes, defined as an Altman score ≥ 2, were observed on the medial facet in 46 knees (32.9%) and on the lateral facet in 71 knees (50.7%). An Altman score of ≥ 2 on both facets of the patellofemoral joint was observed in 42 knees (30.0%) (Table II).

The bivariate analysis, which grouped patients based on the severity of degeneration anywhere in the patellofemoral joint by the KL grade, reported good to excellent outcomes in all groups at mid-term follow-up. Patients with more severe degenerative changes in the patellofemoral joint consistently reported higher patient-reported outcomes, however, these differences were not significant (Table II, Figure 4). Similar results were observed when considering the location of the degenerative changes in the patellofemoral joint by the Altman score, resulting in no significant differences between subgroups (Table II). The multivariate regression analysis combining demographic and radiological parameters showed that mild to moderate patellofemoral radiological degenerative changes had no significant effect on the Kujala score (Table III).

Patellar and lower limb alignment. The lower limb alignment was corrected from mean 5.9° (SD 3.9) of valgus preoperatively to mean 2.8° (SD 1.9) of valgus postoperatively ($p < 0.001$, Wilcoxon signed rank test). The absolute congruence angle decreased from mean 11.8° (SD 10.4) to mean 10.5° (SD 10.3; $p = 0.038$, Wilcoxon signed rank test), while the absolute patellar tilt angle increased from mean 6.4° ((SD 5.0) to mean 7.6° (4.7; $p < 0.001$, Wilcoxon signed rank test). Further evaluation revealed that the patellar congruence angle significantly increased after lateral UKA in the 110 knees categorized as normal (mean -0.2° (SD 9.7) to mean 5.2° (SD 8.5; $p < 0.001$, Wilcoxon signed rank test), while the patellar congruence angle decreased in the 30 knees categorized as abnormal (mean 27.1° (SD 8.4) to mean 22.7° (SD 11.7; $p = 0.006$, Wilcoxon signed rank test). The patellar tilt angle significantly increased after lateral UKA in 126 knees classified as normal (mean 5.0° (SD 3.8) to mean 7.0° (SD 4.1; $p < 0.001$, Wilcoxon signed rank test), while the patellar tilt angle decreased in 14 knees categorized as abnormal (mean 16.2° (SD 2.0) to mean 13.0° (SD 3.3); $p < 0.001$, Wilcoxon signed rank test) (Table IV and Figure 5).

At mid-term follow-up, no difference in any patient-reported outcome measure was found between patients with normal and abnormal patellar congruence or tilt angles, both for



a b

Fig. 4

a) Preoperative Merchant view of a right knee with the lowest Kujala score. b) Preoperative Merchant view of a left knee with the highest Kujala score.

Table III. Multivariate analysis using a linear regression model with Kujala Score as dependent variable including preoperative alignment angles in model one and postoperative alignment angles in model two.

Variable	Coefficient (95% CI)*	p-value
Model one		
Sex (male vs female)	4.0 (-1.3 to 9.4)	0.139
Age	-0.5 (-0.7 to -0.3)	< 0.001
BMI	-1.2 (-1.8 to -0.7)	< 0.001
Time since surgery	-0.4 (-2.0 to 1.2)	0.598
Preoperative patellar congruence angle	0.2 (-0.0 to 0.4)	0.129
Preoperative patellar tilt angle	0.0 (-0.5 to 0.5)	0.967
Preoperative mechanical alignment angle	0.0 (-0.6 to 0.7)	0.890
Altman score medial facet of PFJ	0.3 (-2.5 to 3.1)	0.839
Altman score lateral facet of PFJ	-0.8 (-3.8 to 2.3)	0.627
PFJ Kellgren Lawrence grade (0 to 1 vs 2 to 3)	1.6 (-6.8,10.0)	0.709
Model two		
Sex (male vs female)	4.9 (-0.6 to 10.4)	< 0.001
Age	-0.6 (-0.8 to -0.3)	< 0.001
BMI	-1.3 (-1.8 to -0.7)	< 0.001
Time since surgery	-0.6 (-2.2 to 1.0)	0.459
Postoperative patellar congruence angle	0.3 (0.0 to 0.6)	0.031
Postoperative patellar tilt angle	-0.3 (0.0 to 0.6)	0.403
Postoperative mechanical alignment angle	-0.5 (-1.9 to 0.8)	0.433
Altman score medial facet of PFJ	0.0 (-2.7 to 2.8)	0.982
Altman score lateral facet of PFJ	-1.7 (-4.9 to 1.6)	0.313
PFJ Kellgren Lawrence grade (0 to 1 vs 2 to 3)	2.9 (-5.6 to 11.5)	0.495

*For categorical variables, the coefficient indicates the change in the Kujala score of one group relative to the reference group. For continuous variables, the coefficient indicates the change resulting from a 1-unit increase of the input variable.
BMI, body mass index; CI, confidence interval; PFJ, patellofemoral joint.

Table IV. Preoperative and postoperative patellar and lower limb alignment measures.*

Alignment measure	Mean preoperative angle, ° (SD)	Mean postoperative angle, ° (SD)	p-value*
Patellar congruence angle (all knees)	11.8 (10.4)	10.5 (10.3)	0.038
Normal (≤ 16°)	-0.2 (9.7)	5.2 (8.5)	< 0.001
Abnormal (≥ 17°)	27.1 (8.4)	22.7 (11.7)	0.006
Patellar tilt angle (all knees)	6.4 (5.0)	7.6 (4.7)	< 0.001
Normal (≤ 13°)	5.0 (3.8)	7.0 (4.1)	< 0.001
Abnormal (≥ 14°)	16.2 (2.0)	13.0 (3.3)	< 0.001
Mechanical alignment angle†	5.9 (3.9)	2.8 (1.9)	< 0.001

*Wilcoxon signed rank test was used for statistical comparison. A p-value < 0.05 represents a significant difference between pre- and postoperative measurements
†Mechanical alignment angles greater than zero denote valgus alignment, and those less than zero denote varus alignment

preoperative and postoperative measurements (Table V). Multivariate regression analyses showed no significant association between the Kujala score and preoperative patellofemoral joint alignment measures. However, higher postoperative patellar congruence angles were associated with higher Kujala scores (β = 0.3 (95% confidence interval (CI) 0.0 to 0.6); p = 0.031) (Table III).

Discussion

The present study demonstrated that mild to moderate degenerative changes of the patellofemoral joint and malalignment seen on the preoperative skyline patellar view does not adversely affect patellofemoral joint-specific and general knee patient-reported outcomes after lateral UKA at mid-term follow-up. Secondarily, realignment of the patella was observed on skyline views following lateral UKA.

Some concerns related to the patellofemoral joint after lateral UKA have been raised. A recent study by Kinsey et al[10] found that progression of patellofemoral joint arthritis over five years was greater for the lateral UKA group than for the medial UKA group (0.8 vs 0.4 point on the KL grade, respectively).[10] Therefore, the results of recent medial UKA studies that reported that patellofemoral joint degeneration is not associated with adverse

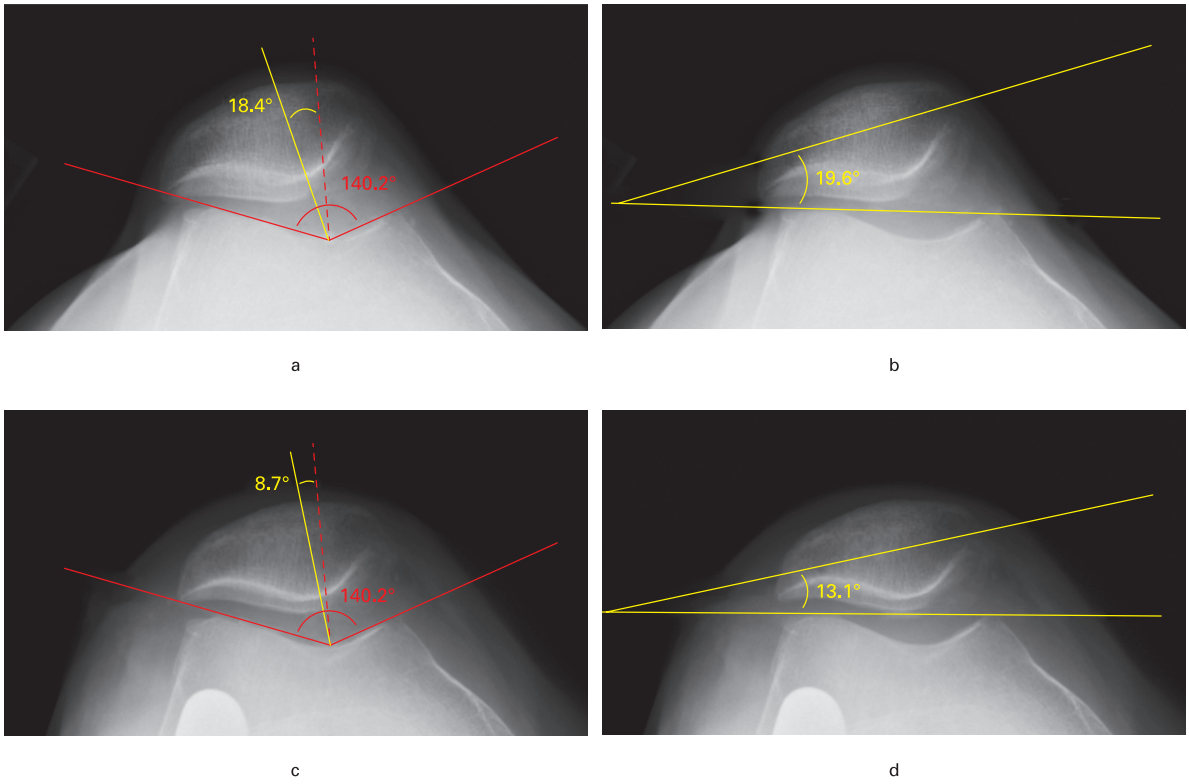


Fig. 5

Preoperative and six-week postoperative Merchant view of a left knee from a 64-year-old female. a) The preoperative sulcus angle is 140.2°, patellar congruence angle is 18.4°, and b) the preoperative patellar tilt angle is 19.6°. c) Although the postoperative sulcus angle is the same (140.2°), the postoperative patellar congruence angle (8.7°), and d) the postoperative lateral patellar tilt angle (13.1°) are decreased to lie within normal ranges compared to the preoperative angles.

Table V. Outcomes after lateral unicompartmental knee arthroplasty categorized by normal and abnormal alignment angles.†

Angle	Patients, n	Mean Kujala (SD)*	Mean KOOS, JR (SD)*	Satisfaction, n (%)†	Repeat surgery, n (%)†
Preoperative patellar congruence angle					
Normal (≤ 16°)	110	83.7 (16.2)	84.7 (14.8)	102 (93)	100 (91)
Abnormal (≥ 17°)	30	84.9 (13.2)	87.8 (12.0)	30 (100)	30 (100)
p-value		0.903	0.431	0.202	0.119
Postoperative patellar congruence angle					
Normal (≤ 16°)	112	83.2 (16.1)	84.4 (14.7)	104 (93)	103 (92)
Abnormal (≥ 17°)	28	87.5 (13.1)	88.8 (12.4)	28 (100)	27 (97)
p-value		0.379	0.458	0.357	0.687
Preoperative patellar tilt angle					
Normal (≤ 13°)	126	83.6 (15.9)	85.0 (14.7)	118 (94)	117 (93)
Abnormal (≥ 14°)	14	87.2 (11.6)	88.8 (10.1)	14 (100)	13 (93)
p-value		0.570	0.440	1.000	1.000
Postoperative patellar tilt angle					
Normal (≤ 13°)	127	83.7 (15.9)	85.1 (14.5)	119 (94)	118 (93)
Abnormal (≥ 14°)	13	86.9 (12.0)	88.3 (11.7)	13 (95)	12 (90)
p-value		0.627	0.548	1.000	1.000

*The ranges from 0 to 100, with higher scores indicating better outcomes. Mann-Whitney U test was used for statistical comparison.
†The values are given as the number (and percentage) of knees from patients who were either very satisfied or satisfied with the results of the surgery or who would opt to undergo the surgery again if given the choice. Fisher's exact test was used for statistical comparison.
‡A p-value of < 0.05 represents a significant difference between subgroups.

outcomes, may not be applicable for lateral UKA.[1–6] Our study showed that preoperative radiological degenerative changes of the patellofemoral joint were more common on the lateral facet than medial facet in patients with preoperative valgus alignment. This is consistent with the findings of the current literature, reporting that valgus alignment increases the risk of degenerative changes

Table VI. Series of fixed-bearing lateral unicompartmental knee arthroplasty with long-term follow-up.

Study	PFJ indication criteria	Sample size, n	Cohort characteristics	Mean FU, yrs (range)	Survival rates	Reasons for revision (n)
Argenson et al[27] 2008*	No clinical or radiological signs of PFJ OA	40	BMI: mean 26 kg/m² (SD 5)	12.6 (3 to 23)	10-yr: 92%	Medial compartment OA (3)
			Age: mean 61.7 yrs (SD 7)		16-yr: 84%	PFJ OA (1)
			Sex female:male (%) 62: 38			Tibial loosening (1)
Heyse et al[29] 2011†	Asymptomatic PFJ and no bone-on-bone OA on skyline view	50	BMI: N/A	10.8 (5 to 16)	10-yr: 91.8%	Medial compartment OA (1)
			Age: < 60 yrs		15-yr: 91.8%	Wear and loosening (1)
			Sex: N/A			Tibial subsidence, wear, loosening (1)
Deroche et al[28] 2019	No clinical or radiological signs of PFJ OA;asymptomatic PFJ OA in selected patients > 70 years old	54	BMI: mean 25.1 kg/m² (SD 3.0)	17.9 (15 to 23)	15-yr: 84.2%	Tibial loosening (1)
			Age: mean 72.2 yrs (SD 15.2)		20-yr: 71.2%	Medial compartment OA (3)
			Sex: female:male (%) 78:22%			Medial and symptomatic PFJ OA (4)

*Most comparable patient characteristics as reported in the present study.
†Most comparable indications as reported in the present study.
BMI, body mass index; FU, follow-up; N/A, not available; OA, osteoarthritis; PFJ, patellofemoral joint

in the lateral facet of the patellofemoral joint.[22,23] However, no evidence was found in our study that these changes within the lateral facet of the patellofemoral joint compromised patellofemoral joint-specific or general knee patient-reported outcomes after lateral UKA at mid-term follow-up. Similarly, there was no impact of mild to moderate degenerative changes in the medial facet of the patellofemoral joint.

There are several possible explanations for the lack of relationship between preoperative patellofemoral joint degenerative changes and outcomes in our study. Degenerative changes seen in the patellofemoral joint may not be symptomatic and ultimately not compromise outcomes, especially in our cohort, as patellofemoral joint-related symptoms were considered to be a contraindication to lateral UKA in the practice of the senior author.[1,24] Furthermore, a new contact surface provided by a UKA would relieve the pain experienced from a diseased lateral femoral condyle articulating in high flexion against degraded surfaces of the patellofemoral joint.

Additionally, most patients in the current study had a normal patellar congruence and tilt angle postoperatively, and patients with abnormal angles preoperatively tend towards normal values postoperatively. These findings suggest that lateral UKA leads to realignment of the patella, resulting in a load redistribution across the patellofemoral joint, and potentially influences patellofemoral symptoms. However, it is important to note that the number of patients with abnormal angles were similar between preoperative and postoperative intervals. Therefore, the clinical relevance of these changes can be questioned. However, more importantly, the abnormal patellar congruence and tilt angles were not associated with poor patient-reported outcomes at mid-term follow-up. In fact, patients with abnormal preoperative patellar alignment angles reported higher outcomes. It may be that these patients benefitted more from the realignment of the patella than those with already normal patellar alignment angles. Nevertheless, these findings need to be interpreted with caution as only a small number of patients with abnormal congruence and tilt angles were included and no preoperative patient-reported outcomes were available.

Furthermore, an important factor that needs to be considered regarding the patellofemoral joint is the surgical technique used for lateral UKA. There is a greater risk of impingement between the leading edge of the femoral component in lateral UKA than medial UKA, as the patella tracks more laterally during knee flexion.[11,25] For this reason, several authors have stated that accurate resection of the femoral condyle, as well as positioning and sizing of the femoral component, is more important in lateral UKA.[11,25] It is conceivable that the enhanced planning and accurate bone resection while using a robotic arm-assisted technique may have contributed to the good to excellent mid-term results in our study.

This study showed that higher BMI, higher age, and female sex was associated with lower postoperative Kujala scores; we did not record preoperative scores, so their health-gain from lateral UKA is unknown. The decreased physical activity in older compared to younger patients may have influenced the scoring of the functional-related questions of the Kujala survey and thereby lowered the score in older patients. This may also be an explanation for the lower scores in those patients with a higher BMI. A possible reason for the lower scores in women may be that they had poorer preoperative functional levels and did not reach the same final functional level as men.[26]

Regarding failures in our series, three patients reported a revision. Although none of these revisions were performed due to patellofemoral-related problems at mid-term follow-up, the

main concern is failure at long-term follow-up. Currently, there are some studies reporting on long-term outcomes of fixed-bearing lateral UKA, although different indications regarding the patellofemoral joint have been described (Table VI). One study by Argenson et al[27] reported on a cohort of 40 lateral UKAs with a mean follow-up of 12.6 years (3.0 to 23.0). Five revisions were reported; one for patellofemoral OA at 2.3 years. Another study by Deroche et al[28] studied a cohort of 54 knees with a mean follow-up of 17.9 (15 to 23 years). Eight revisions were reported of which four for medial OA with symptomatic patellofemoral OA at 6, 9, and 14 years. Finally, a study by Heyse et al[29] evaluated a cohort of 50 lateral UKA with a mean follow-up of 10.8 years (range five to 16). Three were revised, however, not any for patellofemoral-related problems. This latter study had comparable acceptable patellofemoral criteria for performing lateral UKA as the present study, in which radiological degenerative changes of the patellofemoral joint were accepted as long as these were clinically silent and not bone-on-bone (KL grade 4). The present study's patient demographics is most comparable to Argenson et al[27] (Table VI). Although the authors did not report the specific goals for the surgical outcome of the two surgeons performing the procedure, they stated that 73% patients (27/37) returned to their preoperative activity level. In the present study, patients were not encouraged to return to high-impact sports as their main activity; however, all activities were allowed after lateral UKA in consultation with the surgeon and physical therapist. Although patients' preoperative and postoperative activity levels were not reported for our cohort, a recent study, including medial and lateral UKA patients of the senior author (ADP), reported that 85.4% (117/137) returned to similar or higher activity levels compared to their preoperative level.[30]

Our study has certain limitations that should be considered. The first limitation is represented by the retrospective study design. Secondly, a proportion of the patients had no follow-up outcomes (26 patients, 14%). Although this may have resulted in selection bias, a sensitivity analysis showed no difference in terms of demographic characteristics and preoperative radiological measurements between responders and those without follow-up outcomes. Thirdly, severe patellofemoral OA was a contraindication to lateral UKA, and therefore the effect of preoperative severe OA (KL grade 4) on mid-term outcomes remains unknown. Fourthly, the multivariate regression model reported that higher postoperative congruence angles were associated with higher Kujala scores, while the direct comparison between patients with abnormal and normal postoperative congruence angles and Kujala scores showed no difference. These controversial results may be secondary to unequal group sizes between knees with abnormal and normal angles. Fifthly, Merchant radiographs are widely used to assess patellofemoral joint measurements, but there are drawbacks to this method. Rotational variation is not controlled as measurements are assessed on a 2D skyline view. Moreover, common clinical radiographs are static and do not address the dynamic nature of patellar tracking. Finally, no intraoperative assessment of the degree of patellofemoral cartilage wear was recorded; therefore, we were unable to compare our radiological data with intraoperative findings. Of note, none of the planned lateral UKA cases during the study period were converted to another type of arthroplasty after intraoperative assessment of the patellofemoral cartilage wear.

In conclusion, our data suggest that preoperative radiological mild to moderate patellofemoral degenerative changes, and associated malalignment of the patella, do not adversely affect patella-specific and general knee outcomes of lateral UKA at mid-term follow-up. This may be related to the realignment of the patella after lateral UKA, and thereby the redistribution of contact forces around the patellofemoral joint. However, more biomechanical studies focusing on the multifactorial nature of patellar alignment after lateral UKA are needed; as well as larger clinical studies with longer follow-up which examine the relationship between radiological patellofemoral joint degeneration and lateral UKA patient-reported outcomes.

Take home message

- Neither mild to moderate degenerative changes nor malalignment of the patellofemoral joint, seen on a preoperative skyline view, influence mid-term outcomes of fixed-bearing lateral unicompartmental knee arthroplasty (UKA).
- The lack of influence may be due to realignment of the patella after fixed-bearing lateral UKA.

References

1. **Hamilton TW**, **Pandit HG**, **Maurer DG**, **et al**. Anterior knee pain and evidence of osteoarthritis of the patellofemoral joint should not be considered contraindications to mobile-bearing unicompartmental knee arthroplasty: a 15-year follow-up. *Bone Joint J*. 2017;99-B(5):632–639.
2. **Konan S**, **Haddad FS**. Does location of patellofemoral chondral lesion influence outcome after Oxford medial compartmental knee arthroplasty? *Bone Joint J*. 2016;98-B(10 Suppl B):11–15.
3. **Burger JA**, **Kleeblad LJ**, **Laas N**, **Pearle AD**. The Influence of Preoperative Radiographic Patellofemoral Degenerative Changes and Malalignment on Patellofemoral-Specific Outcome Scores Following Fixed-Bearing Medial Unicompartmental Knee Arthroplasty. *J Bone Joint Surg Am*. 2019;101-A(18):1662–1669.
4. **Berger Y**, **Ftaita S**, **Thienpont E**. Does Medial Patellofemoral Osteoarthritis Influence Outcome Scores and Risk of Revision After Fixed-bearing Unicompartmental Knee Arthroplasty? *Clin Orthop Relat Res*. 2019;477(9):2041–2047.
5. **Thein R**, **Zuiderbaan HA**, **Khamaisy S**, **et al**. Medial Unicondylar Knee Arthroplasty Improves Patellofemoral Congruence: a Possible Mechanistic Explanation for Poor Association Between Patellofemoral Degeneration and Clinical Outcome. *J Arthroplasty*. 2015;30(11):1917–1922.
6. **Beard DJ**, **Pandit H**, **Gill HS**, **et al**. The influence of the presence and severity of pre-existing patellofemoral degenerative changes on the outcome of the Oxford medial unicompartmental knee replacement. *J Bone Joint Surg Br*. 2007;89-B(12):1597–1601.
7. **Baré JVV**, **Gill HSS**, **Beard DJJ**, **Murray DWW**. A convex lateral tibial plateau for knee replacement. *Knee*. 2006;13(2):122–126.
8. **Tokuhara Y**, **Kadoya Y**, **Nakagawa S**, **Kobayashi A**, **Takaoka K**. The flexion gap in normal knees. An MRI study. *J Bone Joint Surg Br*. 2004;86-B(8):1133–1136.
9. **Kumar D**, **Manal KT**, **Rudolph KS**. Knee joint loading during gait in healthy controls and individuals with knee osteoarthritis. *Osteoarthritis Cartilage*. 2013;21(2):298–305.
10. **Kinsey TL**, **Anderson DN**, **Phillips VM**, **Mahoney OM**. Disease Progression After Lateral and Medial Unicondylar Knee Arthroplasty. *J Arthroplasty*. 2018;33(11):3441–3447.
11. **Hernigou P**, **Deschamps G**. Patellar impingement following unicompartmental arthroplasty. *J Bone Joint Surg Am*. 2002;84-A(7):1132–1137.
12. **Munk S**, **Odgaard A**, **Madsen F**, **et al**. Preoperative lateral subluxation of the patella is a predictor of poor early outcome of Oxford phase-III medial unicompartmental knee arthroplasty. *Acta Orthop*. 2011;82(5):582–588.
13. **Kellgren JH**, **Lawrence JS**. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis*. 1957;16(4):494–502.
14. **Merchant AC**, **Mercer RL**, **Jacobsen RH**, **Cool CR**. Roentgenographic analysis of patellofemoral congruence. *J Bone Joint Surg Am*. 1974;56-A(7):1391–1396.
15. **Altman RD**, **Gold GE**. Atlas of individual radiographic features in osteoarthritis, revised. *Osteoarthritis Cartilage*. 2007;15(Suppl A):A1–56.

16. **Sasaki T**, **Yagi T**. Subluxation of the patella - Investigation by computerized tomography. *Int Orthop*. 1986;10(2):115–120.
17. **Grelsamer RP**, **Bazos AN**, **Proctor CS**. Radiographic analysis of patellar tilt. *J Bone Joint Surg Br*. 1993;75-B(5):822–824.
18. **Marx RG**, **Grimm P**, **Lillemoe KA**, **et al**. Reliability of lower extremity alignment measurement using radiographs and PACS. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(10):1693–1698.
19. **Sun Y**, **Günther KP**, **Brenner H**. Reliability of radiographic grading of osteoarthritis of the hip and knee. *Scand J Rheumatol*. 1997;26(3):155–165.
20. **Kujala UM**, **Jaakkola LH**, **Koskinen SK**, **et al**. Scoring of patellofemoral disorders. *Arthroscopy*. 1993;9(2):159–163.
21. **Lyman S**, **Lee YY**, **Franklin PD**, **et al**. Validation of the KOOS, JR: A Short-form Knee Arthroplasty Outcomes Survey. *Clin Orthop Relat Res*. 2016;474(6):1461–1471.
22. **Elahi S**, **Cahue S**, **Felson DT**, **Engelman L**, **Sharma L**. The association between varus-valgus alignment and patellofemoral osteoarthritis. *Arthritis Rheum*. 2000;43(8):1874–1880.
23. **Cahue S**, **Dunlop D**, **Hayes K**, **et al**. Varus-valgus alignment in the progression of patellofemoral osteoarthritis. *Arthritis Rheum*. 2004;50(7):2184–2190.
24. **Beard DJ**, **Pandit H**, **Ostlere S**, **et al**. Pre-operative clinical and radiological assessment of the patellofemoral joint in unicompartmental knee replacement and its influence on outcome. *J Bone Joint Surg Br*. 2007;89-B(12):1602–1607.
25. **Sah AP**, **Scott RD**. Lateral unicompartmental knee arthroplasty through a medial approach. surgical technique. *J Bone Joint Surg Am*. 2008;90-A(Suppl 2 Pt 2):195–205.
26. **O'Connor MI**. Implant survival, knee function, and pain relief after TKA: are there differences between men and women? *Clin Orthop Relat Res*. 2011;469(7):1846–1851.
27. **Argenson JNA**, **Parratte S**, **Bertani A**, **Flecher X**, **Aubaniac JM**. Long-term results with a lateral unicondylar replacement. *Clin Orthop Relat Res*. 2008;466(11):2686–2693.
28. **Deroche E**, **Batailler C**, **Lording T**, **et al**. High Survival Rate and Very Low Wear of Lateral Unicompartmental Arthroplasty at Long Term: A Case Series of 54 Cases at a Mean Follow-Up of 17 Years. *J Arthroplasty*. 2019;34(6):1097–1104.
29. **Heyse TJ**, **Khefacha A**, **Peersman G**, **Cartier P**. Survivorship of UKA in the middle-aged. *Knee*. 2012;19(5):585–591.
30. **Kleeblad LJ**, **Strickland SM**, **Nwachukwu BU**, **Kerkhoffs GMMJ**, **Pearle AD**. Satisfaction with return to sports after unicompartmental knee arthroplasty and what type of sports are patients doing. *Knee*. 2020. in press.

Author information:
J. A. Burger, MD, Research Fellow
M. S. Dooley, MA, Co-investigator
A. D. Pearle, MD, Orthopeadic Surgeon
Department of Orthopaedic Surgery and Computer Assisted Surgery Center, Hospital for Special Surgery, New York, New York, USA.

L. J. Kleeblad, MD, Orthopeadic Resident
H. A. Zuiderbaan, MD, PhD, Orthopeadic Surgeon
Department of Orthopaedic Surgery, Noordwest Ziekenhuisgroep, Alkmaar, Netherlands.

Author contributions:
J. A. Burger: Contributed to the study design, Collected, analyzed, and interpreted the data, Drafted, revised, and approved the manuscript.
M. S. Dooley: Collected and interpreted the data, Revised and approved the manuscript.
L. J. Kleeblad: Contributed to the study design, Interpreted the data, Revised and approved the manuscript.
H. A. Zuiderbaan: Contributed to the study design, Interpreted the data, Revised and approved the manuscript.
A. D. Pearle: Contributed to the study design, Interpreted the data, Revised and approved the manuscript.

Funding statement:
No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

ICMJE COI statement:
A.D. Pearle declares personal payment for consultancy from Stryker, unrelated to this study.

Acknowledgements:
The authors wish to thank Hannah Friedrich and Niels Laas for their assistance with this research project.

Ethical review statement:
The study was approved by the institutional review board (Hospital for Special Surgery IRB ID: Study #2013-056-CR6).

This article was primary edited by K. Logishetty and first proof edited by G. Scott.