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Medial Unicondylar Knee Arthroplasty Improves Patellofemoral Congruence: a Possible Mechanistic Explanation for Poor Association Between Patellofemoral Degeneration and Clinical Outcome

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ABSTRACT

The purpose was to determine the effect of medial fixed bearing unicondylar knee arthroplasty (UKA) on postoperative patellofemoral joint (PFJ) congruence and analyze the relationship of preoperative PFJ degeneration on clinical outcome. We retrospectively reviewed 110 patients (113 knees) who underwent medial UKA. Radiographs were evaluated to ascertain PFJ degenerative changes and congruence. Clinical outcomes were assessed preoperatively and postoperatively. The postoperative absolute patellar congruence angle (10.05 ± 10.28) was significantly improved compared with the preoperative value (14.23 ± 11.22) ($P = 0.0038$). No correlation was found between preoperative PFJ congruence or degeneration severity, and WOMAC scores at two-year follow up. Pre-operative PFJ congruence and degenerative changes do not affect UKA clinical outcomes. This finding may be explained by the post-op PFJ congruence improvement.

Increased utilization of medial unicondylar knee arthroplasty (UKA) for treatment of medial compartment osteoarthritis has been reported over the last two decades [1]. Historically, patellofemoral joint (PFJ) degeneration, and more specifically advanced lateral PFJ facet degeneration, along with anterior knee pain were considered exclusion criteria for medial UKA [2,3]. However, recent studies have reported that PFJ degenerative changes do not influence clinical outcomes following UKA [4,5]. Therefore, controversy still exists on whether pre-existing PFJ degeneration is a contraindication for UKA. Although, patellar alignment after total knee arthroplasty (TKA) has been extensively studied, [6–9] there is a paucity of reports on the association between functional outcomes and pre-operative and post-operative patellar alignment and PFJ congruency following medial UKA. Relevant studies are limited to a case series of patellar impingement after UKA [10] and reports of an association between lateral patellar displacement and poor outcomes following UKA [11].

Recently, Robotic-Assisted (RA) UKA is gaining in popularity [12]. Various studies have shown that medial RA-UKA improves postoperative implant positioning and limb alignment when compared to conventional manual techniques [13–16]. In addition, it has been reported that lateral RA-UKA improves the congruence of the medial compartment and that pre-existing tibiofemoral subluxation is being restored after medial and lateral UKA [16,17]. Nevertheless, to the best of our knowledge there are no published data on the ability of either conventional or RA medial UKA in affecting preoperative PFJ incongruence.

The purpose of this study was to 1) determine whether PFJ degeneration is associated with lower clinical outcomes and 2) analyze the effect of medial fixed bearing RA-UKA on postoperative PFJ congruence in a series from a single surgeon who specializes in RA-UKA. We hypothesized that preoperative PFJ arthritic changes do not adversely affect clinical outcomes, and that medial RA-UKA improves PFJ congruence.

Methods

Patient Selection

This study was based on a prospective cohort of patients assembled for the senior author's surgical arthritis registry. Patients were eligible for this analysis if they were adult participants in the registry and underwent medial RA-UKA between October 1st, 2008 and May 1st, 2012. This study was approved by the Institutional Review Board at our hospital, and all patients provided informed consent for participation in the registry. Surgical indications for medial RA-UKA included medial compartment osteoarthritis (OA), no significant joint space narrowing in the lateral compartment, an intact anterior cruciate

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ligament, a correctable varus deformity and a fixed-flexion-deformity of <10°. Contraindications included the presence of Kellgren–Lawrence (K–L) [18] grade III or greater OA of the lateral compartment, PFJ related pain symptoms (specifically patient-reported anterior knee pain with sitting [i.e. "movie theater sign"] or stair climbing), or inflammatory arthritis. All enrolled patients underwent minimally invasive medial RA-UKA technique [12] by the senior author utilizing a standardized surgical technique and onlay prosthesis (MCK Medial Onlay Unicompartmental, MAKO Tactile Guidance System [TGS], MAKO Surgical Corporation, Fort Lauderdale, Florida, USA).

Overall, 122 patients (133 knees) were identified and were considered eligible for the study. However, in 12 patients (20 knees) radiographic evaluation could not be completed; in six patients the radiographs could not be retrieved, in five technical difficulties prevented accurate radiographic measurements, and one patient underwent early revision due to symptomatic progression of degenerative changes in the lateral compartment.

Therefore, 110 patients (113 knees) with an average follow-up of 2 years (range, 1 to 4.2) were included in the study. The mean age of the patients at the time of surgery was 63.9 ± 10.4 years. There were 52 (47.3%) females and 58 (52.7%) males with a mean BMI of 28.26 ± 4.6. One hundred and seven unilateral and 3 staged bilateral procedures were performed

Radiographic Evaluation

Radiographic evaluation included preoperative and postoperative anterior posterior (AP) weight bearing views, axial views at 45° of flexion (Merchant view) [19] using a Merchant board to control the flexion angle, and lateral views at 30° of flexion [20]. For the radiographic evaluation of the degenerative changes, pre-operative weight bearing knee radiographs and preoperative and postoperative Merchant view radiographs were used. The change in lower limb mechanical axis was calculated based on pre-operative and post-operative weight-bearing AP views, respectively.

Evaluation of Patellofemoral Degeneration

Arthritic changes of the PFJ was graded according to the Modified Altman scale [21,22]. Patients were divided into a "Mild PF OA group" (Modified Altman grade 0 & I) and "Severe PF OA group" group (Modified Altman grade II & III). Pre-operatively, 72.5% (82) the knees were classified as Modified Altman score 0 or I (mild degenerative changes), whereas 27.5% (31) were classified as Modified Altman score II or III (severe degenerative changes). The Insall–Salvati index was calculated based on lateral radiographs [23].

Patellar Congruence

The patellar congruence was measured on the Merchant views based on the technique described by Merchant et al [19] (Fig. 1). Furthermore, preoperative and postoperative lateral patellar displacement was calculated. The lateral patellar displacement (L) is the length between a line from the highest point of the medial condyle which is perpendicular to a line connecting the highest points of the lateral and medial condyles and a parallel line touching the medial border of the patella (Fig. 1).

The radiograph measurements were performed by two investigators. Inter-observer reliability between the two observers was assessed using Interclass correlation coefficients (ICCs). The ICCs were interpreted using previous published semi-quantitative criteria: excellent for $0.9 < P < 1.0$, good for $0.7 < P < 0.89$, fair/moderate for $0.5 < P < 0.69$, low for $0.25 < P < 0.49$ and poor for $0.0 < P < 0.24$ [24]. Interclass correlation coefficients for all radiographic measurements were excellent. Specifically, the ICC for patellar congruence angle was 0.981, for Insall–Salvati index 0.995, for lateral patellar displacement 0.993, and for mechanical alignment 0.990, respectively.

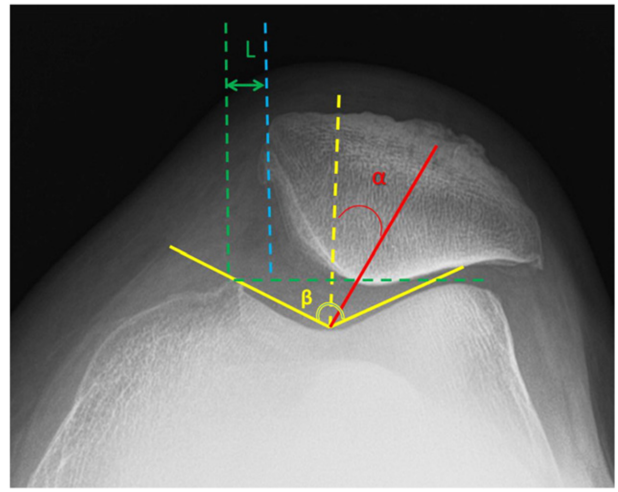

Fig. 1. Radiographic measurements of patella femoral joint. Bisect line (Dashed yellow line) of the sulcus angle (β) established a zero reference. A second line extending from the vertex of the sulcus angle to the vertex of the patellar facets forms the patellar congruence angle (α). The length between a line from the highest point of the medial condyle (dashed green line) which is perpendicular to a line connected to the highest points of the lateral and medial condyles and a parallel line connected to the medial border of the patella (dashed blue line) is the lateral patellar displacement (L).

Assessment of Symptoms and Function: WOMAC Questionnaire

Clinical measures were collected prospectively both preoperatively and postoperatively using the Western Ontario and McMaster Universities Osteoarthritis Index score (WOMAC). The WOMAC is a widely used validated measure of symptoms and function in patients with osteoarthritis of the knee or hip, [25,26] consisting of 3 subscales, pain, stiffness, and physical function. Scores for each subscale can range from 0 to 100, with higher scores indicating better condition. All patients completed postoperative WOMAC questionnaires (N = 110) at latest follow-up. However, 53 (48.2%) patients completed the preoperative questionnaires. To account for this discrepancy, we performed sensitivity analysis tests comparing the baseline clinical characteristics and radiographic measures between participants with missing preoperative WOMAC scores (non-respondents) and those who fully completed the preoperative WOMAC scores questionnaires (respondents). No significant difference was observed between the two groups except for the patellar congruence angle measurements. Non-respondents were associated with lower patellar congruence angle both preoperatively (11.58 ± 8.37 versus 17.24 ± 13.22), and postoperatively (7.88 ± 7.5 versus 12.51 ± 12.33).

Statistical Analysis

Preoperative and postoperative radiographic measurements and WOMAC scores were tabulated using means ± standard deviation and 95% confidence intervals. Paired t-tests were used for the comparison of preoperative and postoperative values of radiographic measurements and WOMAC scores. The association between preoperative radiographic measures and postoperative WOMAC scores was assessed using multiple linear regression, adjusting for age, gender, and BMI. Pearson product moment correlation coefficient was used to estimate the correlation between preoperative limb alignment, severity of degenerative changes, patellar congruence angle, patellar lateral displacement and postoperative WOMAC scores. All analyses were performed using SAS for Windows 9.2 (SAS Institute Inc., Cary, NC, USA). All tests were two-sided, and statistical significance was set at 0.05 for all comparisons.

Results

WOMAC pain, stiffness and function scores improved significantly following medial RA-UKA ($P < 0.0001$) (Fig. 2). Statistically significant

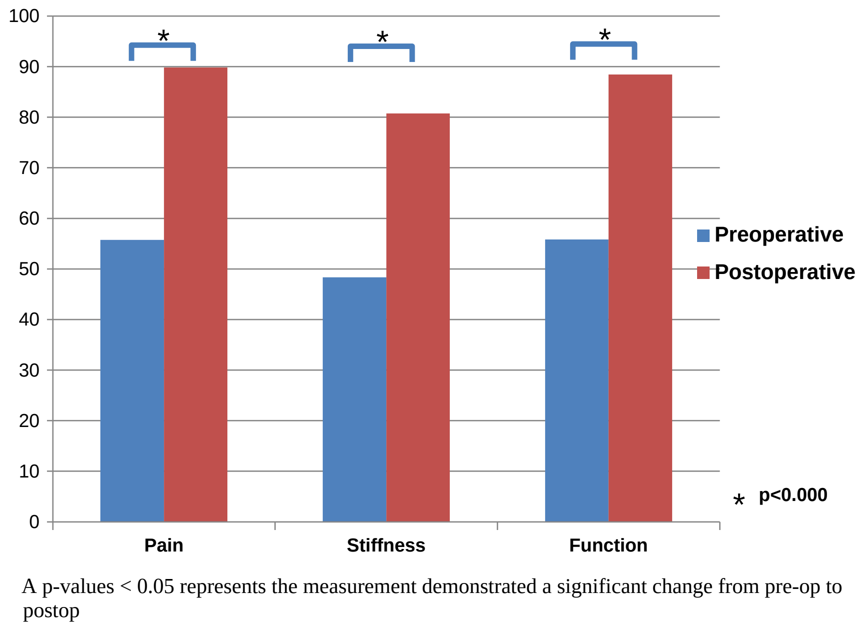

Fig. 2. Preoperative and post-operative WOMAC scores. A P value < 0.05 represents the measurement demonstrated a significant change from preop to postop.

difference was not reached in any comparison, however, knees with preoperative modified Altman score of II–III versus 0–I were associated with better improvement in WOMAC pain, stiffness, and function scores, respectively (+8.8; +5.4; +3.0 points). The results from multiple linear regressions are illustrated in Table 1. No significant association was found between preoperative patellar congruence angle, lateral patellar displacement, limb alignment, age, gender, and BMI and postoperative WOMAC subscale scores.

Pearson product moment correlation test showed no significant correlation between WOMAC subscale scores and pre-operative or post-operative limb alignment, Insall–Salvati index, lateral patellar displacement and patellar congruence angle (Table 2).

Pre-operative and post-operative radiographic measurements for the whole cohort are summarized in Table 3. Mechanical lower limb alignment was corrected from 7.69 (SD ±3.58) of varus angle preoperatively to 2.95 (SD ±2.65) of varus postoperatively ($P < 0.0001$). The patellar congruence angle was improved from 14.23 (SD ± 11.22) to 10.05 (SD ± 10.28), postoperatively ($P = 0.0038$) (Figs. 3 and 4). No significant change was recorded in the lateral patellar displacement and Insall–Salvati ratio.

Table 1
Multiple Linear Regression Model: Association Between Preoperative Radiographic Measures and Demographics and Postoperative WOMAC Scores.

	Estimate	Standard Error	Pr > |t|
WOMAC pain			
Intercept	53.2	24.3	0.034
Limb alignment	0.0	0.7	0.9807
Lateral patellar displacement	0.2	0.3	0.6355
Modified Altman (2–3 vs 0–1)	8.8	5.7	0.1273
K–L grade (3–4 vs 1–2)	−3.1	5.3	0.5598
Age	0.2	0.3	0.3682
Gender (Female vs Male)	−4.5	5.0	0.3739
BMI	0.7	0.5	0.1467
WOMAC stiffness			
Intercept	44.1	27.0	0.11
Limb alignment	0.3	0.8	0.6843
Lateral patellar displacement	0.5	0.4	0.1824
Modified Altman (2–3 vs 0–1)	5.4	6.3	0.393
K–L grade (3–4 vs 1–2)	−2.7	5.8	0.643
Age	0.0	0.3	0.8813
Gender (Female vs Male)	−2.0	5.6	0.7242
BMI	1.0	0.6	0.0905
WOMAC function			
Intercept	76.0	24.1	0.0031
Limb alignment	−0.2	0.7	0.823
Lateral patellar displacement	0.2	0.3	0.4748
Modified Altman (2–3 vs 0–1)	3.0	5.5	0.5864
K–L grade (3–4 vs 1–2)	−4.5	5.0	0.3768
Age	0.1	0.3	0.5772
Gender (Female vs Male)	−3.1	4.8	0.5261
BMI	0.2	0.5	0.6723

Discussion

Debate still exists on whether pre-existing PFJ degeneration remains a contraindication for medial UKA. Furthermore, there are no reports on the ability of either conventional or RA medial UKA in correcting preoperative PFJ incongruence. Therefore, we aimed to determine whether severe PFJ degeneration is associated with lower clinical outcomes and to analyze the effect of medial fixed bearing RA-UKA on postoperative PFJ congruence.

Historically, radiographic degenerative changes of the PFJ have been considered a contraindication for UKA. Kozinn and Scott popularized that preexisting PFJ degenerative changes are a contraindication for UKA which has been supported by others as well [27]. Furthermore, preexisting PFJ degeneration has been reported to be a risk factor for PF pain following medial UKA [10]. Berger et al [28] highlighted that strict patient selection criteria (i.e. minor degenerative PFJ alterations) is essential for successful clinical outcomes. The authors reported that 78% of patients who underwent fixed bearing UKA reported excellent outcomes and 20% good outcomes, using the Hospital for Special Surgery Score (6–10 years of follow-up). However, the current study shows no association between the preoperative radiographic PFJ measurements and adverse clinical outcomes following RA medial UKA at an average 2 years of follow-up. Degenerative changes of the PFJ and pre-operative patellar incongruence were not found to affect postoperative WOMAC scores in UKA candidates presenting without severe anterior knee pain. Our results are in agreement with other published studies. The Oxford Group has reported a significant increase in the Oxford Knee Score (OKS) after UKA in patients with preoperative medial patellar degenerative changes as well as those with intact PFJ [29]. Multiple studies, most of them using mobile bearing medial UKA, have

Table 2
Pearson Product Moment Correlation Coefficients to Estimate the Correlation Between Pre-Operative and Post-Operative Radiographic Measurements and Postoperative WOMAC Scores.

			WOMAC pain		WOMAC Stiffness		WOMAC Function
			Post		Post		Post
Variable		N	Corr (95% CI)	N	Corr (95% CI)	N	Corr (95% CI)
Limb alignment	Post	111	0.10 (−0.09, 0.28)	110	0.02 (−0.17, 0.21)	104	0.04 (−0.15, 0.23)
Limb alignment	Pre	98	0.02 (−0.18, 0.22)	97	0.09 (−0.12, 0.28)	91	−0.01 (−0.22, 0.19)
Insall–Salvati index	Post	113	−0.10 (−0.28, 0.08)	112	−0.03 (−0.22, 0.16)	106	−0.12 (−0.30, 0.07)
Insall–Salvati index	Pre	113	−0.06 (−0.24, 0.13)	112	0.03 (−0.16, 0.21)	106	−0.07 (−0.25, 0.13)
Lateral patellar displacement	Post	113	−0.04 (−0.22, 0.15)	112	0.03 (−0.16, 0.21)	106	0.04 (−0.15, 0.23)
Lateral patellar displacement	Pre	113	−0.04 (−0.22, 0.14)	112	0.04 (−0.15, 0.23)	106	0.02 (−0.17, 0.21)
Congruence angle	Post	113	−0.03 (−0.22, 0.15)	112	0.07 (−0.12, 0.25)	106	0.05 (−0.15, 0.23)
Congruence angle	Pre	113	−0.01 (−0.19, 0.17)	112	0.08 (−0.10, 0.26)	106	0.04 (−0.15, 0.23)

reported minimal or no correlation between clinical outcomes and failure rates, and preoperative degenerative changes of the PFJ. Goodfellow et al [30] and Song et al [31] reported no correlation between preoperative degenerative PFJ changes and postoperative PFJ related pain. An MRI study [32] found no significant differences in function or failure rates, after comparing 33 patients with degenerative changes of the adjacent compartment and/or PFJ with 967 medial UKA patients.

In this series, with an average follow-up of 2 years, only one case out of 132 knees (0.75%) was revised due to symptomatic progression of degenerative changes in the lateral compartment. No revision was performed due to PFJ symptoms. Similarly, Hernigou and Deschamps reported that only one of the 22 revisions (cohort 99 fixed bearing medial UKAs) was revised because of PFJ symptoms due to impingement 11 years following index surgery [10].

The Oxford Group showed no correlation between PFJ cartilage damage pre-operatively and poor clinical outcomes. These authors reported that none of the 1701 UKAs were revised because of symptomatic PFJ degenerative changes [29]. The Swedish Knee Arthroplasty Registry [33] has reported, in a series of 699 mobile bearing UKAs, that only 1 out of 50 UKA revisions was performed due to PFJ symptoms. Additionally, long-term (>10-year) studies including multiple UKA designs, have stated that failure rate related to the patellofemoral and/or adjacent tibiofemoral compartment is relatively low, and ranges from 3% to 9% [10,34–39] Furthermore, Foran et al [3] showed radiographic evidence of patellofemoral or adjacent tibiofemoral compartment degeneration progression in most of their patients with minimal effect on clinical outcomes. The same group reported that only 2 out of 51 medial fixed bearing UKAs were revised because of progressive PFJ degeneration [3]. Taken together, the historical literature, along with our current data, suggests that radiographic PFJ degeneration does not predict adverse functional outcome after medial UKA in either mobile or fixed bearing implant designs.

We found that the patellar congruence angle was improved following fixed bearing medial UKA. Our finding of patellar congruence angle centralization after RA medial UKA, without interfering with patellar height (Insall–Salvati Index), which might unload the PFJ, may be a mechanistic explanation for the limited impact of PFJ degeneration of clinical outcome after medial UKA. Indeed, medial UKA imparts a multiplanar realignment to the joint. In the coronal plane, our lower limb realignment after medial UKA was improved by an average of 4.74°. While we were not able to measure the axial plane realignment, selectively opening the medial compartment with medial UKA presumably externally rotates the femur as the knee flexes, which could account for the improved PFJ congruence as the patella engages in trochlea. This assumption is supported by the current study. We report that patients with more severe Altman score have higher WOMAC score improvement. This may suggest that improved patellofemoral congruence after medial UKA may lead to redistribution of contact forces across the patellofemoral joint and secondarily treat patellofemoral symptoms.

Our study has specific limitations. First, the retrospective nature of our analysis consists of an important shortcoming. However, this study was based on a prospective cohort of patients assembled for the senior author's surgical arthritis registry, in which clinical outcomes scores were collected prospectively. Second, we had complete preoperative WOMAC scores for 48.2% of our cohort. Nevertheless, except for the patellar congruence angle, no significant difference was found between respondents and respondents in baseline demographics and radiographic measures. In addition, Pearson product moment correlation test showed no correlation between WOMAC subscale scores and pre-operative or post-operative patellar congruence angle, potentially mitigating the effect of missing pre-operative WOMAC scores on our analysis. Third, radiographs may be subjected to rotational variations and variability in flexion degrees which may influence the measurements. Still, all radiographs were obtained following a standardized protocol (using a Merchant board jig). Fourth, the measurements were performed on two-dimensional radiographs and may have missed 3 dimensional joint realignments after UKA like patellar rotation or translation. Moreover, radiographs are performed in a static position and the

Table 3
Radiographic Measurements of the Patella–Femoral Joint for the Whole Cohort Pre and Post Medial UKA (N = 113).

	Preoperative	Postoperative	*P* Values
	Mean (± Std)	Mean (± Std)	
Long Limb alignment	7.69 (±3.58)	2.95 (±2.65)	<**.0001**
Insall–Salvati index	1.07 (±0.16)	1.07 (±0.16)	0.9678
Lateral patellar displacement (L)	6.67 (±8.81)	5.77 (±8.86)	0.4467
Lateral patellar angle	11.21 (±6.23)	11.33 (±6.34)	0.8799
Congruence angle (α)	14.23 (±11.22)	10.05 (±10.28)	**0.0038**

P values obtained from paired T test.
A *P* value < 0.05 represents the measurement demonstrated a significant change from preop to postop.

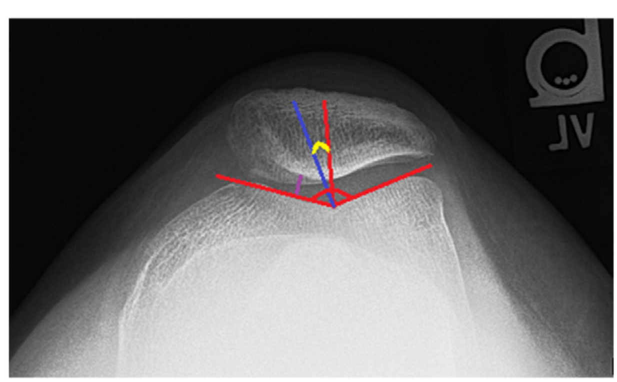

Fig. 3. Pre-operative Merchant View of a left knee. The trochlear angle (Red angle) is 140°. The congruence angle (yellow angle) is 14°. The medial patella–femoral joint space is represented by the purple line.

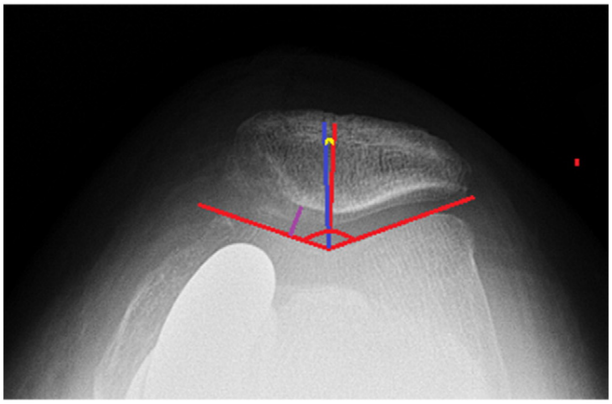

Fig. 4. Post-operative Merchant View of a left knee. The trochlear angle (Red angle) is 140°. The post-operative congruence angle (yellow angle: 6°) is decreased compared to the pre-operative one (Fig 3). Moreover, the medial patella–femoral joint space (purple line) is increased by 1.5 mm following Unicondylar Knee Arthroplasty.

dynamic influence of the muscles on the final alignment of the patella cannot be determined. However, this method is widely used since no dynamic modality is available for commercial use. Finally, though studies support the adequacy of the measurement properties of the WOMAC, two potential weaknesses have been debated. Initially, there is little evidence regarding the measurement properties of the stiffness subscale, and its test–retest reliability has been low [40]. Moreover, some studies have found inadequate factorial validity of the WOMAC pain and physical function subscales, potentially leading to weaknesses in the ability of the physical function subscale to detect change when there is a weak association between pain and function [41]. In the context of these limitations, to our knowledge, this is the first study to report patellar congruence alterations following fixed bearing RA medial UKA.

In conclusion, in patients with medial compartment degeneration, radiographic PFJ incongruence and degenerative changes in patients without clinical symptoms of patellofemoral disease do not negatively affect short-term clinical outcomes scores following RA medial UKA. In addition, medial UKA appears to improve PFJ congruence, presumably by increasing the external rotation of the femur as the knee flexes. The improved PFJ congruence after medial UKA suggests that medial UKA may secondarily redistribute contract pressures across the PFJ and may help protect the PFJ against progressive degeneration. This may be a mechanistic explanation for the multiple studies, as well as our data, that demonstrate that PFJ degeneration is not associated with adverse functional outcomes, or increased failure rate, in medial UKA using either a mobile bearing or fixed bearing implant. Further studies, with larger sample sizes and longer follow-up, are warranted to confirm our findings and further investigate the role of multiplanar realignment that occurs during medial UKR on the mechanics of the PFJ.

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