OPEN Research Article

Severity Of Radiographic Osteoarthritis: Association with Improved Patient Reported Outcomes Following Knee Arthroplasty

Yoav S. Zvi, MD
Shoran Tamura, BS
Jonathan Rubin, BS
Zeynep Seref-Ferlengez, PhD
Eli Kamara, MD

ABSTRACT

Introduction: The Kellgren and Lawrence (KL) classification for knee osteoarthritis estimates disease severity. Its utility in predicting patient-reported outcomes (PROs) after primary total knee arthroplasty (pTKA) has been suggested. We hypothesized that patients who had higher preoperative KL grades would demonstrate greater improvements in PROs after pTKA.

Methods: This was a retrospective review of patients who underwent pTKA between 2016 and 2021. Two observers graded preoperative radiographs (KL1/2, KL3, and KL4). Knee Injury and Osteoarthritis Outcome Score (KOOS) for activities of daily living (KOOS-ADL) and pain (KOOS-Pain) were collected at preoperative and 12-month postoperative visits. Changes in KOOS-ADL (ΔADL) and changes in KOOS-Pain (ΔPain) scores were compared from the preoperative to 12-month postoperative mark across different groups, with the minimal clinically important difference (MCID) for both ΔADL (MCID-ADL) and ΔPain (MCID-Pain) also being calculated. A P-value of < 0.05 was considered statistically significant.

Results: A total of 1651 patients were included in the study. The KL3 and KL4 groups exhibited significantly higher ΔADL scores and ΔPain scores compared with the KL1/2 group ($P < 0.01$). Patients who had KL3 and KL4 were 1.42 ($P = 0.03$) and 1.88 ($P < 0.01$) times, respectively, more likely to achieve MCID-ADL compared with those who had KL1/2. Furthermore, patients who had a KL4 were 1.92 times ($P < 0.01$) more likely to reach MCID-Pain compared with those who had KL1/2.

Conclusions: This study determined that patients who had higher preoperative KL grades experienced markedly greater improvements in KOOS-ADL and KOOS-Pain scores than those who had lower KL grades. These findings offer surgeons an objective tool when counseling patients on expected outcomes after pTKA.

From the Department of Orthopaedic Surgery, Montefiore Einstein, Bronx, NY (Dr. Zvi, Dr. Seref-Ferlengez, and Dr. Kamara), and the Albert Einstein College of Medicine, New York, NY (Mr. Tamura, Mr. Rubin).

Correspondence to Dr. Seref-Ferlengez: sereffer@montefiore.org zeynep.seref@gmail.com

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The presence of moderate-to-severe osteoarthritis (OA) on preoperative radiographs is a recognized indication for primary total knee arthroplasty (pTKA) in patients who have failed all conservative treatment measures. The efficacy of pTKA to improve patients' quality of life with long-term success has been demonstrated and reported on extensively.[1-3] With the growing demand for this cost-effective procedure, it is estimated that by 2030, the annual number of pTKA procedures in the United States alone will increase to approximately 3.5 million.[4] Meanwhile, although notable advancements in surgical techniques and implants have been developed since the inception of this procedure, approximately 20% of patients remain dissatisfied after their surgery.[5,6] For this reason, it is important to preoperatively identify patient characteristics that may negatively or positively influence patient-reported outcomes (PROs).

A number of prior studies have characterized the association between patient outcomes with respect to patient characteristics such as medical comorbidities, body mass index (BMI), race/ethnicity, socioeconomic status, functional status, and preoperative radiographs.[7-12] In most studies evaluating the effect of OA severity on postoperative outcomes, the Kellgren and Lawrence (KL) grading system was used. This classification system for knee OA is based on anterior-posterior (AP) weight-bearing radiographs of the knee. Grading ranges from 0 to 4 and is determined by the presence or absence of osteophytes, joint space narrowing, sclerosis, and bone end deformity.[13,14] While the KL classification system is indicative of OA severity, few studies have investigated its utility in predicting improvements of PROs after pTKA. We hypothesized that patients with a higher preoperative KL grade would demonstrate greater improvements in PROs in activities of daily living (ADL) and pain after pTKA, when compared with patients with a lower preoperative KL grade.

Methods

Patient Inclusion/Exclusion Criteria

This was a retrospective review of prospectively collected data of patients who underwent pTKA between 2016 and 2021 at a single, high-volume academic joints center. Patients included had available preoperative knee radiographs confirming the presence of OA as well as PROs at preoperative and 12-month postoperative visits. We excluded patients who did not have these data available. This study was IRB approved.

Radiographic Evaluation

Two independent observers reviewed the most recent preoperative AP weight-bearing knee radiographs of all patients. Before reviewing all patient radiographs, a validation test was conducted to establish an acceptable interobserver reliability. After the first 100 radiographs were reviewed by both observers, a kappa = 0.87 was achieved, which was deemed to be sufficient to continue grading the remaining radiographs. Each patient was then assigned a KL grade from 0 to 4 based on the presence or absence of joint space narrowing and/or osteophyte formation.[13,14] Patients were categorized into one of three groups based on KL grade—KL grade 1 or 2 (KL1/2), KL grade 3 (KL3), or KL grade 4 (KL4). No patients were found to have a KL grade of 0.

Outcome Measures

PROs as measured by the Knee Injury and Osteoarthritis Outcome Score (KOOS) were prospectively collected as part of the FORCE-TJR registry at preoperative and 12-month postoperative visits. KOOSs for ADL (KOOS-ADL) and pain (KOOS-Pain) were collected from these surveys. The primary outcome of this study was the change between preoperative and 12-month postoperative KOOS-ADL and KOOS-Pain scores (ΔADL and ΔPain, respectively). We then calculated the percentage of patients within each KL group who reached the minimal clinically important difference (MCID) for ΔADL (MCID-ADL) and ΔPain (MCID-Pain). The MCID was calculated using the anchor-based approach described by Lyman et al., and the MCID-ADL and MCID-Pain subscales were 16 and 18, respectively.[15,16] Patient demographic and medical data were also collected including age, sex, race/ethnicity, BMI, smoking, insurance type, educational level, Charlson Comorbidity Index, American Society of Anesthesiologist Classification of Physical Health score, and number of joints with moderate-severe pain.

Statistical Analysis

Differences in KOOSs among the three KL groups were compared using Kruskal-Wallis tests. Wilcoxon rank-sum tests were used for post hoc pairwise comparisons between groups with Bonferroni correction for multiple testing. The ΔADL and ΔPain scores between each group of KL grades were compared to determine whether the severity of KL grade is predictive for improvement in PROs. A *P*-value of < 0.05 was considered statistically significant. Binary logistic regression was used to calculate the odds ratios (OR) with a 95% confidence interval to determine the likelihood of satisfying the MCID-ADL and MCID-Pain

Table 1. Baseline Patient Demographic Characteristics

	KL 1/2 (n = 230)	KL3 (n = 760)	KL4 (n = 661)	ALL (n = 1651)	*P*
Age, mean (SD)	62.5 (9.2)	64.8 (9)	67.6 (9.5)		< 0.01
Sex					
Female	202 (88%)	596 (79%)	495 (76%)	1293 (78%)	< 0.01
Male	28 (12%)	159 (21%)	159 (24%)	346 (22%)	
BMI, mean (SD)	32.4 (6)	33.1 (6.1)	33.5 (6.4)		0.2
Cig smoker	30 (13%)	84 (11%)	42 (6%)	156 (9%)	< 0.01
Health insurance					
Medicaid	42 (18%)	127 (16%)	88 (13%)	257 (15%)	
Medicare	75 (31%)	254 (32%)	257 (37%)	586 (34%)	
Private	49 (21%)	154 (19%)	137 (20%)	340 (20%)	
Other	29 (12%)	103 (13%)	76 (11%)	208 (12%)	
Education level					0.6
< High School	52 (22%)	186 (23%)	136 (19%)	374 (22%)	
High School/College	104 (44%)	357 (45%)	317 (45%)	778 (45%)	
≥College Graduate	34 (14%)	88 (11%)	92 (13%)	214 (12%)	
Other	13 (5%)	36 (5%)	31 (4%)	80 (5%)	
CCI					0.1
0	119 (50%)	399 (50%)	362 (52%)	880 (51%)	
1	70 (29%)	215 (27%)	186 (27%)	471 (27%)	
2–5	37 (16%)	123 (16%)	81 (12%)	241 (14%)	
6+	7 (3%)	28 (4%)	28 (4%)	63 (4%)	
ASA score					0.08
1-2	115 (48%)	389 (49%)	366 (52%)	870 (50%)	
3-4	114 (48%)	359 (45%)	311 (45%)	784 (45%)	
No. of Joints with Moderate-Severe Pain					< 0.01
0	51 (22%)	221 (29%)	254 (38%)	526 (32%)	
1	88 (38%)	255 (33%)	222 (34%)	565 (34%)	
2	33 (14%)	119 (16%)	76 (12%)	228 (14%)	
3	61 (26%)	168 (22%)	107 (16%)	336 (20%)	

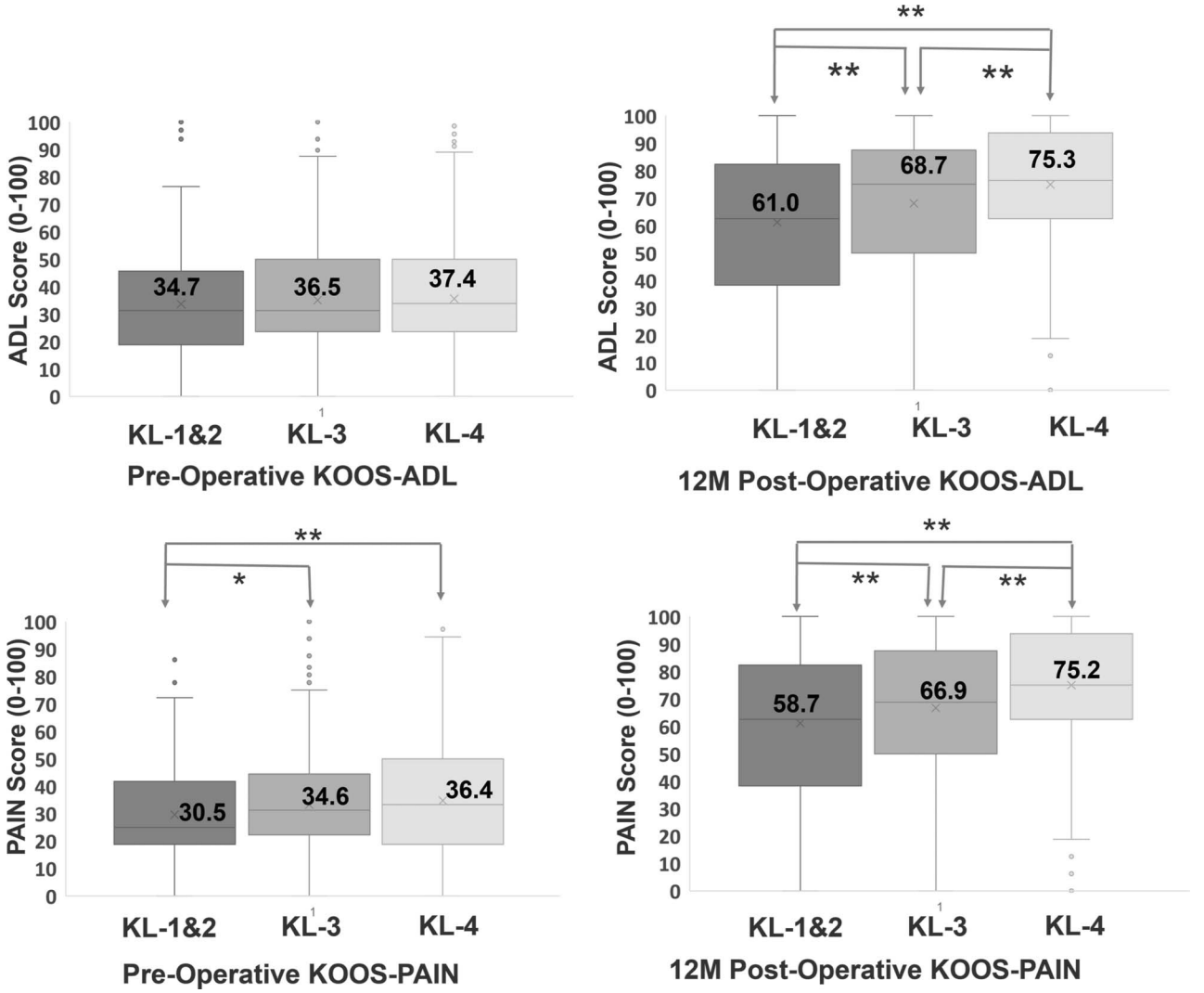
ASA score = American Society of Anesthesiologist classification of Physical Health score, CCI = Charlson Comorbidity Index, KL = Kellgren and Lawrence

thresholds for KL3 and KL4 cohorts compared with KL1/2 as a reference.

Results

A total of 1,651 patients were included in this study. Two hundred thirty patients were with KL1/2, 760 patients with KL3, and 661 patients with KL4. Patients with KL1/2 were significantly younger with a mean age of 62.5 years (±9.2), followed by KL3 with a mean age of 64.8 years (±9) and KL4 with a mean age of 67.6 years (±9.5; $P < 0.01$). When comparing sex across groups, KL1/2 had a significantly higher percentage of women at 88%, followed by KL3 at 79% and KL4 at 76% ($P < 0.01$). No significant differences were found between groups with respect to BMI; however, KL1/2 had the lowest mean BMI 32.4 ($P = 0.2$). The proportion of smokers across the groups were also significantly different. Patients with KL1/2 had the highest proportion of smokers at 13%, followed by KL3 at 11% and KL4

Figure 1



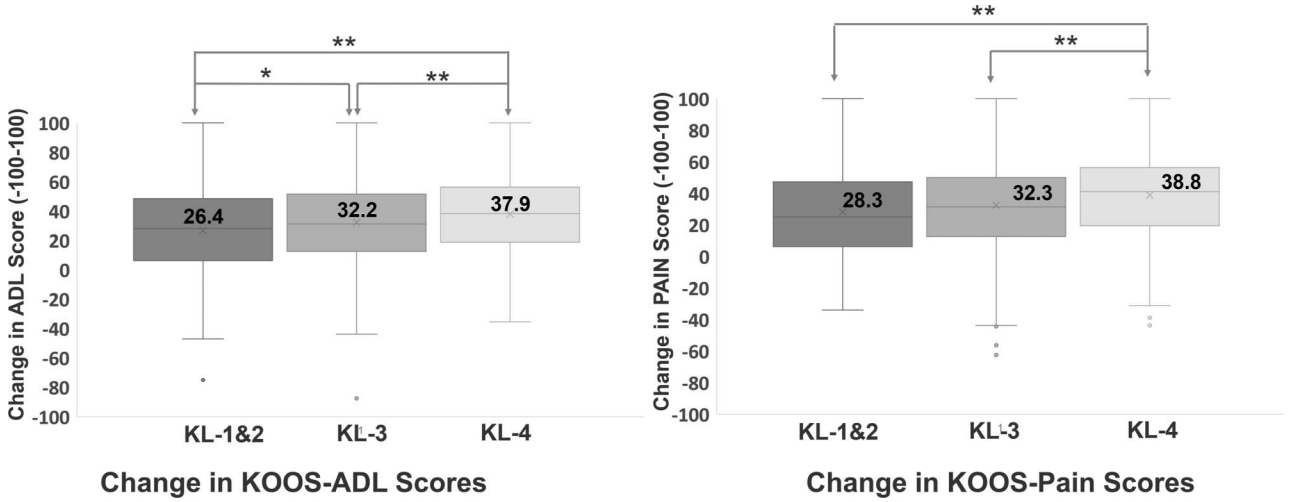
Graphs showing comparison of preoperative and 12-month postoperative ADL and Pain scores between groups of KL grades. Means are compared using Kruskal-Wallis tests with post-hoc tests. *$P < 0.05$, **$P < 0.01$. ADL = activities of daily living, KL = Kellgren and Lawrence

at 6% ($P < 0.01$). No significant differences were found between KL groups when comparing health insurance type, educational level, Charlson Comorbidity Index, or American Society of Anesthesiologist classification of Physical Health score. Significant differences were found between KL groups with respect to the number of joints with moderate-severe pain; KL1/2 had the highest proportion of patients with three joints affected ($P < 0.01$; Table 1).

The mean preoperative KOOS-ADL scores were KL1/2 = 34.7 ± 21, KL3 = 36.5 ± 20, and KL4 = 37.4 ± 21 ($P = 0.2$). The mean preoperative KOOS-Pain scores were KL1/2 = 30.5 ± 18.6, KL3 = 34.6 ± 19, and KL4 = 36.4 ± 20 ($P < 0.01$). Significant differences were observed in preoperative KOOS-Pain scores between groups KL1/2 versus KL3 ($P < 0.01$) and KL1/2 versus KL4 ($P < 0.01$); however, there was no significant difference between KL3 versus KL4 ($P = 0.5$; Figure 1).

The mean KOOS-ADL scores 12 months postoperatively were KL1/2 = 61.0 ± 27, KL3 = 68.7 ± 22, and KL4 = 75.3 ± 22 ($P < 0.01$). Significant differences were observed in 12-month KOOS-ADL scores between groups KL1/2 versus KL3 ($P < 0.011$), KL1/2 versus KL4 ($P < 0.01$), and KL3 versus KL4 ($P < 0.01$). The mean KOOS-Pain scores 12 months postoperatively were KL1/2 = 58.7 ± 26, KL3 = 66.9 ± 23, and KL4 = 75.2 ± 21 ($P < 0.01$). Significant differences were found in 12-month KOOS-Pain scores between groups KL1/2

Figure 2



Graphs showing comparison of changes in ADL and Pain scores between groups of KL grades. Means are compared using Kruskal-Wallis tests with post hoc tests *$P < 0.05$, **$P < 0.01$. ADL = activities of daily living, KL = Kellgren and Lawrence

versus KL3 ($P < 0.01$), KL1/2 versus KL4 ($P < 0.01$), and KL3 versus KL4 ($P < 0.01$; Figure 1).

The mean ΔADL score increased as the KL grade increased—KL1/2 = 26.4 ± 28, KL3 = 32.2 ± 27, and KL4 = 37.9 ± 27 ($P < 0.01$). Significant differences were noted in ΔADL scores between groups KL1/2 versus KL3 ($P = 0.04$), KL1/2 versus KL4 ($P < 0.01$), and KL3 versus KL4 ($P < 0.01$). The average ΔPain score also increased as KL grade increased—KL1/2 = 28.3 ± 27, KL3 = 32.3 ± 27, and KL4 = 38.8 ± 26 ($P < 0.01$). Significant differences in ΔPain scores between groups KL1/2 versus KL4 ($P < 0.01$) and KL3 versus KL4 ($P < 0.01$); however, no significant difference was found between KL1/2 versus KL3 ($P = 0.06$; Figure 2).

The number of patients within each KL group that met the threshold score for MCID-ADL increased in concordance with KL grade—MCID-ADL KL1/2 = 151 (65.1%), KL3 = 552 (72.6%), and KL4 = 515 (77.8%); there was a statistically significant difference between the three groups ($P < 0.01$). The number of patients within each KL group that met the threshold score for MCID-Pain similarly increased with KL grade—MCID-Pain KL1/2 = 154 (66.4%), KL3 = 546 (71.3%,) and KL4 = 526 (79.1%); these differences between the three groups were also statistically significant ($P < 0.01$; Figure 3).

Compared with the KL1/2 patients, KL3 and KL4 patients were 1.42 (95% CI = 1.04 to 1.95, $P = 0.027$) and 1.88 (95% CI = 1.36 to 2.60, $P < 0.01$) times more likely to meet the MCID-ADL, respectively. Regarding KOOS-Pain scores, KL4 patients were 1.92 (95% CI = 1.38 to 2.67, $P < 0.01$) times more likely to meet the MCID-Pain, when compared with KL1/2 patients (Table 2).

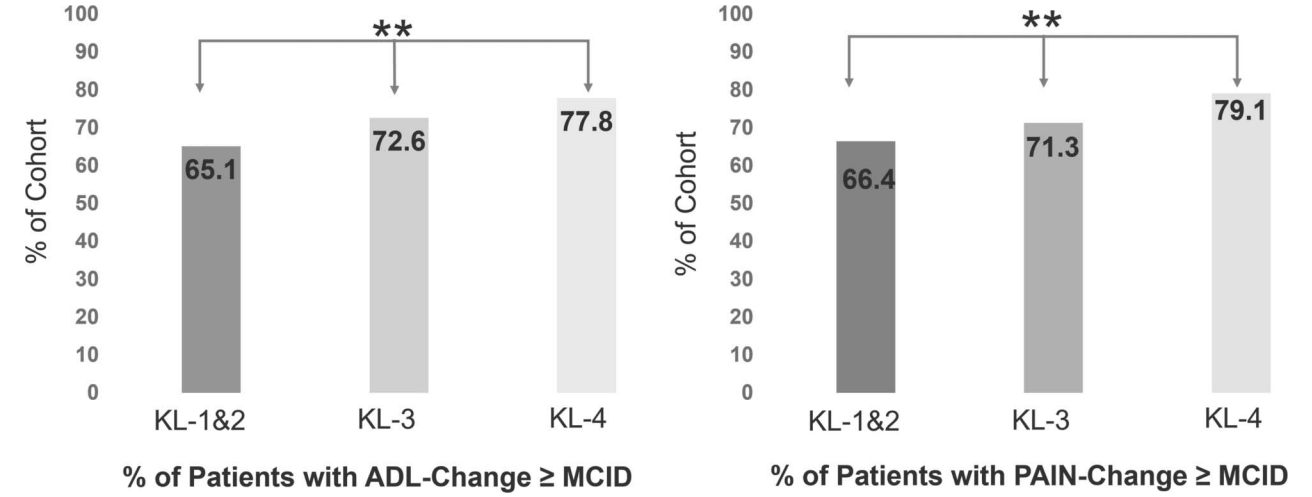
Discussion

This study demonstrated that patients with preoperative KL3 and KL4 had markedly higher improvements in KOOS-ADL when compared with patients with KL1/2. Patients with KL4 also had markedly higher improvements in KOOS-ADL when compared with KL3, as well as improvements in KOOS-Pain when compared with patients with KL1/2 and KL3. Proportions of patients who met MCID Pain and MCID-ADL following pTKA were higher in the higher KL grade groups (KL3 and KL4) compared to KL2 group. Furthermore, patients with KL3 and KL4 were 1.42 times and 1.88 times, respectively, more likely to meet MCID-ADL when compared with patients with KL1/2; patients with KL4 were 1.92 times more likely to meet the MCID-Pain when compared with patients with KL1/2.

Several studies in arthroplasty literature have investigated the role of preoperative OA severity on postoperative patient satisfaction and reported outcomes. Typically, the KL classification system is used, in addition to other radiographic views, to assess the degree and pattern of OA about medial, lateral, and patellofemoral compartments. A variety of patient outcomes looking at pain, function, and satisfaction have been compared with radiographic OA severity to determine the association with preoperative radiographs.

Using data from the Osteoarthritis Initiative (OI), Kahn et al[12] studied 172 pTKA patients to determine whether

Figure 3



Graphs showing comparison of percentage of cohorts that met MCID between groups of KL grades; comparisons by chi-square tests. $^{**}P < 0.01$. KL = Kellgren and Lawrence, MCID = minimal clinical important difference

radiographic measures of knee OA, including varying angles as well as medial, lateral, or combined compartment KL grade, were correlated with postoperative patient outcomes. They found that more severe lateral KL grade was positively associated with larger decreases in Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) total scores, a score to assess pain, stiffness, and physical functioning of hip and knee joints with OA. Combined KL grade was inversely associated with WOMAC disability (r = −0.152; P = 0.045) and pain (r = −0.153; P = 0.044) and strongly associated with decreases in WOMAC total (r = 0.254; $P < 0.01$) and disability (r = 0.256; $P < 0.01$). Although these associations were modest, they demonstrated that higher KL grades were associated with less symptoms and greater improvements in WOMAC scores.

Niemelainen et al followed 250 pTKA patients aged 65 years or younger over a 2-year period to report on their postoperative outcomes about the Oxford Knee Score and KOOS.[17] Preoperative KL grade was demonstrated to markedly affect patient outcomes—KL2 patients had markedly worse median visual analog scale satisfaction when compared with KL3 (85 versus 94 points; $P < 0.01$) and KL4 (85 versus 91 points; P = 0.015) patients. The authors report that all three KL groups had notable improvements overall in PROs at 2 years when compared with preoperative PROs; however, KL2 patients had the highest rates of dissatisfaction.

The same group conducted a similar study to further investigate whether postoperative patient satisfaction was affected by preoperative KL grade.[18] They found

Table 2. Adjusted Odds Ratios of Crossing the Thresholds for MCID-ADL and MCID-Pain When Comparing KL1/2 with KL3 and KL4

	Adjusted Odds Ratio (95% CI)	*P*
MCID-ADL Threshold		
KL4	1.88 (1.36 to 2.6)	< 0.01
KL3	1.42 (1.04 to 1.95)	0.04
KL 1/2 (reference)	1	
MCID-Pain Threshold		
KL4	1.92 (1.38 to 2.67)	< 0.01
KL3	1.26 (0.92 to 1.72)	= 0.15
KL 1/2 (reference)	1	

ADL = activities of daily living, MCID = minimal clinically important difference, KL = Kellgren and Lawrence

that patients with mild knee OA, KL2, were significantly more dissatisfied when compared with patients with more severe OA, KL3 or KL4 (28.6% versus 8.7%, $P < 0.01$). Patients with KL2 were 4.22 times more likely to express dissatisfaction after pTKA when compared with patients with KL3 or KL4.

Several prospective studies with small sample sizes investigated the association of radiographic severity and patterns of knee OA with pain and function at 12 months after pTKA. A study by Scott et al[19] included 259 patients with KL3 or higher who underwent unilateral pTKA. Contrary to previous studies, they did not find KL grade to be associated with Oxford Knee Score, visual analog scale pain, or EQ-5D to TKA, nor did they find extent and pattern of cartilage loss to affect preoperative PROs. Furthermore, no notable association was demonstrated between OA severity and PROs postoperatively. On the other hand, a similar prospective study by Rehman et al,[20] which included 156 patients, found OA severity was markedly associated with the PRO improvements in their usual activities and knee pain at 1-year follow-up.

In patients with severe knee OA, as represented by KL3 or KL4, improvements in postoperative PROs should be expected regardless of disease location. Furthermore, although patients with mild knee OA, as represented by KL2 or lower, may experience improvements in some PRO measures, overall dissatisfaction was higher in these patient groups. These findings are consistent with the current data presented in this study, which found notable improvements in KOOS-ADL, KOOS-Pain, MCID-ADL, and MCID-Pain for patients with KL3 and KL4 compared with patients with KL1/2. Taken together, these findings should stress the importance of preoperative counseling for patients undergoing pTKA. Patients' expectations from surgery, specifically those with mild OA on preoperative radiographs, should be discussed thoroughly.

This study is not without limitations. First, the retrospective nature of the review from an institutional database introduces inherent biases associated with data collection and chart analysis. The PRO data were sourced exclusively from patients who returned for office follow-up, which could introduce selection bias into the results. Second, the interpretation of preoperative radiographs for assessing knee OA severity in patients who had already undergone pTKA may lead to grading bias. We sought to mitigate this by ensuring a minimum level of interobserver reliability before completing all radiographic evaluations. In addition, the KL grading system, although popular for evaluating OA severity, is dependent on AP knee radiographs. This approach may not comprehensively assess all three compartments within the knee, potentially underestimating OA severity in certain cases. The study's follow-up duration is another limitation. Data were collected only until the 12-month postoperative mark, not considering long-term outcomes such as patient satisfaction or efficacy of pTKA beyond the first 12 months. This limited follow-up may not capture the full spectrum of recovery or later arising complications that can affect PROs. Furthermore, the absence of data on preoperative and postoperative narcotic use represents another limitation. Narcotic medication can markedly affect PROs because of their effect on pain perception. Patients accustomed to long-term narcotic use may exhibit altered pain thresholds, which could affect the rate of improvement in PROs after pTKA. Similarly, patients who took narcotics postoperatively would similarly experience pain differently from those who did not take narcotics, again, affecting the rate of improvement in PROs after pTKA. Without this information, we cannot account for the confounding effects of narcotics on the improvements noted in the KOOS-ADL and KOOS-Pain scores. Finally, this study did not adjust for variables such as sex or smoking status, although the clinical significance of these factors as potential confounders remains uncertain.

The KL classification system is an indication of OA severity; its role in predicting PROs after pTKA has been described. The primary outcome of this study found that patients with a higher preoperative KL grade had markedly greater changes in KOOS-ADL and KOOS-Pain PROs, when compared with patients with a lower KL grade. Patients with higher preoperative KL grade were also markedly more likely to reach MCID-ADL and MCID-Pain compared with patients with KL1/2. These findings may offer surgeons an objective tool when counseling patients on their expected outcomes after pTKA. Additional investigations into the utility of the KL classification system as a prognostic tool for additional PROs after pTKA are warranted.

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