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Radiographic Differentiation of Tibiofemoral Joint Space Width in Kellgren–Lawrence Grade 2 and 3 Osteoarthritis in Malang

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ABSTRACT

Introduction: Osteoarthritis (OA) is a leading cause of disability worldwide. Although the Kellgren–Lawrence (KL) grading system is widely used, it remains subjective. Quantitative fixed joint space width (fJSW) offers a more objective assessment of structural severity, and is particularly relevant in populations such as Javanese communities, where habitual squatting may influence knee joint loading patterns, making evaluation in Malang, East Java, of specific interest.

Material and Methods: This study analyzed 111 knees (KL grade 2 or 3) at Saiful Anwar Hospital in 2024. Medial and lateral fJSW were measured on standardized weight-bearing radiographs using a perpendicular subchondral technique.

Results: The participants were predominantly female (69.86%) and aged 40-60 years (47.95 %). KL grade 2 was more frequent than grade 3 (56.76% vs. 43.24%), with more bilateral involvement observed (52.05%). Mean medial fJSW are 3.55 ± 1.72 mm in KL 2 and 3.12 ± 1.89 mm in KL 3, while mean lateral fJSW are 4.47 ± 1.26 mm in KL 2 and 5.15 ± 2.27 mm in KL 3. An optimal medial cutoff of 5.03 mm demonstrated high sensitivity (93.8%) but low specificity (25.4%) for disease staging. Despite limited specificity, this threshold may be useful as a screening tool to reduce underdiagnosis of KL grade 3 osteoarthritis by prioritizing sensitivity in detecting more advanced disease.

Conclusion: Findings confirm a pattern of medial narrowing and lateral preservation characteristic of varus-driven attrition. However, the low specificity of fJSW suggests that quantitative narrowing alone is insufficient for grading; it must be integrated with other structural domains, such as osteophyte formation, to differentiate KL2 from KL3.

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INTRODUCTION

Osteoarthritis is a degenerative joint disease characterized by progressive damage of articular components, particularly hyaline cartilage, leading to impaired joint function. Osteoarthritis (OA) is one of the most common musculoskeletal conditions causing disability, especially among the elderly population. It is the most frequently encountered joint disease in both developing and developed countries and represents a leading cause of chronic disability, particularly when involving the knee and hip joints.

Osteoarthritis (OA) represents a major global health challenge, affecting approximately 595 million people worldwide in 2020, equivalent to

7.6% of the global population, with 132.2% increase since 1990. Projections indicate a substantial rise, with knee OA cases expected to increase by 74.9% by 2050 due to population aging and growth [1]. In Indonesia, OA prevalence has surged dramatically, with cases more than doubling from 3.9 million in 1990 to 9.7 million in 2019, reflecting a 147.44% rise—higher than the global increase of these cases [2]. In populations such as those in Indonesia, habitual activities including squatting and kneeling may influence knee joint loading patterns and compartmental joint space narrowing. These biomechanical differences may limit the applicability of thresholds derived from Western cohorts, highlighting the importance of population-specific evaluation [3,4].

Although other imaging modalities, such as magnetic resonance imaging and ultrasound, have been shown to reveal pathological changes associated with knee osteoarthritis, conventional radiography remains the cornerstone for OA diagnosis and evaluation due to its accessibility, low cost, and ability to detect key features such as osteophytes, subchondral sclerosis, and joint space narrowing (JSN). It serves as a primary tool for confirming structural changes in tibiofemoral joints, guiding clinical management, and monitoring progression of the disease [5,6].

The Kellgren–Lawrence (KL) grading system is the most widely used radiographic classification for assessing the severity of knee osteoarthritis based on radiographic findings. This system categorizes osteoarthritis into five grades (0–4) according to the presence of osteophytes, joint space narrowing, subchondral sclerosis, and bone deformity [7]. However, inconsistencies in its original descriptions particularly regarding the definition of grade 2 joint space narrowing have resulted in variable application across studies [8]. A major limitation of this system is its inherent subjectivity, especially in differentiating grade 2 (minimal or possible joint space narrowing) from grade 3 (definite joint space narrowing). This subjectivity contributes to low interobserver agreement and poses significant challenges in classifying intermediate disease stages that will influence clinical management. These considerations, therefore, prompted the increasing use of quantitative parameters such as joint space width (JSW), which is defined as the distance between the subchondral margins of the tibial and femoral bones in the weight-bearing position [9,10].

Joint space width (JSW) is a quantitative radiographic measure of joint space narrowing and serves as an objective surrogate for articular cartilage thickness. It is assessed in both the medial and lateral compartments and is widely used as a research standard because it provides numerical, objective values compared with the semiquantitative nature of Kellgren–Lawrence grading. Scientific evidence from 2020 to 2024 demonstrates that JSW has higher sensitivity for detecting structural changes than traditional assessment methods, particularly in longitudinal studies [11].

This descriptive study objectively measured medial and lateral compartment tibiofemoral fixed joint space width (fJSW) on weight-bearing radiographs in patients with KL grade 2 and 3 knee osteoarthritis at Saiful Anwar Hospital. Through compartment-specific quantitative joint space width measurements, this study minimizes subjective interpretation of joint space narrowing and offers a practical reference for reliably distinguishing Kellgren–Lawrence grade 2 from grade 3 osteoarthritis in clinical practice.

MATERIAL AND METHODS

Study Design and Study Population

This retrospective descriptive study was conducted at Saiful Anwar Hospital and included patients diagnosed with knee osteoarthritis classified as Kellgren–Lawrence (KL) grade 2 or 3 between January 2024 and December 2024. A total of 111 knees were analyzed. Demographic and clinical variables were collected from medical records, including age, sex, body mass index (BMI), and knee laterality (right or left). Exclusion criteria comprised a history of fracture involving the tibiofemoral joint at the measurement site and prior surgery.

Imaging Acquisition

Standardized weight-bearing anteroposterior knee radiographs were obtained using a fixed

imaging protocol with a tube-to-film distance of 100 cm. All images were acquired in a semi-flexed position (approximately 20–30° of knee flexion) to optimize visualization of the joint space.

Joint Space Width Measurement

Fixed joint space width (fJSW) measurements were performed on weight-bearing AP radiographs at both the medial and lateral tibiofemoral compartments. JSW was defined as the perpendicular distance between the subchondral margin of the femoral condyle and the corresponding subchondral surface of the tibial plateau by a single radiologist with more than five years of experience in musculoskeletal imaging. Measurements were obtained using a fixed-location technique to provide standardized and reproducible quantitative values, reducing reliance on subjective visual interpretation of joint space narrowing, particularly in intermediate KL grades.

Statistical Analysis

Statistical analysis was performed using SPSS for Windows (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize demographic characteristics and fJSW measurements. Continuous variables were reported as mean and standard deviation.

RESULTS

Total of 111 knees from patients with Kellgren–Lawrence (KL) grade 2 and 3 knee osteoarthritis were included in the analysis. The demographic characteristics of the study population are summarized in Table 1. Most patients were aged ≥40 years, with the highest proportion in the 40-60 year age group (47.95%), followed by those aged > 60 years (46.58%). Female patients predominated (69.86%), while males accounted for 30.14% of cases. Regarding body mass index (BMI), the majority of patients were classified as normal or obese I (30.14% and 26.03%, respectively), with 24.66% categorized as overweight.

The distribution of knee osteoarthritis severity and laterality is presented in Table 2. KL grade 2 osteoarthritis was more frequent (56.76%) than grade 3 (43.24%). Bilateral knee involvement was observed in 52.05% of patients, whereas unilateral disease was more common on the right knee (30.14%) than the left (17.81%).

Quantitative analysis of fixed joint space width (fJSW) measurements is shown in Table 3. In KL grade 2 knees (n = 63), the mean medial joint space width (MJSW) was 3.55 ± 1.72 mm, while the mean lateral joint space width (LJSW) was 4.47 ± 1.26 mm. In KL grade 3, the mean MJSW decreased to 3.12 ± 1.89 mm, whereas the mean LJSW increased to 5.15 ± 2.27 mm, indicating greater medial compartment narrowing, while the mean LJSW was increased. These findings suggest a progressive reduction in medial tibiofemoral joint space with increasing KL grade, highlighting the value of compartment-specific quantitative JSW measurements in differentiating KL grade 2 and 3 osteoarthritis.

The medial-to-lateral joint space width (MJSW/LJSW) ratio showed no significant difference between KL grade 2 and KL grade 3 (0.88 ± 1.05 vs. 0.89 ± 3.90, p = 0.965). This finding indicates that the MJSW/LJSW ratio lacks discriminative value for differentiating adjacent KL grades, and therefore may not be a reliable standalone marker of disease progression (Table 4).

Receiver operating characteristic (ROC) analysis demonstrated poor discriminatory performance of joint space width measurements for differentiating KL grade 2 from grade 3. The area under the curve (AUC) for medial joint space width was 0.582, while lateral joint space width showed a slightly higher AUC of 0.611. Both estimates were close to 0.5, indicating limited discriminative ability and substantial overlap between adjacent KL grades. The small absolute difference in AUC between compartments was unlikely to be clinically meaningful. Despite the marginally higher AUC of LJSW, distributional assessment demonstrated greater variability and overlap across grades compared with MJSW, which exhibited a more consistent separation pattern. Given the predominant involvement of the medial compartment in osteoarthritis and the more stable data distribution observed, the optimal cutoff derived from MJSW was selected for subsequent analyses to differentiate KL grade 2 from grade 3 (Figure 1).

Table 1. Baseline Demographic and Anthropometric Characteristics of the Study Population

Variable		Number	Precentage (%)
Age (n = 73)	<40	4	5.48
	40-60	35	47.95
	>60	34	46.58
Sex (n = 73)	Male	22	30.14
	Female	51	69.86
BMI (n = 73)	Underweight	5	6.85
	Normal	22	30.14
	Overweight	18	24.66
	Obese I	19	26.03
	Obese II	9	12.33

Table 2. Distribution of Kellgren–Lawrence Grades and Knee Involvement in the Study Population

Variable		Number	Precentage (%)
Kalgren-Lawrence (n = 111)	Grade 2	63	56.76
	Grade 3	48	43.24
Knee side	Left Only	13	17.81
	Right Only	22	30.14
	Left and Right	38	52.05

Table 3. Medial and Lateral Joint Space Width According to Kellgren–Lawrence Grade

		min	mean	max	stdev
KL 2 (n=63)	MJSW	0.76	3.55	7.26	1.72
	LJSW	1.53	4.47	7.48	1.26
KL3 (n=48)	MJSW	0.39	3.12	9.67	1.89
	LJSW	0.34	5.15	12.29	2.27

KL: Kellgren–Lawrence grade, MJSW: Medial Joint Space Width (mm), LJSW: Lateral Joint Space Width (mm)

Table 4. Comparison of Medial-to-Lateral Joint Space Width Ratio Between KL Grade 2 and KL Grade 3

Parameter	KL Grade 2 (n=63)	KL Grade 3 (n=48)	p-value
MJSW/LJSW Ratio (mean ± SD)	0.88 ± 1.05	0.89 ± 3.90	0.965

The next step is to determine the optimal cutoff values from the medial joint space width that best differentiate KL grade 2 from KL grade 3, using the Youden index to balance sensitivity and specificity. The optimal cut-off value of medial joint space width for differentiating KL grade 2 from KL grade 3 was determined using the Youden index, yielding a threshold of 5.03 mm. Values ≤ 5.03 mm were indicative of KL grade 3, with a sensitivity of 93.8% and a specificity of 25.4%.

DISCUSSION

The demographic profile of this study, characterized by a predominance of patients aged over 40 years (93.7%, with 48.65% >60 years), females (65.77%), and a majority with normal or overweight BMI (69.37%), aligns closely with a 2024 study on 116 patients by *Sandesh et al.* that reported 58% females and peak prevalence in the 51-60 age group [12], while a 2025 study in Surabaya by *Ahmad et al*. showed 64% female

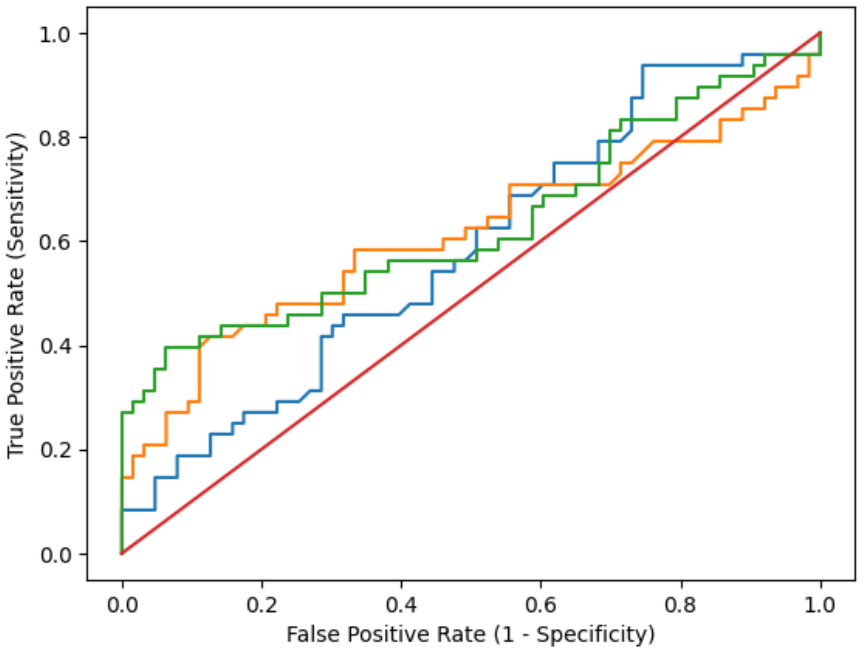


Figure 1. Receiver operating characteristic (ROC) curve analysis of medial joint space width, lateral joint space width, and their combined model for discriminating Kellgren–Lawrence (KL) grade 2 from KL grade 3 knee osteoarthritis. Blue line = medial joint space width alone, Orange line = lateral joint space width alone, Green line = Combined model (medial and lateral joint space width), Red diagonal line = Reference line (no discrimination, AUC = 0.50)

predominance and majority in 51-60 years among similar moderate-grade cases [13]. BMI profiles in this recent study were slightly different in prevalence, compared with a cross-sectional analysis linking obesity and overweight status to KL grades held in 2021 by *Rosita et al* in Surabaya that showed most patients were obese (58.5%), with the highest percentage was on 45-59 years old (51.3%) (14). In this descriptive study focusing exclusively on KL grade 2 and 3 knee osteoarthritis, the narrower KL 2-3 focus here likely captures earlier-stage disease less influenced by advanced obesity-driven progression.

The distribution of OA severity (56.76% KL2 vs. 43.24% KL3) and laterality bilateral (52.05%), with unilateral favoring on the right knee (30.14 %), compared with the left (17.81 %), aligns closely with previous study by *Shinde et al*. that showed bilateral involvement predominantly seen in 68% of patients [12] and also with a study held in Surabaya that showed the most prevalent side of the knee that involved is bilateral (37.5%), right knee (16.1%), and left knee (8,9%) [15]. Unilateral involvement in our study demonstrated right-sided predominance, which aligns with *Alexander et al.,* that evaluate tibiofemoral knee osteoarthritis progresses symmetrically by knee compartment in the GOGO cohort that showed the greater prevalence of more severe OA of right knees may be related to the greater prevalence of right foot dominance that in turn may relate to asymmetrical loading of the lower extremities [16].

The use of fixed joint space width (fJSW) measurement on conventional radiography in this study was based on its methodological and practical advantages over alternative approaches. Compared to minimum joint space width (mJSW), fJSW provides improved reproducibility and responsiveness by measuring at predefined anatomical locations, thereby reducing variability associated with the inconsistent identification of the narrowest joint point. Prior studies have demonstrated that location-specific JSW measurements show superior responsiveness in more advanced osteoarthritis (KL grade 2–3), with standardized response means reaching 0.74 compared to 0.49 for mJSW, indicating greater sensitivity to structural change. In addition, mJSW measurements may be unreliable in cases where no clear minimum exists or where joint margins

converge irregularly, leading to increased measurement variability [17].

Furthermore, conventional weight-bearing radiographs remain the most widely used imaging modality in osteoarthritis assessment due to their accessibility, low cost, and ability to reflect functional joint loading conditions. Radiography has been established as a validated and practical tool for monitoring disease progression in large-scale studies, including major cohorts such as the Health ABC and Osteoarthritis Initiative. While advanced imaging modalities such as CT or MRI provide superior three-dimensional evaluation of cartilage and subchondral bone, they are less feasible for routine clinical use and population-based research. Therefore, the use of fJSW on plain radiographs represents a balanced and evidence-based approach, combining improved measurement reliability with broad clinical applicability in the assessment of osteoarthritis severity [17].

Quantitative fJSW findings demonstrate medial compartment narrowing (3.55 ± 1.72 mm in KL2 to 3.12 ± 1.89 mm in KL3) with relative lateral preservation (4.47 ± 1.26 mm to 5.15 ± 2.27 mm), a hallmark of varus progression. Quantitative assessment of the total cohort (n=6,047) using fJSW measurement reveals that the medial compartment is consistently narrower than the lateral compartment across all stages of osteoarthritis, especially in grades 2 and 3 KL [18]. The consistent narrowing of the medial fJSW relative to the lateral compartment highlights the medial compartment as the primary site of mechanical loading and degenerative failure, especially in the early-to-moderate stages of osteoarthritis, and also can be one of the indicators for progressive varus malalignment and medial compartment collapse. Because medial fJSW exhibits more aggressive attrition compared to the relatively stable lateral fJSW, it represents a highly sensitive objective biomarker for differentiating between KL Grade 2 and KL Grade 3.

The medial-to-lateral joint space width ratio (MJSW/LJSW) in our study demonstrated no significant difference between KL grade 2 and KL grade 3 (0.88 ± 1.05 vs. 0.89 ± 3.90, p = 0.965), indicating limited discriminative ability in distinguishing adjacent stages of knee osteoarthritis (OA). This finding is consistent with prior observations reported by Sugiyanto et al. [19], who showed no significant differences in manually measured medial and lateral JSW between KL grade I and II (p = 0.605 and p = 0.344, respectively), suggesting that early to moderate OA stages exhibit substantial overlap in compartmental joint space measurements. Furthermore, data derived from the OARSI cohort support this interpretation, demonstrating considerable overlap in both medial and lateral fJSW values across KL grades, particularly between grades 2 and 3, where mean medial fJSW values remain closely approximated (approximately 4.45 vs. 3.15) with overlapping variability ranges, while lateral fJSW values also show minimal separation. These findings collectively suggest that, despite progressive structural degeneration in OA, the medial-to-lateral fJSW ratio lacks sufficient discriminatory power to reliably differentiate between moderate (KL 2) and more advanced (KL 3) disease stages, likely due to heterogeneous patterns of compartmental involvement and variability in joint space narrowing progression [20].

The optimal cut-off value of medial joint space width for differentiating KL grade 2 from KL grade 3 was determined using the Youden index, yielding a threshold of 5.03 mm. Although this cut-off demonstrated high sensitivity, it is low in specificity, indicating substantial overlap in medial joint space width measurements between the two KL grades, suggesting that joint space width alone has limited discriminative ability and may be more suitable as a screening parameter rather than a definitive tool for distinguishing adjacent disease severity. This limited performance is biologically plausible, as KL grading incorporates multiple structural features, including osteophyte formation, subchondral sclerosis, deformity, and joint space narrowing, rather than joint space width alone. Similar findings have been reported in prior studies, where joint space width alone demonstrated limited discriminatory ability due to inter-individual variability and compartmental heterogeneity.

The identified MJSW cut-off of 5.03 mm for differentiating KL grade 2 and grade 3 appears higher than the reference values reported in the OARSI atlas. In the OARSI framework, moderate joint space narrowing (JSN grade 2) in the medial

compartment corresponds to a mean JSW of approximately 2.1 mm, while severe narrowing (JSN grade 3) is associated with markedly reduced values around 0.3 mm. Similarly, within the Kellgren–Lawrence system, grade 2 and grade 3 are typically associated with mean JSW values of approximately 2.8 mm and 1.3 mm, respectively [21].

This discrepancy likely reflects methodological and population-related differences. First, the current study utilizes fixed joint space width (fJSW) measurements based on a perpendicular subchondral technique, which may yield systematically higher values compared to atlas-based semi-quantitative estimations. Second, the OARSI atlas represents generalized reference data, whereas the present findings are derived from a specific population, where biomechanical factors such as habitual squatting may influence joint loading and compartmental preservation [21].

Importantly, the higher cut-off value and its associated low specificity further support the presence of substantial overlap between KL grade 2 and grade 3 in real-world measurements. This highlights that absolute JSW thresholds may not directly correspond to atlas-based severity categories and should be interpreted within the context of measurement technique and population characteristics [21].

CONCLUSION

In this study of KL grade 2 and 3 knee osteoarthritis, medial fJSW reflects preferential medial compartment narrowing consistent with varus-driven degeneration and demonstrates an optimal cutoff value for differentiating KL grade 2 and 3, although with recognized limitations, including overlap between grades. In contrast, the medial-to-lateral fJSW ratio was not statistically significant, indicating limited utility in distinguishing adjacent disease stages. The use of the fJSW measurement technique offers advantages in providing a more standardized and reproducible quantitative assessment of joint space width. Nevertheless, fJSW should be interpreted as a complementary structural biomarker within a multimodal framework, as it lacks sufficient discriminative power as a standalone parameter. Clinically, these quantitative measurements may be integrated as a decision-support tool to objectively assess compartmental severity, assisting in the selection of joint-preserving procedures such as high tibial osteotomy (HTO) in medial-dominant disease, or guiding the indication for total knee arthroplasty (TKA) in more advanced cases.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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